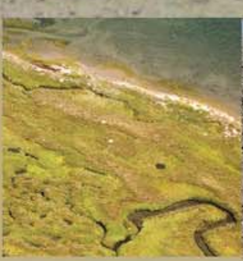
San Diego Bay

Integrated Natural Resources Management Plan

September
2013



Unified Port
of San Diego

Navy Region Southwest
One Team, One Voice, One Mission

NAVFAC
Naval Facilities Engineering Command

San Diego Bay

Integrated Natural Resources Management Plan

September 2013

Unified Port of San Diego

NAVFAC Naval Facilities Engineering Command

Navy Region Southwest
One Team, One Voice, One Mission

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Key words/phrases: Natural Resources Management; NAVORDCENPACDIV; OPNAVINST 5090.1B; Natural Resources Plan; Wildlife Management Plan; Ecosystem Management Plan; Coastal Resources.

SAN DIEGO BAY
INTEGRATED NATURAL RESOURCES MANAGEMENT PLAN
San Diego, California

APPROVAL

This Integrated Natural Resources Management Plan (INRMP) fulfills the requirements for the INRMP in accordance with the Sikes Act (as amended), DoDINST 4715.3, and OPNAVINST 5090.1C (as amended). This document was prepared and reviewed in coordination with U.S. Fish and Wildlife Service and California Department of Fish and Wildlife Central Region in accordance with the 2013 Memorandum of Understanding for a Cooperative Integrated Natural Resource Management Program on Military Installations.

Approving Official—U.S. Navy, Navy Region Southwest

C.L. Stathos
Fleet Environmental Director
Navy Region Southwest
San Diego, California

Date

Approving Official—U.S. Navy, Navy Region Southwest

Douglas Powers
Conservation Manager (EV5)
Naval Facilities Engineering Command Southwest
Environmental Conservation
San Diego, California

Date

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Approving Official—U.S. Navy, Navy Region Southwest

10 JAN 2014
Date

C.L. Stathos
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Approving Official—U.S. Navy, Navy Region Southwest

10 Jan 2014
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Approving Official—San Diego Unified Port District

A. Y. Moore (signature) Nov. 19, 2013

Chair, Board of Port Commissioners
San Diego Unified Port District
3165 Pacific Highway
San Diego, CA 92101

Date

SAN DIEGO BAY
INTEGRATED NATURAL RESOURCES MANAGEMENT PLAN
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Concurring Agency— U.S. Fish and Wildlife Service

November 15, 2013

Jim A. Bartel, Field Supervisor
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Carlsbad, California 92008

Date

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San Diego, California

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Concurring Agency—California Department of Fish and Wildlife

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Mr. Craig Shuman
Regional Manager – Marine Region
California Department of Fish and Wildlife
1933 Cliff Drive, Suite 9
Santa Barbara, CA 93109

Date

INTEGRATED NATURAL RESOURCES MANAGEMENT PLAN
San Diego Bay, San Diego, California

APPROVAL

The U.S. National Marine Fisheries Service has participated in the revision of this INRMP, in accordance with the Sikes Act (16 U.S.C. 670a *et seq.*) as amended.

Concurring Agency - National Marine Fisheries Service

William W. Stelle, Jr.
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12/30/2013
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SAN DIEGO BAY
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Approving Official—San Diego Unified Port District

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Concurring Agency— U.S. Fish and Wildlife Service

Jim A. Bartel, Field Supervisor
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Concurring Agency—California Department of Fish and Wildlife

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Concurring Agency— National Marine Fisheries Service

William W. Stelle, Jr. Date
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National Marine Fisheries Service, West Coast Region
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Long Beach, CA 90802

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Executive Summary

This San Diego Bay Integrated Natural Resources Management Plan (INRMP) sets forth a long-term vision and strategy sponsored by two of the major managers of the San Diego Bay: the U.S. Navy and Port of San Diego (Port). Its intent is to provide direction for the good stewardship that natural resources require, while supporting the ability of the Navy and Port to achieve their missions and continue functioning within San Diego Bay. The ecosystem approach reflected in the Plan looks at the interconnections among all of the natural resources and human uses of the Bay and across ownership and jurisdictional boundaries. San Diego Bay is viewed as an ecosystem rather than as a collection of individual species or sites or projects.

This is a collaborative strategy for managing the Bay's natural resources and a primary means by which the U.S. Navy and the Port jointly plan natural resources work in San Diego Bay with their government and non-government partners. The INRMP emphasizes work for the bay that can be done better together than separately. Recognizing the joint responsibility, a cooperative effort of many people and 14 government and non-government organizations brought this Plan together under the primary "umbrella" working group of the Technical Advisory Committee. This Technical Advisory Committee was created to include those entities that are most directly affected by the INRMP's strategies and could contribute significantly to its development. The members provided professional and personal experience, scientific data, and a "reality check" on the material and ideas used. Their varying perspectives helped ensure that sustainable, ecosystem-based strategies were considered in institutional, social, and economic contexts to validate the Plan's approach.

Main Messages of this Updated INRMP

The previous (2002) San Diego Bay INRMP faced implementation challenges, and this was a key issue for this INRMP revision. Other key issues included the need to expand the subject matter scope to include concerns about water quality, sediment quality, climate change, sustainability in the interface between the built and natural environments, and natural resources damage assessment.

The biodiversity and habitat values of San Diego Bay are hard to overstate in terms of ecosystem function locally, regionally, and globally. Due to its relatively small size, yet estuary-like function, San Diego Bay may experience more juxtaposition of urban and natural uses, and thus potentially more conflict, than any other bay on the U.S. west coast. There is a fragile and complicated interaction between human, urban uses, and natural resources in the narrow shore environment where values are dense for both. In the next 50 years, the diversity of marine species found in this environment will almost certainly be different from today.

A key finding of this revised INRMP is that climate change and invasive species are now principal drivers of change, whereas habitat loss due to development was the main driver in the past. The degradation of productivity and biodiversity in the bay in the next 50 years from climate change and invasion by non-native species may overtake the Navy's and Port's achievements in habitat and species protection, mitigation, and restoration. Intertidal habitats—mudflats, sandy beaches, and salt marsh—are the most at risk from these drivers.

Another key finding is that shoreline structures can provide more habitat and biodiversity value than they currently do but that maximizing their infrastructure function and their ecosystem productivity in the small spaces available has challenged bay managers. This INRMP seeks high-performing shore structures that enhance habitat value.

The outlets of streams entering the bay are another key area of work, and these areas are tied to sediment and water quality concerns.

It will take partnerships to evaluate each choice, trade-off, and potential synergy of actions undertaken by bay managers to successfully reduce the vulnerability of the bay's ecosystem values.

Implementation Matters

The challenge of implementation will involve evaluating plausible future scenarios for San Diego Bay and assessing what we can do to foster healthier shorelines and more sustainable infrastructure. At the same time, implementation must reduce threats and vulnerabilities to both natural communities and human access to shore resources.

Since this INRMP emphasizes work that can be done better together, implementation strategies emphasize climate change adaptation, enhancing the value of artificial structures, work involving watershed processes, education and outreach, natural resources damage assessment, invasive species detection and control, long-term monitoring, baywide studies, and supporting research. Agency-specific regulatory matters would be left to jurisdictions. This INRMP also strongly emphasizes pilot projects.

At least $200,000,000 is needed to fully implement the INRMP over the next several years. Since the first INRMP written in 2000 and signed in 2002, millions of dollars have been invested in implementation by the partner agencies to benefit San Diego Bay's natural resources. However, locally available resources and institutional mechanisms for implementation are insufficient to address key findings of the INRMP regarding the condition and trend of natural resources, water and sediment quality, and imminent threats to human and ecological resources. Some of the Plan's objectives can be achieved with projects funded through existing institutional structures and processes, while others will require organizational change and innovation, including funding mechanisms that are not currently working. Many projects will require innovation in how agencies interact and how funding is allocated and prioritized. Agency work plans, incentive structures, budgets, and evaluation protocols will need to be transformed.

Seven Initiatives

The recommendations of the INRMP are organized into a detailed implementation table in Chapter 7. However, they may be condensed into a set of seven initiatives:

- Sustainability By Design. A new initiative on sustainability in the interface between the built and natural environment will provide a means for baywide sustainability planning. This initiative adds habitat value, sea level rise, and shore access for the strategic missions of the Port and Navy to conventional sustainability "green building" concerns.
- Habitat Enhancement of Shoreline Structures. Shoreline structures should achieve multiple objectives besides shore stabilization, such as provide habitat for organisms that are native to the Bay; contribute to sustainability with respect to nonpoint source pollution prevention; avoid harboring predators of sensitive birds; provide access for wildlife viewing; and accommodate the expected rise in sea level.
- Water and Sediment Quality Initiative. Priority will be on work that informs and allocates the most benefit to the Bay on an ecosystem level.
- Invasive Species Detection and Control. Vigilant work is necessary to address this present and growing threat. A Watch List for San Diego Bay, identification of high risk areas, and protocols for rapid response are needed.

- San Diego Bay Restoration Partnership. A formalized Restoration Partnership would foster the collaboration needed to apply for and manage funds from multiple sources and to execute the consensus-based projects that achieve multiple public objectives.
- Ecological Indicator Program. As stated in the Senate Bill 68 Report to the Legislature, there is a need to invest in understanding the link between native species abundance and diversity and indicators of water and sediment quality that is specific to the resources of San Diego Bay.
- Improved Information Access and Reporting. Provide a central clearinghouse for data and reports on the Bay's natural resources that is accessible to both agencies and the public.

Top Nine Highest Priority Projects

The Technical Advisory Committee has identified by consensus its Top Nine Priority projects for implementation:

- Sustainable Shoreline Structures and Habitat Enhancement. The Plan seeks to improve the habitat value of shoreline infrastructure through innovation in construction, experimentation, demonstration projects, education, and interdisciplinary design criteria.
- Restoration Business Plan. Develop a coordinated, inter-jurisdictional business plan for implementing restoration projects that achieves the objectives of this INRMP.
- Enhancement of South Bay vicinity as an integrated and cross-jurisdictional project. Create additional upland transition, intertidal and subtidal habitat including filling tidal channels as appropriate. Improve California least tern nesting habitat. Support the eastern Pacific green sea turtle.
- Fish Abundance, Health, and Habitat Monitoring with Implications for Recreational Fisheries. Assess the abundance, diversity, and biomass of fish occupying various habitats including artificial structures.
- Benthic Study. Detect changes in quality of the benthic invertebrate assemblage, especially with respect to food for shorebirds, water quality, toxics, and overall ecosystem health.
- Water/Sediment Quality Indicator Species. Water and sediment quality monitoring of indicator species and physical parameters is needed to evaluate spatial and long-term trends of contaminants of concern, toxicity, benthics, microorganisms, and bioaccumulation in bivalves, to be included in “State of the Bay” reporting.
- Invasive Species Monitoring, Detection, and Education Program. This would result in a protocol for reporting and rapid response to detection.
- Shallow Unvegetated Habitat Value. Study and describe seasonal patterns of temperature, salinity, plankton, invertebrates, fish, and birds for shallow unvegetated habitats.
- Cooperative Mitigation Management and Banking Plan. Develop interagency agreements whereby mitigation for a series of projects may be combined for the purpose of accomplishing a larger or more ecologically effective project. Coordinate placement of dredged sediment for beneficial use.

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Appendices

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1.0 Welcome to the San Diego Bay INRMP

This Integrated Natural Resources Management Plan (INRMP) is a long-term, collaborative strategy for managing the bay's natural resources, and the primary means by which the U.S. Navy and Port of San Diego (Port) jointly plan natural resources work in San Diego Bay. The INRMP became a joint initiative with the Port in recognition of the need for partnership in stewardship and compliance with environmental laws, while supporting the ability of the Navy and the Port to accomplish their mission-related work. Required by the Sikes Act Improvement Act of 1997 (SAIA) for the U.S. Department of Defense (DoD), it is the primary means by which natural resources compliance and stewardship priorities are set and funding requirements are determined. A commitment to implement priority projects, as funding permits, comes with the signatures in the front of this INRMP.

In 2002 the first INRMP for San Diego Bay was signed by the Commander, Navy Region Southwest (CNRSW), the Chair of the Board of Port Commissioners (BPC), the Regional Administrator of National Marine Fisheries Service (NMFS), the Field Supervisor of U.S. Fish and Wildlife Service (USFWS), and the Regional Director of California Department of Fish and Game (CDFG). This comprehensive revision continues many of that plan's objectives and strategies, while expanding coverage on water quality, sediment quality, sustainable development, and other topics (See Section 1.2). Additional detail is added to guide implementation, including condensing a long list of projects priority into several initiatives and discussion on the practical mechanics that drive implementation.

In the chapters that follow, the current state of San Diego Bay is described in Chapters 2 and 3. Management objectives and strategies are described in Chapters 4 through 6. The steps toward implementation are described in Chapter 7.

1.1 Vision and Goal of the INRMP

This INRMP is intended to be an agent of natural resources stewardship and agency partnership. By understanding and considering the interconnections among all of the living resources and human uses of the bay and across ownership and jurisdictional boundaries, San Diego Bay is viewed as a fragile ecosystem that requires management to maintain sustainable native populations and natural biodiversity.

The INRMP identifies a progression towards a bay that supports shorelines and waters richer and more abundant in native life. It also describes a future bay that, while used for thriving urban, commercial, and military needs, has greater opportunities for public access, recreation, education, and enjoyment of the myriad benefits of a healthy ecosystem.

Natural resources and human socioeconomic functions interact intensely here. There is probably more potential conflict here among resources and resource uses than in any other California harbor. These functions overlay each other and underpin each other's viability. Home to the largest naval complex in the world and California's second largest city, San Diego Bay receives waters and urban runoff from a watershed of

415 square miles (mi^2) (668 square kilometers [km^2]) and is where 50% of the county's population lives and/or works. At the same time, it supports a many-tiered and complex food chain and is a thriving area for fish and wildlife populations. The proportion of migrants on the Pacific Flyway or marine species navigating ocean currents that enter the bay to breed, raise young, or rest is high considering the bay's relatively small size (10,532 acres of water and 4,419 acres of tidelands). Due to these functions, there is a great need to manage conflict, to understand ecosystem connections, and to make the most strategic investment possible in the bay's future.

The U.S. Navy and the Port, along with a working group of bay stakeholders called the Technical Oversight Committee developed this goal through a consensus process:

Goal: To ensure the long-term health, restoration, and protection of San Diego Bay's ecosystem in concert with the bay's economic, Naval, navigational, recreational, and fisheries needs.

1.1.1 Plan Background

Beginning in 1992, an emerging frustration with project-by-project management of the bay was identified as a major concern among biologists within the Navy and the Port, as well as by the USFWS, NMFS, and CDFG. At that time, the agencies were meeting every few months to discuss project management that fell under their joint review authorities. As a group, they observed that piecemeal management of natural resources resulted in lengthy and often redundant efforts by both project proponents and the resource agencies. The project-by-project approach led resources to be managed on a very site-specific basis and based on political boundaries instead of natural, ecosystem boundaries.

While natural resources plans had been completed for the separate land portions of most of the Naval installations around the bay, no plan had been developed to focus on the water resources of the bay as an integrated whole. The Navy decided that a "big picture" approach to managing resources and planning for future needs would prove more valuable than a piecemeal approach in the long run. In 1993, the agencies began to jointly collect data necessary to develop a baywide resources management plan. With Congress' SAIA reauthorization in place by 1997, the DoD requirement for INRMPs for all of its properties that contain natural resources became the Navy venue for doing this planning under the primary Navy guidance document (Chief of Naval Operations Instruction [OPNAVINST] 5090.1C October 2007; updated July 2011).

Sharing similar experiences, the Port became interested in working collaboratively with the Navy on a single natural resources plan for the bay. As a result, the BPC voted on January 7, 1997 to become a partner with the Navy in jointly developing a natural resources management plan for the bay, expressing concern that "a balance be achieved in designating sites for mitigation and preserving the valuable natural resources while not precluding development opportunities." In 2006, the Port joined with the Navy once again to update and revise this INRMP due to the time that had passed, new data that had been acquired, and many other developments since 2002.

1.1.2 Navy and Port Missions

The structure and content of this joint plan is designed to support the missions of both the Navy and the Port, as described below. There are complexities to joint planning partly due to the differing jurisdictions, institutional frameworks, and natural resources that are partly owned and shared. As became evident during the planning process for this INRMP, it is only possible to develop a joint document by placing each organization's mission in the forefront. The Navy views the environmental management of its installations as key to military readiness. Similarly, environmental stewardship is one of four components of the Port's mission.

U.S. Navy

The mission of the U.S. Navy in San Diego Bay and its environs is to equip, maintain, train, and support Naval surface and aviation units of the Pacific Fleet in order to conduct military operations in support of the Fleet's operational commanders. Additionally, the U.S. Navy in San Diego Bay supports Naval operations in the eastern and northern Pacific Ocean, protecting the western sea approaches to the United States.

The mission of the U.S. Navy is to equip, maintain, train, and support Naval surface and aviation units of the Pacific Fleet in order to conduct military operations in support of the Fleet's operational commanders.

The CNRSW is responsible for shore installation management of the Naval facilities surrounding San Diego Bay. Its mission is: *"To enhance our Nation's combat readiness through efficient and effective management of our shore installations while preserving the critical resources necessary to secure the future of our forces."*

The CNRSW serves as the Naval shore installation management headquarters for the southwest region (California, Arizona, Nevada, Colorado, Utah, and New Mexico). CNRSW provides coordination of base operating support functions for operating forces throughout the region. This includes providing expertise in areas such as housing, environmental, security, family services, port services, air services, bachelor quarters, supply, medical, and logistical concerns for the hundreds of thousands of active-duty, reserve and retired military members in the area. The implementation of Navy natural resources functions is also provided by Naval Facilities Engineering Command (NAVFAC) Southwest, one of ten facilities engineering commands in the Navy. NAVFAC Southwest is responsible for the public works, planning, engineering/design, construction, real estate, and environmental services in a six state area on the West Coast.

Conservation responsibilities for natural resources on all DoD installations are required by laws and Executive Orders (EOs) and specified in instructions and guidance. This INRMP's scope is largely defined by the SAIA, DoD Instruction (DoDI) 4715.3, and the Navy's Environmental and Natural Resources Program Manual (OPNAVINST 5090.1C). The SAIA stipulates that this INRMP provide for:

- Conservation and rehabilitation of the natural resources on military installations;
- Sustainable, multipurpose use of the resources;
- Public access to facilitate their use, subject to safety requirements and military security; and
- Specific natural resource goals and objectives and time frames for acting on them.

INRMPs as defined under the SAIA are developed jointly by the Navy, fish and wildlife agencies such as the CDFG, USFWS, NMFS, and other resource agencies as appropriate. Mutual agreement from these agencies is sought for the fish and wildlife component of natural resources management identified in the INRMP, and an annual review with the agencies discussing Navy-wide natural resources is mandatory.

INRMPs are the primary mechanism through which natural resource projects are identified and prioritized, and funding is requested on DoD installations. Implementation of the strategies and projects described in an INRMP are guided by the DoD budget standard as described in DoDI 4715.03 (March 2011) on Environmental Conservation Programs, which implements policy, assigns responsibilities, and prescribes procedures for the integrated management of natural and cultural resources on property under DoD control (See Chapter 7). The budget process funds a wide range of projects besides INRMPs, such as baseline inventories, species studies and surveys, mapping, impact assessment, predator management and control, habitat restoration, soil erosion assessment and control, invasive species control, and natural resources outreach and interpretive materials.

Port of San Diego

The Port is a public benefit corporation and special government entity. Created in 1963 by an act of the California legislature, the Port manages San Diego harbor and administers the public lands along San Diego Bay. It is responsible for the protection and enhancement of 2,508 acres of tideland and 2,860 acres of water. It has operated without tax dollars since 1970 and has been responsible for substantial financial contributions to public improvements in its five member cities—Chula Vista, Coronado, Imperial Beach, National City, and San Diego. With a significant economic impact on the San Diego region, the Port oversees two maritime cargo terminals, a cruise ship terminal, 16 public parks, various wildlife reserves and environmental initiatives, a Harbor Police Department, and the leases of 600 tenant businesses around San Diego Bay. Formerly the Port managed the San Diego International Airport at Lindbergh Field since it occupies Port tidelands; however, a regional airport authority replaced this part of the mission in 2003 by an act of the California legislature.

The Port's mission is to balance economic benefits, community services, environmental stewardship, and public safety.

The Port's mission is to, while protecting the Tidelands Trust resources, balance economic benefits, community services, environmental stewardship, and public safety on behalf of the citizens of California.

During its history, the Port has taken the lead in a variety of initiatives to enhance the environmental quality of San Diego Bay and its surrounding tidelands. These include wildlife and natural resources management, stormwater runoff programs, integrated pest management, environmental education programs, and environmental partnerships with public and private entities. Recently, two programs were established to provide funding intended under the Port Environmental Policy to restore or enhance the condition of the bay (BPC Policy No. 730) and are described below.

Senate Bill 68 Environmental Committee

In 2003, California Senate Bill (SB) 68 (Alpert) was passed and directed the creation of the San Diego Bay Advisory Committee for Ecological Assessment (Environmental Committee). The intent of the legislation was to support an independent assessment of conditions and trends in the bay's health, as well as planning and regulatory matters that limit comprehensive decisions about fully protecting beneficial uses of the bay, restoring marine life, improving habitat and species diversity, and establishing fair and equitable water quality objectives and standards. The legislation also directed the development of a report to provide information on:

- Historic data and trends in indicators of bay health such as pollutant levels and number and diversity of species;
- Habitat enhancement projects proposed in the 2000 San Diego Bay INRMP; and
- The best available and economically practical technology to meet stormwater toxicity standards.

The legislation identified 18 entities that could appoint one representative to the Committee as a voting member and designated entities that could participate on the committee as non-voting members. The legislation directed the Port to provide staffing for the Committee, as well as provide the Committee's chair. The Committee membership included one member from each of the following entities.

Senate Bill 68 Environmental Committee membership

- San Diego City Council
- City of Chula Vista
- City of Coronado
- City of Imperial Beach
- City of National City
- Environmental Health Coalition
- California Coastal Commission
- City of San Diego Metropolitan Wastewater Joint Powers Authority
- San Diego Baykeeper
- San Diego Audubon Society
- San Diego Chapter of the Surfrider Foundation
- Sierra Club
- San Diego Port Tenants Association
- San Diego Convention and Visitors Bureau
- Scripps Institute of Oceanography
- Industrial Environmental Association
- Two members appointed by the San Diego County Board of Supervisors (one of the persons appointed to be a recreational boat owner who resides in San Diego County)
- Additional entities were authorized to appoint a non-voting member to the committee: the U.S. Navy, CDFG, USFWS-Refuges and USFWS-Ecological Services, NMFS, University of California San Diego, and San Diego State University.
- The San Diego RWQCB was encouraged to participate in the proceedings.

The SB 68 Committee completed the direction of the implementing legislation with the submission of a Final Report to the California legislature, San Diego Regional Water Quality Control Board (RWQCB), State Water Resources Control Board (SWRCB), and the California Coastal Commission (CCC) on or before December 31, 2005.

While its legislative mission was complete, the Port saw a continuing need to receive advice and have collaborative discussions regarding natural resources direction and management of the bay. To this end, the SB 68 mandate for the Environmental Committee evolved into a permanent standing advisory committee of the Port with the same groups participating.

Port Environmental Advisory Committee

With the growing recognition that restoration of San Diego Bay could not be accomplished through regulatory compliance, as discussed in the SB 68 Final Report, the Port has initiated a "beyond compliance and beyond mitigation" program. In the belief that this work will require the concerted, coordinated efforts of all stakeholders of the bay, as stated above, the BPC created the Environmental Advisory Committee to advise it on significant ecosystem and environmental issues relating to San Diego Bay. Officially established in 2006, the Committee operates according to the guidelines for all Board Advisory Committees as established in BPC Policy No. 018 (2005-78, 10 May 2005) and as reiterated in the charter prepared specifically for the Committee. The Committee is staffed by the Port's Environmental Services Department. It is run by a member of the BPC.

In the Port's Environmental Policy Statement (BPC Policy No. 730), the BPC charges the Committee with providing the funding and decision-making direction necessary to select and execute projects aimed at improving the condition of the bay and surrounding Port tidelands. This Committee is advisory in nature and has no authority to negotiate for, represent, or commit the Port in any respect. It is intended that, at a minimum, the representatives of the Committee will include a balance of resource and regulatory representatives from academia, environmental advocacy groups, government agencies, and Port tenants.

According to its charter, the goal of the Committee is to identify, rank, and complete projects. As such, the Committee is tasked to seek matching funds from other sources.

This INRMP and the SB 68 Final Report are the two primary documents used to support the Environmental Committee's decision making.

The Port's Environmental Fund Advisory Program

Three distinct programs support environmental initiatives of the Port: the Clean Port Environmental Program managed by the Environmental Services Department, the Environmental Fund, and the Tenant Environmental Compliance Loan Program.

The Environmental Fund allows the Port to pursue initiatives that are "beyond compliance and beyond mitigation" and focused on restoration efforts. The Environmental Fund is designed to restore or enhance San Diego Bay and surrounding tidelands by funding programs that include but are not limited to habitat, restoration, sediment and water quality, air quality, and conservation education, research, and endangered species.

It is intended to provide the decision-making structure and funding necessary to assist in the restoration of the bay and Port tidelands. On September 5, 2006, the BPC directed that $3 million be allocated from reserves into the Environmental Fund. The BPC also specified that an additional $2 million would be placed into the fund if matching funds were identified. Finally, each year the BPC shall set aside ½ of 1% of the district's projected gross revenues for that year to be expended for specific environmental projects or allocated to a fund set aside within the Port District Revenue Fund for environmental projects within the Port District.

In selecting projects, the Committee looks for those that will create or restore habitat, protect endangered species, conduct research on the bay, improve air, water, and sediment quality in and around the bay, improve energy conservation, enhance the public's enjoyment of the bay without impacting the environment, increase environmental education, and improve environmental decision making. Projects also must be located within San Diego Bay and its surrounding tidelands or directly benefit the bay and tidelands.

The Environmental Committee recommends projects to the BPC based, in part, on whether such projects create new habitat for fish or birds; restore historic habitat that has been lost through development or other means; remediate or hasten the move towards remediation of a contaminated area of the bay; enhance the public's enjoyment of the bay without impacting the environment; improve environmental decision-making; prevent contamination of the bay in a way that is not addressed by existing regulatory structures; resolve a regulatory impasse which has prevented or significantly slowed the restoration of the bay; or directly benefit the bay and the surrounding region.

In addition to the Environmental Fund, the Port has a Tenant Environmental Compliance Loan Program. The Loan Program provides a low-cost source of funds to Port tenants to support environmental remediation or tenant environmental enhancement. The Port makes available to its tenants low interest loans for projects that will improve the environmental conditions of the tidelands and the bay. Tenants may qualify for a maximum amount of $100,000 at a low fixed interest rate, payable over five years. Tenant-recommended projects are submitted by the selection committee to the Executive Director for his/her concurrence and, if he/she concurs, then to the BPC for project approval. The BPC has sole discretion to award funds. The Port has dedicated $1 million to fund this program.

1.1.3 Who Helped Build this Plan?

A Technical Advisory Committee was developed to make cooperative, consensus-based decisions about the INRMP's approach, content, strategy, and implementation.

A cooperative effort of many people has brought this INRMP together. The primary "umbrella" working group is the Technical Advisory Committee (TAC). This group of 14 different organizations was created to include those entities that are most directly affected by the INRMP and could contribute significantly to its development. The size of the TAC was purposely limited since it had the role of making cooperative, consensus-based decisions about the INRMP's approach, content, policy, and implementation. The members also provided professional and personal experience, scientific data, and a "reality check" on the material and ideas used. Their varying perspectives helped ensure that sustainable, ecosystem-based strategies were considered in institutional, social, and economic contexts to validate the INRMP's approach. Drafts of the INRMP were reviewed, discussed, and approved by the TAC on a consensus basis. The membership is identified as follows.

San Diego Bay Integrated Natural Resources Management Plan Technical Advisory Committee membership 2008.

- U.S. Navy Region Southwest Environmental Program
- U.S. Naval Facilities Engineering Command Southwest Environmental Program
- San Diego Regional Water Quality Control Board
- National Marine Fisheries Service
- U.S. Fish and Wildlife Service - Ecological Services
- U.S. Fish and Wildlife Service - Refuges
- U. S. Army Corps of Engineers
- National Park Service Cabrillo National Monument
- Port of San Diego, Environmental Services
- California Department of Fish and Game
- San Diego Audubon Society
- San Diego Association of Governments
- State Lands Commission
- California Coastal Commission

1.2 What's New About this INRMP Update?

This INRMP is both updated and expanded with regard to its content scope from the 2000 version. The Navy and Port sponsors of the INRMP have agreed to expand the scope in the following ways:

- There are increased information, goals, objectives, and planning for *water and sediment quality* concerns with a focus on the fundamental ecosystem and legal connections between these and the status and trend of natural resources. This update addresses that link as one of the designated beneficial uses derived from clean water. This effort includes the ability to take on anticipated regulatory requirements in a coordinated, local, and proactive approach that has the most benefit to natural resources.

- A new focus on *sustainability* is added as an overarching theme for natural resources use. A growing regulatory and business climate for environmentally integrated development has facilitated better practices with respect to construction designs and the use of renewable and nonrenewable natural resources, as well as pollution prevention. A limited discussion of *air quality* is added within the context of sustainability planning. Existing programs are identified where they link to natural resources management, but only limited management measures are proposed.
- *Global warming and climate change* and its implications for San Diego Bay are presented. Climate change is treated both as a topic in itself with its own objective and strategy and as a driving force that permeates other INRMP topic areas. With higher sea levels, altered water temperatures and chemistry, and more extreme storm surge expected, habitat losses and species shifts are likely. Impacts on San Diego Bay's resources are positioned to lead those of other bays on the west coast; therefore, statewide and national leadership in adapting to sea level rise can occur locally.
- A discussion of *natural resources damage assessment* (NRDA) in the context of oil spill response planning is added, along with the related *Ephemeral Data Collection Plan* as defined in OPNAVINST 5090.1C.
- There is an expanded look at *key ecological indicators* that are tied to drivers of change and vulnerable habitats and food chains. These are intended to help link natural resources with water/sediment quality concerns within the regulatory framework. This is an outcome of the SB 68 Final Report that identified a need for biological indicators that provide adaptive management cues and help disparate programs operating under different laws and regulations to function as a more cohesive bay-wide program to protect the beneficial uses of the bay. As the report identified, there are fundamental ecosystem and legal connections between the status and trend of natural resources and water quality. Key indicators are also part of the Navy INRMP Metrics recently required as part of the annual review of INRMPs.
- In order to build on one of the SB 68 Final Report's key recommendations to the California legislature, there is an expanded analysis of ways to implement a San Diego Bay *cross-jurisdictional partnership* to implement the INRMP, to address other findings of the Report, and to provide the integrated stewardship necessary to improve wetlands, other aquatic habitats, and water quality.

Many updates have been made to the INRMP as a result of recent surveys and studies, new EOs, laws, regulations, and policies. Coincident with this is a new planning environment with the San Diego South Bay National Wildlife Refuge (NWR) Comprehensive Conservation Plan (CCP) and associated Environmental Impact Statement (EIS). In addition, the Port, Navy, and other stakeholders have jointly worked through the SB 68 process of identifying baywide issues including problems with implementing this INRMP. These discussions along with development of the Port's Environmental Advisory Committee and Environmental Fund have led to new potential for structuring a Navy-Port partnership with reshaped roles and responsibilities for natural resources stewardship.

The complexities of this altered planning environment are integrated into this INRMP through the TAC's linkage of goals, objectives, and tasks as summarized in the project implementation table found in Chapter 7.

1.3 Ecosystem and Sustainability Framework

Natural resources practitioners have, over the decades, continued to develop and adapt conceptual models to reflect their expanding understanding of the complexity and interconnectedness of the resources they manage and how human society draws benefit from them. The science, governance, and art of managing natural resources has had to respond to declining resource conditions and emerging natural and human stresses evident to practitioners closest to the resource and to distant observers. This is as true for San Diego Bay as it is nationally and globally.

Progressively, more integrated models developed as it became evident that traditional approaches were too narrow in scope: they were project-oriented, agency-oriented, species-focused, use-specific, special interest-oriented, or too constrained to regulatory "stovepipes." Ecosystem management became a national initiative in the 1990s as a conceptual model in reaction to deficiencies of the more narrow approaches. An inter-agency Memorandum of Understanding (MOU) on Fostering an Ecosystem Approach (1995) was signed by the DoD along with 14 other agencies in an attempt to create a more consistent approach to ecosystem management among federal agencies, enhance coordination, and encourage more regional ecosystem initiatives (Council on Environmental Quality [CEQ] *et al.* 1995). The DoD's Ecosystem Initiative (1996) states that "ecosystem management is a process that considers the environment as a complex system functioning as a whole, not as a collection of parts, and recognizes that people and their communities are part of the whole." This approach shall take a long-term view of human activities, including military uses, and biological resources as part of the same environment.

Considering ecosystem management as the holistic approach that takes the long view, considers the whole as well as the parts, and recognizes the socioeconomic connection of communities and natural resources, the concept of sustainability can be seen as an important application of ecosystem management principles (described below). Another application, at a geographically-focused scale, is watershed management (See Chapter 5).

To guide the path and establish metrics of health, a statement of the bay's core ecosystem functions, or those values that make San Diego Bay irreplaceable and unique, is necessary.

1.3.1 San Diego Bay's Core Ecosystem Functions

San Diego Bay supports a many-tiered and complex food chain, a productive feeding and resting ground, and safe haven for nesting seabirds. Some physical elements that foster productive habitats also make the bay ideal for commercial uses, military staging, and recreation.

San Diego Bay's core ecosystem functions are its warm, nutrient-rich, shallow waters, intertidal shorelines, shelter from waves, and relative protection from marine predators. From these physical elements derive habitats that serve as a nursery, breeding, and resting ground for many marine species. See Figure 1-1 for species richness and habitat functions. The proportion of migratory birds arriving from the Pacific Flyway or marine species navigating ocean currents which enter the bay to breed, raise their young, or rest is high considering the bay's size. It supports a many-tiered and complex food chain, a productive feeding and resting ground, and a safe haven for nesting seabirds. Adjacent land attracts nesting and roosting birds as well as human uses. Some of the bay's estuary-like functions are those presently concentrated in the southern end, where warmer water and higher salinities provide opportunities for organisms indigenous to estuaries. Throughout the bay, eelgrass beds support fisheries productivity unmatched by most habitats, while soft-bottom habitats provide foraging for species that depend upon resident invertebrates for food. The intertidal shorelines support foraging shorebirds and, especially at high tide, juvenile and adult fishes. Some of the physical elements that foster productive habitats also make the bay ideal for commercial uses, military staging, and recreation. The harbor-like northern end of the bay, which opens onto the ocean, provides shelter for vessels and the necessary depth for commercial transit.

Fully one-third of birds dependent on San Diego Bay have been identified as sensitive or declining by the federal or state governments or by the Audubon Society. Twenty-six bird species are on the USFWS (2008) list of Birds of Conservation Concern. San Diego Bay provides the largest expanse of protected waters in southern California for migratory birds on the Pacific Flyway. The majority are migratory and rely on the bay as an important resting and feeding stopover. Others, especially those arriving from tropical latitudes, spend the winter, breed, or nest. The southern portions of San Diego Bay are designated a Globally Important Bird Area (National Audubon Society 2011) due to the presence of globally significant numbers of nesting gull-billed terns (*Sterna nilotica*) and continentally significant numbers of surf scoters (*Melanitta perspicillata*), Caspian terns (*Sterna caspia*), and western snowy plovers (*Charadrius alexandrinus nivosus*). The entire southern end of San Diego Bay is recognized as a Western Hemisphere Shorebird Reserve Network Site (Western Hemisphere Shorebird Reserve Network 1999) due to harboring more than 20,000 shorebirds each year.

Figure 1-1. Habitat and species richness of San Diego Bay, taken from species lists (See also Appendix D).

San Diego Bay provides the largest expanse of protected waters in southern California for migratory birds on the Pacific Flyway.

- At least 304 species of marine and coastal birds
- 4 species of marine mammals commonly occur
- 109 species of marine fishes and one marine reptile have been documented
- 640 species of marine invertebrates documented so far
- 46 species of algae documented so far
- 11 federal /state threatened or endangered species; 50 special status species

- 823 acres (333 ha) of salt marsh
- 978 acres (396 ha) of tidal flats
- 1,065 acres (431 ha) of eelgrass beds
- 45 miles (73 km) of hard substrate and fouling communities
- 9,331 acres (3,776 ha) of mud and sand bottom assemblages in shallow to deep water

San Diego Bay functions as a nursery and refuge for marine fishes such as juvenile California halibut (*Paralichthys californicus*) and young spotted and barred sand bass (*Paralabrax maculatofasciatus* and *P. nebulifer*). The warm water temperatures and high productivity in shallow and intertidal waters enable it to support larval and juvenile fishes in large numbers. An abundance of fish eggs and larvae in planktonic form find shelter in eelgrass beds, the salt marsh, or move about in bay currents. Many of these fishes are important food chain forage for fishes of commercial or sport fishing value and for seabirds.

Unique species assemblages not found outside of southern California are noteworthy in San Diego Bay contributing to the biodiversity of fish populations.

The bay's shallow subtidal habitat also supports a group of twelve species of fish that are indigenous to the bays and estuaries of the Southern California Bight (SCB). The extensive shallow water habitat and eelgrass beds provide important habitat for these and a variety of other fish, such as northern anchovies (*Engraulis mordax*), slough anchovies (*Anchoa delicatissima*), and topsmelt (*Atherinops affinis*). The warmer, hypersaline waters of South Bay also offer shelter for a number of fish species commonly encountered further south in the eastern subtropical and tropical Pacific. Intertidal mudflats provide foraging habitat for fish during high tide, while at low tide, great numbers of shorebirds assemble to forage on the many invertebrates available on the exposed flats.

The bay naturally attracted the growth of a city and the U.S. Navy to base a large portion of its Pacific Fleet in San Diego. Today more than 25% of the American Naval fleet is homeported here. Over 95,000 sailors and 240,000 family members live and work in the San Diego area, with 29,000 civilian employees working at the Navy and Marine Corps bases.

Bayfront locations for real estate development and Port trade generate $8.4 billion annually in total economic impact (San Diego Unified Port District [SDUPD] 2007). Since 1970 the Port has also been responsible for over $1.5 billion in public improvements in the five member cities.

Together, the Navy and the Port generate an annual economic benefit of about $18 billion to San Diego.

1.3.2 Defining Ecosystem Management for this INRMP

This INRMP complies with federal guidelines regarding adoption of an ecosystem approach to land and coastal management, including the definition of ecosystem management identified in EO 13547 establishing a National Ocean Policy for Stewardship of the Ocean and Coasts (19 July 2010). It is federal and DoD policy to incorporate ecosystem management as the basis for land use planning and management on its installations (DoD Ecosystem Initiative 1996). The SAIA states that the INRMP goals "shall be to maintain or develop an ecosystem-based conservation program…" DoDI 4715.03 requires that U.S. Navy installations incorporate ecosystem management principles.

These principles and guidelines are generally acceptable to academicians and practitioners alike, and they provide more specific guidelines to installation managers. It also provides a DoD definition of ecosystem management as *"A goal-driven approach to managing natural and cultural resources that supports present and future mission requirements; preserves ecosystem integrity; is at a scale compatible with natural process; is cognizant of nature's time frames; recognizes social and economic viability within functioning ecosystems; is adaptable to complex changing requirements; and is realized through effective partnerships among private, local, State, tribal, and Federal interests."* The Navy directs (OPNAVINST 5090.1C) that ecosystem-based management shall include a shift from single species to multiple species conservation.

The EO creating a National Ocean Policy describes how ecosystem management will be defined for stewardship of coasts and oceans:

- Base management areas on ecosystems, not only political jurisdictions;
- Focus on overall, long term ecosystem health;
- Consider cumulative impacts of different activities;
- Recognize connectivity among and within ecosystems;
- Respond to uncertainty with precaution;
- Coordinate at scales appropriate to specific goals;
- Restore and protect native biodiversity to strengthen resilience;
- Develop indicators to gauge the effectiveness of management measures;
- Acquire more and better science for decision making;
- Engage stakeholders and the public; and
- Provide for adaptive management through systematic monitoring and adjustment.

Table 1-1 shows how ecosystem management principles are interpreted for this INRMP.

Table 1-1. Integrated Natural Resources Management Plan ecosystem management definitions.

What Ecosystem Management Means to the San Diego Bay INRMP
1 Defining the Problem - Emphasis is placed on the resiliency of natural processes and linkages and on whole habitats and communities rather than individual species or projects. - Problems are defined without regard to jurisdictional boundaries or technical disciplines, and cooperative solutions are sought when the problem crosses jurisdictional boundaries.
2 Assessing the State of the Bay—Natural and Human "Core Ecosystem Functions" (Section 1.3.1) - Assessment and monitoring strategies are prioritized in part based on their ability to provide insight into the strength and dependencies of one habitat or community upon another and into both the structure and processes that make the ecosystem function. - Assessment and monitoring strategies are prioritized in part based on their ability to detect long-term trends and the cause of significant ecosystem change. - Assessment and monitoring strategies are identified that shed light on how the bay sustains vibrant, healthy, and economically diverse human activities.
3 Ecosystem Planning Process - Ecological, social, and economic goals are integrated. - The process involves diverse government and nongovernment groups coming together with significant participation by community stakeholders.
4 Management Strategies - Management works at multiple scales appropriate to the problem. - Market- and incentive-based approaches are considered, as well as the need for regulation. - Management approaches, including projects and mitigation, acknowledge the role of regulation, National Environmental Policy Act, and California Environmental Quality Act in contributing to ecological and socio-economic objectives.
5 Implementation Based on Goals So That Objectives and Tasks Are Clearly Tiered in an Ecosystem Goals Framework - Management and research are implemented at multiple scales appropriate to the understanding of the problem and to encourage experimentation and innovation. Small-scale prototypes with adaptive management and maximum dissemination of learned information are advocated. - Emphasis is on cooperative, interjurisdictional, cross-boundary conservation partnerships, with potential new roles for government and nongovernment groups. - Project evaluation draws on socioeconomic and political expertise, as well as that of biologists and natural resources managers.

1.3.3 Defining Sustainability for this INRMP

The U.S. Navy and the Port, for the purposes of this INRMP, adopt the following sustainability definition:

Sustainability in San Diego Bay is the capacity to achieve the missions of the U.S. Navy and the Port of San Diego into the future without decline or compromise to the growth of natural resource assets that support these missions.

A growing regulatory and business climate for sustainable building, natural resources use, and pollution prevention has facilitated the incorporation of environmental sustainability as a core theme of this INRMP. Accommodating use while improving the health of the bay's natural resources is to some degree possible through technological and planning advances that allow for more environmentally integrated development. As understanding of the San Diego Bay's ecosystem becomes more refined, our capacity to both increase use while concurrently improving the health of the bay's natural resources has become possible. This combined aim is encompassed in the concept of sustainability.

The topic of sustainability encompasses:

- Sustainability of the institutional missions of the Navy and the Port.
- Water quality and sustainable practices on land that influence and enhance water quality in the bay and along the coast (as stated in EO 13547).
- Sustainability of natural resources and their functions for San Diego Bay. This includes resource-specific best practices for sustainable energy, water, water and sediment quality, air quality and deposition, greenhouse gas management, reducing threats to shorelines, both natural and developed, securing habitat for special status and indicator species into the future, and preparing for sea level rise and global warming.
- Sustainability in the built environment with respect to energy use, greenhouse gas emissions, and water use. A federal task force agreed to a set of federally accepted principles for sustainability in the built environment, and these are described in Chapter 5. This topic includes Leadership in Energy and Environmental Design (LEED™) and Low Impact Development (LID) planning as an emerging requirement of water quality permits.
- Sustainability indicators that help monitor progress toward sustainability objectives.

The topic of sustainability in this INRMP includes practices on land that influence and enhance water quality in the bay and along the coast (from EO 19 July 2010 establishing a National Ocean Policy for Stewardship of the Ocean and Coasts).

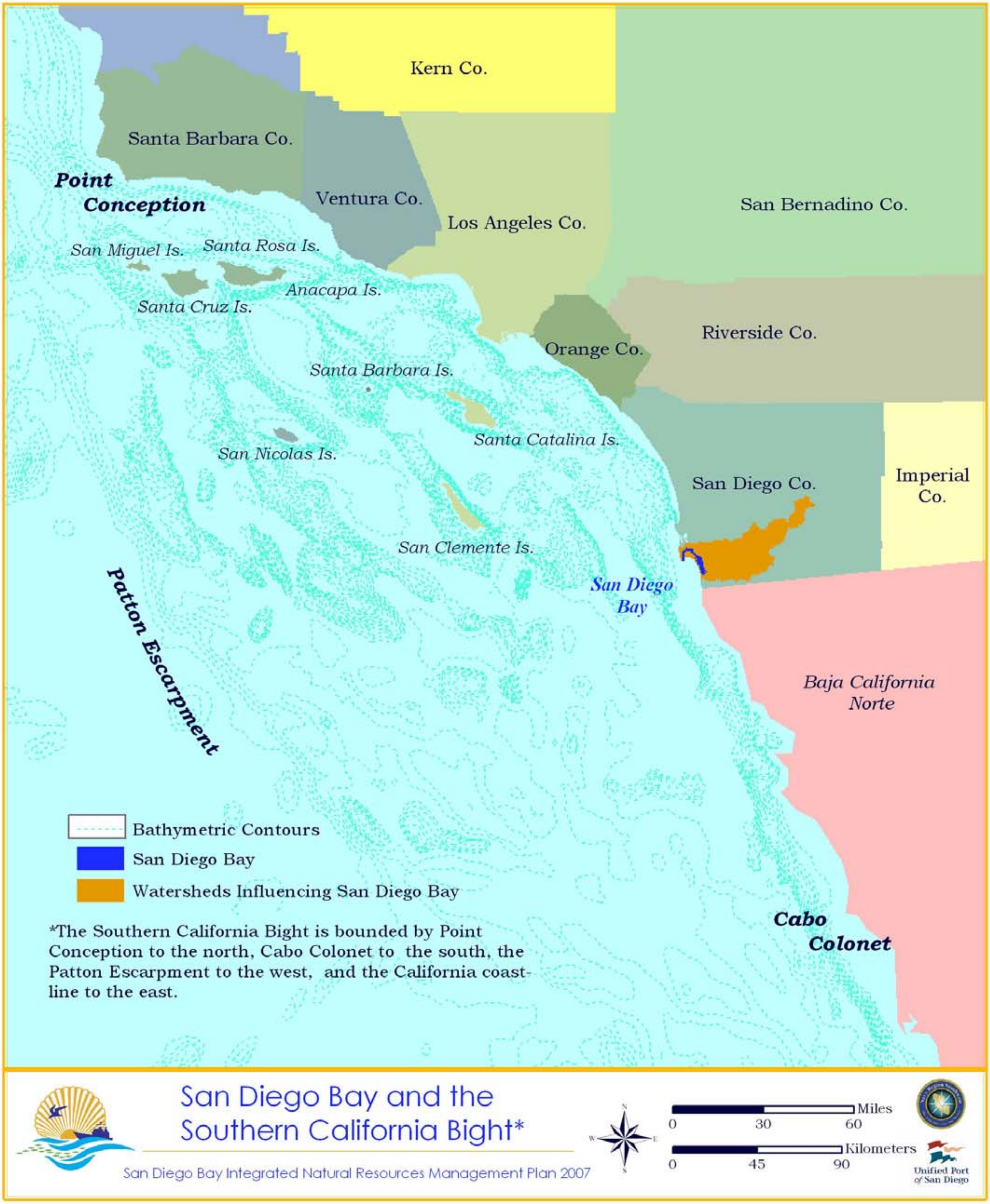
1.4 INRMP Scope and Context

This INRMP will serve as a nonregulatory guide to better, more cost-effective decisions by those involved with the bay. It generally covers bay-dependent resources to the Higher High Water mark and more upland areas as appropriate. As shown in Map 1-2, this zone includes everything bayward of the current higher high tide line west to Ballast Point, Point Loma and south to the end of Zuniga Jetty, with the addition of the South San Diego Bay National Wildlife Refuge (NWR). This area of water, tidelands, and land encompasses 12,132 acres.

San Diego Bay is part of the greater ecosystem of the SCB (See Map 1-1 and discussion of the SCB in Section 2.1: Ecoregional Setting) and covers 10,532 acres of water and 4,419 acres of tidelands around the bay, according to Port maps (SDUPD 1995a). “Tidelands” legally include land below the historic (1850) mean high tide line; some are now filled in and developed (e.g. Lindbergh Field, Coronado golf course, Naval Amphibious Base [NAB]). These developed fill areas are not intended to be a primary focus of the INRMP, so they are not included in the plan’s Functional Planning Zone, or “footprint.”

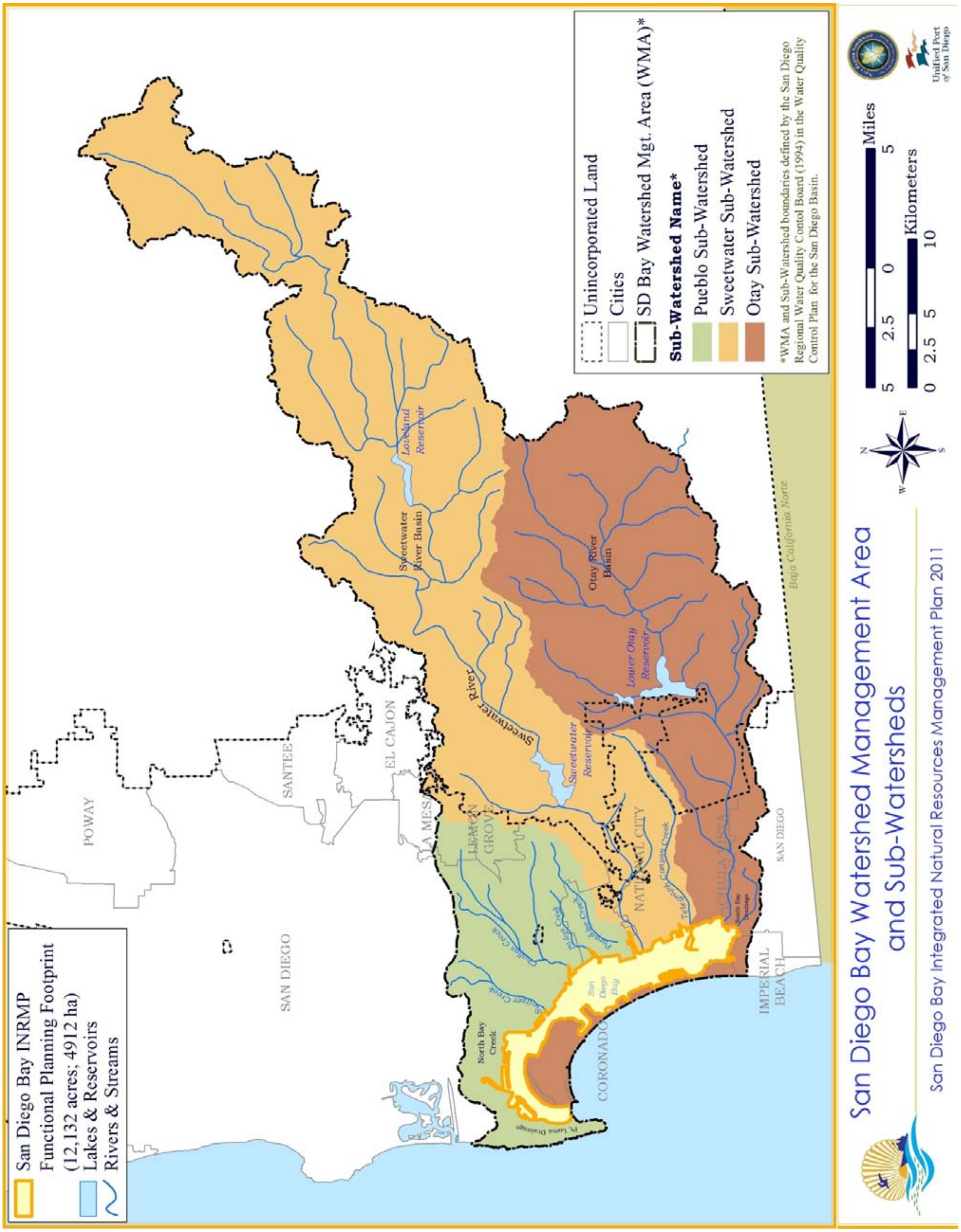
Map 1-3 shows the Watershed Influence Zone, an area of 277,129 acres directly linked to the bay’s resources. This zone includes the Sweetwater River and Otay River drainages, small urban creeks (e.g. Chollas Creek) and stormwater drains flowing directly into the bay, and portions of Silver Strand and Point Loma. This zone includes the waterfront areas of the cities, Navy, and Port adjacent to the bay. Watersheds are important to include in concept because of the functional connectivity and interrelationships between the bay and upstream biological, physical, and chemical processes.

Certain topics, particularly air quality, are not considered in depth because of their coverage in other plans or processes. However, this INRMP addresses these topics within other important components of the bay ecosystem. By considering the bay as one ecosystem that encompasses many political jurisdictions, the INRMP covers the natural components as well as the geographic and time scales necessary to address the ecosystem’s needs.



Map 1-1. San Diego Bay, the "Watershed Influence Zone," in the Southern California Bight.

Map 1-2. San Diego Bay Integrated Natural Resources Management Plan Functional Planning Zone, or "Footprint."



Map 1-3. San Diego Bay Integrated Natural Resources Management Plan Functional Planning Zone and Watershed Influence Zone.

1.4.1 Relationship to Other Regional Plans

Established to protect endangered and threatened species, the Refuge encompasses approximately 2,620 acres of land and water in and around San Diego Bay.

This updated San Diego Bay INRMP will build on the many related concurrent efforts in the region as represented by these recent plans:

Comprehensive Conservation Plan for San Diego Bay National Wildlife Refuge. The USFWS has prepared a CCP that will guide operations, habitat management, and visitor services for the next 15 years at the Sweetwater Marsh and South San Diego Bay Units. The CCP is prepared pursuant to the National Wildlife Refuge System Administration Act of 1966, as amended by the National Wildlife Refuge System Improvement Act of 1997 (Public Law [PL] 105-57). This plan recognizes the need for expanded opportunities for compatible public use including wildlife observation, environmental education, and interpretation; provisions to protect cultural resources; recommendations for addressing existing contaminant issues; and proposals for establishing partnerships to address concerns such as water quality, the accumulation of discarded fishing line around the bay, and stewardship of Refuge resources. Finally, the CCP fulfills the USFWS obligation to prepare "a holistic habitat restoration plan" for a 1,035-acre portion of the existing salt works property, as described in a Cooperative Agreement between the USFWS and the Port, dated October 1998 and amended in March 1999.

The Refuge, which was established to protect endangered and threatened species, encompasses approximately 2,620 acres of land and water in and around San Diego Bay. The approved refuge boundary would expand this to 3,940 acres. The habitat restoration proposals within the CCP focus on supporting a number of listed species such as the California least tern (*Sterna antillarum browni*), western snowy plover, and light-footed clapper rail (*Rallus longirostris levipes*). The USFWS is proposing to restore portions of the salt ponds to the historic habitats of intertidal mudflat and coastal salt marsh, while retaining other ponds as managed water areas to support species that favor the brine invertebrates present in the current system. The plan would result in the restoration of up to 140 acres of intertidal salt marsh, freshwater wetland, and coastal sage scrub habitat within the Otay River floodplain. In addition, up to 410 acres of salt ponds would be restored to intertidal salt marsh habitat. The trade-off for these gains is a decreased potential habitat for shorebirds by reducing area of salt ponds by 145-440 acres. Nesting habitat for seabirds would be expanded by about 28 acres. The increase in tidal wetlands is up to about 800 acres. Implementing the CCP will affect the status of natural resources baywide, as well as use patterns on the bay (especially recreational use).

Integrated Natural Resource Management Plans for Naval Base Coronado, Naval Base Point Loma, and Naval Base San Diego. These INRMPs for Navy bases in the San Diego metropolitan area address many terrestrial natural resources concerns, but only address marine resources in the small areas where the Navy owns real estate in the water. For example, California least tern nesting is covered in the Naval Base Coronado (NBC) INRMP, but foraging activity of the tern is addressed in this baywide INRMP.

The Otay River Watershed Management Plan was completed in 2006 and adopted by the jurisdictions that encompass this watershed draining into the bay: County and City of San Diego, City of Imperial Beach, City of Chula Vista, and San Diego Port District. Included in the plan are water quality, natural resources, and watershed protection measures, as well as watershed baseline indicators. In an area of 93,000 acres (154 mi^2 [248 km^2]), population and housing demands are expected to double by 2030. Impervious cover could increase from 9% to 16%. The county has obtained federal funding to develop a Special Area Management Plan (SAMP), which provides for "natural resource protection and reasonable economic growth" within geographic areas of special sensitivity. Approval of these plans by the U.S. Army Corps of Engineers (USACE) will result in the issuance of General Permits under the Clean Water Act (CWA) for projects within the Otay River watershed. The SAMP will identify baseline conditions of the watershed including water quality and the extent of wetlands that can be used in other programs. This SAMP could affect water quality planning for this INRMP.

The San Diego Bay Watershed Urban Runoff Management Program (WURMP) coordinates the ten municipal co-permittees who are required to meet the requirements of the San Diego RWQCB's Municipal Stormwater Permit within the San Diego Bay Watershed Management Area (WMA) (See Map 1-3). The program's goal is to "positively affect the water resources of the San Diego Bay Watershed while balancing economic, social, and environmental constraints." Monitoring of water quality and abating pollutant sources is its primary focus. The WURMP contributes to water quality objectives of this INRMP.

The *San Diego Integrated Regional Water Management Plan* was developed by a consortium of municipalities, water districts and nonprofit organizations in 2007 so the region could apply for Proposition 50 and other future State bond grants in a coordinated manner. Its vision is an integrated, balanced, and consensus approach to ensuring the long-term sustainability of San Diego's water supply, water quality, and natural resources. A package of projects consistent with the Integrated Regional Water Management Plan is to be submitted for each round of grant opportunities. San Diego Bay's three watersheds are among the hydrologic units that would benefit, and as such, this would directly integrate with the objectives of this INRMP.

Water quality and endangered species are the focus of at least two other plans. The San Diego Bay INRMP will complement these efforts where applicable.

Multiple Species Conservation Program (MSCP). The southwestern region of San Diego County is covered by the City of San Diego's MSCP. The Cities of San Diego and Chula Vista, among others, are active participants in the MSCP and have jurisdiction over some bay marsh lands and waters. This regional habitat conservation plan is aimed at protecting multiple species and their habitats in place of the single species protection approaches of the past (City of San Diego [CSD] and MSCP Policy Committee 1996). By creating an interconnected habitat preserve system for the region and obtaining approval from the regulatory agencies, the local governments and landowners can receive permission to "take" species listed under the state and federal Endangered Species Acts (CESA and ESA, respectively). The plan was adopted by both the City and County of San Diego (CSD and USFWS 1997). With the MSCP's emphasis on terrestrial habitats, the overlap between this INRMP and MSCP planning are for those species that cross into the footprint of this INRMP.

San Diego Association of Governments (SANDAG) Bayshore Bikeway. The Bayshore Bikeway Plan Update focuses on ways to connect gaps in the route identifying an off-street bike path alignment for the entire Bikeway loop around San Diego Bay. A pedestrian pathway is proposed for the southwestern edge of the Refuge, for use by both Refuge visitors and those traveling along the Bayshore Bikeway.

Relationship to Local Government Plans. Local land use planning is performed by each incorporated city and the county. The Cities of Chula Vista, Coronado, Imperial Beach, National City, and San Diego, as well as San Diego County have all adopted general plans and implemented zoning ordinances as required by the state. Within general plans are elements (e.g. Land Use, Conservation, Open Space) that may or may not address San Diego Bay's natural resources. Sensitive resources such as wetlands, wildlife corridors, and threatened habitats can be designated, with adoption and implementation of resource protection ordinances (as cited in SANDAG 1992). Since the Port and the state have jurisdiction on most of the bay's nonfederal tidelands and submerged lands, the city and county plans can only recommend changes in use within these areas, while applicants must apply to the Port and state for leases or change in leases. The local general plans and the Port's Master Plan overlap in these sites.

The California Coastal Act requires each local government with property within the coastal zone to prepare and adopt a Local Coastal Plan. The intent of the INRMP is to exchange information and strategies with local planning efforts.

In addition, the California Coastal Act (CCA) requires each local government with property in the coastal zone to prepare and adopt a Local Coastal Plan (LCP), which has more stringent environmental protections than a general plan. Once certified by the CCC, a LCP is used as the basis for local government approval of proposed developments. Each local entity in the San Diego Bay region has an adopted and certified LCP with amendments sent periodically to the CCC for approval. The Port's Master Plan is considered their LCP. The intent of this INRMP is to exchange information and strategies with local planning efforts.

Other Watershed Programs are active for improving the condition of certain watersheds leading directly into San Diego Bay, and thus affecting water quality there. For example is the grant funding received by the City of San Diego's Stormwater Pollution Prevention Division "Think Blue" from the state of California to restore Chollas Creek. There are two grants: the San Diego Region Integrated Pest Management Education and Outreach Project grant and the Chollas Creek Water Quality Protection & Habitat Enhancement Project grant. Both grants are funded by the SWRCB with funds approved by voters in the Proposition 13 Coastal Nonpoint Source Pollution Control Grant Program. In 2002, Chollas Creek was identified by the U.S. Environmental Protection Agency (EPA) as an impaired water body with high concentrations of diazinon, coliform, and metals such as cadmium, copper, zinc, and lead. In its current state, the Creek has also become a collector of trash and debris. The purpose of these two grants is to improve the health of Chollas Creek, improve water quality, alleviate flooding, and provide essential pollution prevention information to residents and businesses who will sustain the creek improvements beyond the life of the grants. The restoration work will focus on the aesthetic improvements that will restore the creek to a natural setting. The project is done in accordance with the "Chollas Creek Enhancement Program" plan adopted by the San Diego City Council in May 2002. As envisioned, the work would bring both aesthetic, recreational, and environmental improvements to the South Branch of the Encanto Tributary of Chollas Creek. Additional elements include public trails, environmental signage along the creek, and community-based art. This project is implemented in cooperation with the Jacobs Foundation.

The Paradise Creek Enhancement Plan is implemented by National City, an effort that originated and is led by community volunteers in a low-income neighborhood. The plan includes an educational park with a field-based learning center. The educational park was built with contributions from the City, Coastal Conservancy, National City School District, National Park Service's Rivers, Trails, and Conservation Assistance Program, California State University Dominguez Hills, local clubs and business groups, San Diego County, the Port, AmeriCorps, the National Endowment for the Arts, and the San Diego Bay Council (a consortium of area environmental groups including the San Diego Chapter of Sierra Club, San Diego Chapter Audubon Society, San Diego Coastkeeper, Environmental Health Coalition, San Diego Surfrider Foundation, and Surfers Tired of Pollution).

California Wildlife Action Plan (WAP). Integrating the goals and objectives of the state WAPs and those of INRMPs is now a U.S. Navy metric that must be evaluated each year during the annual INRMP update process. In 2000, Congress enacted the State Wildlife Grants Program to support state programs that broadly benefit wildlife and habitats but particularly "species of greatest conservation need." As a requirement for receiving funding under this program, state wildlife agencies were to have submitted a WAP to the USFWS in 2005. The California WAP identifies 807 vulnerable "species of conservation concern" (CDFG 2007b). It contains three sets of actions: statewide, regional, and adaptive management and monitoring. The most relevant to this INRMP are the actions related to the South Coast and Marine regions. These are summarized below in Table 1-2. Integrated goals and objectives allow possibilities for joint and efficient project funding.

Recovery Plans for Federally Listed Species. The relevant recovery documents for federally listed species are identified in Table 1-3.

Fishery Management Plans and Essential Fish Habitat (EFH). The Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S. Code [USC] 1801, *et seq.*), as amended by the Sustainable Fisheries Act (PL 104-267) mandates that the Secretary of Commerce shall establish guidelines, by regulation, to assist the Fishery Management Councils in the description and identification of EFH in Fishery Management Plans (FMP), including adverse impacts on such habitat. Section 305(b)(2) of the Act requires that proposed federal projects or projects that require federal permitting complete an EFH plan in accordance with requirements in 50 Code of Federal Regulations (CFR) §600.920(g)(2). The coastal waters of southern California, including those within San Diego Bay, are designated as EFH for the species listed in the California Coastal Pelagic Species FMP and the Pacific Coast Groundfish FMP.

Table 1-2. Conservation actions identified in the California Wildlife Action Plan for the South Coast and Marine Regions.

South Coast Region	Marine Region
▪ Wildlife agencies and local governments should work to improve the development and implementation of regional Natural Community Conservation Plans, which is the primary process to conserve habitat and species in the region's rapidly urbanizing areas.	▪ The state should fully implement the Marine Life Management Act to ensure that marine fisheries and the marine ecosystem are managed sustainably.
▪ Wildlife agencies should establish regional goals for species and habitat protection and work with city, county, and state agency land-use planning processes to accomplish those goals.	▪ The state should move forward in implementing the Marine Life Protection Act by establishing a network of marine protected areas.
▪ Federal, state, local agencies, and private conservancies should safeguard and build upon Camp Pendleton's contribution to the regional network of conservation lands, and similarly, protect habitats on lands adjacent to the Marine Corps Air Station Miramar.	▪ The state should secure Tidelands Revenues for implementation of the California Ocean Protection Act.
▪ To address regional habitat fragmentation, federal, state, and local agencies, along with nongovernmental conservation organizations, should support the protection of the priority wildlands linkages identified by the South Coast Missing Linkages project.	▪ The state should increase efforts to restore coastal watersheds.
▪ Federal, state, and local agencies, along with nongovernmental conservation organizations, should protect and restore the best remaining examples of coastal wetlands that provide important wildlife habitat.	▪ The state should adopt a "no net loss" policy for critical marine habitat.
▪ Public agencies and nongovernmental conservation organizations should invest in efforts to protect and restore the best remaining regional examples of ecologically intact river systems.	▪ The federal and state resource agencies should expand efforts to eradicate introduced predators from all seabird colonies.
▪ Federal, state, and local agencies should provide greater resources and coordinate efforts to eradicate or control existing occurrences of invasive species and to prevent new introductions.	▪ The state should systematically review and monitor the distribution and abundance of non-harvested marine fish and invertebrates.
▪ Federal, state, and local public agencies should sufficiently protect sensitive species and important wildlife habitats on their lands and should be adequately funded and staffed to do so.	▪ Federal and state resource agencies and institutions should foster and facilitate interstate collaborative research on marine species whose ranges cross jurisdictional boundaries.
▪ Federal and state agencies and nongovernmental partners should collaborate to institute appropriate fire management policies and practices to restore the ecological integrity of the region's ecosystems while minimizing loss of property and life.	▪ The federal and state resource agencies should expand efforts to eradicate introduced predators from all seabird colonies.
▪ The state should coordinate the development of a model ordinance and building codes for new or expanding communities in fire-adapted landscapes to make those communities more fire compatible and reduce the state's liability for fire suppression.	
▪ State and federal wildlife agencies, the U.S. Forest Service, state and county parks, Bureau of Land Management, and nongovernmental partners should collaborate to develop a comprehensive Southern California Outdoor Recreation Program to provide recreational opportunities and access that do not conflict with wildlife habitat needs.	

Table 1-3. Plant and animal species of San Diego Bay that are Federally Protected under the Endangered Species Act (ESA), their Federal and State of California (CA) listing status, Federal listing date, and recent Federal recovery documents.

Scientific Name	Common Name	USFWS/CA Status[1]	ESA Listing	USFWS/NMFS Recovery Documents
Plant				
Cordylanthus maritimus ssp. *maritimus*	salt marsh bird's beak	FE/CA E	43 FR 44810 September 28, 1978	Final Recovery Plan December 6, 1985
Animals				
Sternula antillarum browni	California least tern	FE/CA E	35 FR 16047 October 13, 1970	Final Recovery Plan Revision 1 1985 5-Year Review September 26, 2006
Charadrius alexandrinus nivosus	western snowy plover (Pacific Coast population)	FT/CA SSC	58 FR 12864 March 5, 1993	Final Recovery Plan August 13, 2007 5-Year Review May 31, 2006 Critical Habitat Designation September 29, 2005
Rallus longirostris levipes	light-footed clapper rail	FE/CA E	35 FR 16047 October 13, 1970	Final Recovery Plan August 13, 2007 5-Year Review May 31, 2006
Chelonia mydas	east Pacific green sea turtle	FE (FT for the population in the bay)	43 FR 32800 July 28, 1978	Final Recovery Plan Revision 1 January 12, 1998 5-Year Review August 22, 2007

[1] *Federally endangered (FE), federally threatened (FT), CA endangered (CA E), CA species of special concern (CA SSC)*

The Pacific Coast Groundfish FMP manages at least 82 species over a large and ecologically diverse area (Pacific Fishery Management Council [PFMC] 2008). In addition, the FMP identifies seven "composite" EFHs, including estuarine, rocky shelf, non-rocky shelf, canyon, continental slope/basin, neritic zone, and oceanic zone. The FMP also identifies both fishing related and non-fishing related activities that may cause adverse impacts to EFH. Species for which occurrence is known and the habitat in the bay is suitable may be identified (See Chapter 4). Habitat Suitability Probabilities for all fish in the Groundfish FMP are available in Appendix B to Amendment 19 of the FMP (PFMC 2008).

As well as designating EFH the PFMC also designates Habitat Areas of Particular Concern. These are ecologically important, rare, or sensitive habitats that should be given special attention when evaluating the effects of non-fishing impacts. San Diego Bay meets two criteria for an Habitat Areas of Particular Concern: an estuary and a site where eelgrass grows.

The FMP for Coastal Pelagic Species includes four species that could be in the bay: northern anchovy, jack mackerel (*Trachurus symmetricus*), Pacific sardine (*Sardinops sagax*), and Pacific (chub) mackerel (*Scomber japonicus*) (PFMC 1998). Non-fishing related activities that have the potential to harm groundfish species could also have the same effect on these pelagic species.

1.5 Strategic Design of Plan

1.5.1 Organization of Plan

The major sections of this INRMP, aside from this chapter, are divided into three parts:

- The current state of ecosystem resources and human use of San Diego Bay is at the beginning of the INRMP (Chapters 2 and 3, respectively);
- Management strategy sections (Chapters 4 through 6) are a synthesis of management issues, and needs are first provided for each component; and
- Implementation strategy (Chapter 7).

Also in Chapter 7 there is a section entitled “7.1 What's Accomplished and New Since the 2000 INRMP” that highlights how this INRMP has been updated.

The strategy statements in Chapters 4 through 7 are in a hierarchical format, beginning with broad, long-term statements and ending with specific, short-term methods. The definitions of the planning terms are described in Table 1-4.

Table 1-4. Planning Definitions.

Hierarchy	Definition
Goal	Broad statement of intent, direction, and purpose. An enduring, visionary description of where one wants to go. A goal is not necessarily completely obtainable.
Objective	Specific statement that describes a desired condition. Can be quantitative. Should be good for five years or so.
Strategy	Explicit description of ways and means chosen to achieve objectives.
Policy	Formally-adopted strategy or decision to carry out a course of action.
Task/Activity/Tactic	Specific step, practice, or method to get the job done, usually organized sequentially with timelines and duty assignments. These go out of date quickly and should be updated annually.

1.5.2 Implementation

To be put into effect, the INRMP must first be understandable, practical, and supportable by those who need to implement it. If those criteria are met, then the INRMP will need a commitment by the implementers and their supporters in terms of time and money. A framework for organizing stakeholders and resources is provided in Chapter 7. Some of the strategies involve specific actions that may need cooperative funding (e.g. habitat monitoring). However, other strategies suggest changes in direction and do not necessarily require direct funding to implement (e.g. biological assessment methods or criteria for habitat conservation). Whatever the case, cooperative efforts are essential to ensure the implementation of this INRMP. Signature approval by the Navy and Port authorities as well as by other agencies and organizations provides an authority for implementation.

1.6 Summary of Updated Issues

An initial effort by the INRMP's TAC to identify key problems and focus areas for the INRMP rendered over 30 issues, some of which were suggested by the public members. This list was honed over months, including during Environmental Committee meetings associated with SB 68. The issues were revised and reworded to contain nine key focus areas listed below. In addition to these topics, numerous subject matter concerns are listed and addressed in later chapters. These concerns define the level of emphasis placed on the topics covered in this INRMP. The locations in this INRMP where each topic is addressed is listed after each of the nine headings below.

1. *Implementation difficulties (See Chapter 7 Implementation Strategies).* Relatively few of the more than 1,000 actions identified in the 2000 INRMP have been implemented. While the 2000 INRMP provided a consensus about a baywide strategy for natural resources stewardship, eliminating the past strategy vacuum that existed, an implementation strategy (Chapter 7, 2000 INRMP) did not get off the ground. Many INRMP projects have no regulatory "driver" for implementation that allows government stakeholders to allocate sufficient resources. Complying with environmental laws usually addresses the offsetting of impacts due to each individual project. The result is that natural resources are nominally maintained with only incidental isolated improvements in their status and few instances of recovery of what has been lost in the past. While efforts to offset incremental losses of ongoing projects are important, significant funds are needed for restoring historic losses, for moving forward with improving and repairing system-level deficiencies in the bay, and for making use of restoration or enhancement opportunities.

   Certain projects are expected to be implemented eventually through normal regulatory channels and mitigation for construction projects. Of the habitat restoration projects identified in the 2000 INRMP (Chapters 4 and 5), about 20 are not likely to be implemented because:

   - These projects are large, complex, and inter-jurisdictional, with multiple landowners and agencies involved.
   - Mitigation work in a NWR is restricted. Some of San Diego Bay's most exceptional restoration potential, scarcest habitats, and sensitive natural resources reside in the Refuge.

2. *Intertidal losses (See 4.3.5 Intertidal Mudflats and Chapter 6 Implementation).* Intertidal mudflats losses appear to be the most severe since modification of the bay shoreline began in the late 1800s. Both the Port and Navy have undertaken projects to offset some of the losses and enhance intertidal habitat since the previous INRMP was signed. Still, resources committed to creating or restoring this habitat, which has experienced a greater percentage loss than any other from the historic bay, are needed. Many shorebirds dependent on mudflats are declining along the Pacific Flyway. While the Salt Works has replaced some of the original ecological role of intertidal habitat, impacts continue, and some of these functions will be exchanged for salt marsh species in the proposed restoration planning for the South Bay NWR. Young-of-year California halibut appear to make substantial use of intertidal flats (Chapter 2), and this species shows evidence of a decline in abundance (Chapter 4). The losses of this habitat and the species depending on it are tied to the need to fill and armor the shoreline in order for the bay to function as a harbor.

3. *Problems arising in the watershed are cumulative and amplified as they reach San Diego Bay (See 5.5 Cumulative Effects).* It is established that upstream contaminants are coming down Switzer, Chollas, and Paleta Creek to the bay (see Chapter 5, Section 5.4.1: Remediation of Contaminated Sediments), but there are many unknowns about relative amounts and what is a historic versus current problem. Therefore, it is difficult to properly allocate resources to addressing the problem.

4. *There are imminent threats to the bay ecosystem such that doing nothing carries a risk to biological integrity and special status species (See 4.5 Strategy for Habitat Management; 4.4.1 Invasive Species; 5.1 Toward a Sustainable Ecosystem in San Diego Bay; 7.2 Seven Major INRMP Initiatives).* The bay's resilience to buffer future impacts that we can already anticipate may be diminishing, such as sea level rise, invasive species introductions, and shoreline development. The pressure for more intensive use of the bay's shoreline and open water is ongoing. Without provisions in current mitigation projects to accommodate and provide buffers for expected changes, the long-term success of mitigation projects may be jeopardized. (See Chapter 5, Section 5.2.1: Dredge and Fill Projects.) For example, cordgrass (*Spartina foliosa*) at the lower end of the salt marsh could be drowned out, or eelgrass could be killed by lack of light penetration when water deepens. Nesting sites for protected species by regulation may be flooded, and their foraging areas may become unsuitable for supporting forage species. With an increasing number of nonnative aquatic nuisance species also being found, the bay's ecological integrity is being challenged.
5. *Information sharing is needed in order to implement the best available science (See 6.3 Data Integration, Access, and Reporting; 7.2.7 Data Management and Reporting /Improved Information Access).* Information should be accessible, consistent, and commensurable. The ability to use the best available science is constrained by the lack of sufficient ease of sharing information across jurisdictions, collaborating on studies, and integrating scientific work conducted outside of agency venues. Ecosystem management is based on a scientific understanding of ecosystem composition, structure, function, and interlinking processes. It requires more and better research and data collection, as well as better coordination and use of existing data and technologies.
6. *Planning is agency specific, site specific, and piecemeal, while the planning need is cross-jurisdictional (See 7.0 Implementation Strategies).* Bay stakeholders have separate forums to address shared problems. The Environmental Committee is a Port-led forum that advises the BPC. The TAC associated with this INRMP, in contrast, is a DoD requirement. Problem-solving is segmented; as a result, it is not as effective as it needs to be. To successfully take an ecosystem approach to problem solving, these separate venues require a means of integration. A mechanism is needed for bay-wide decision making, investment, and management. Interagency and public-agency planning and problem-solving is currently cumbersome and so simply does not occur.
7. *Work is accomplished primarily within regulatory stovepipes although some progress has been made since the last INRMP (See 7.0 Implementation Strategies).* There are missed opportunities for getting the most out of available funding for work related to regulatory compliance with separate laws, the result being that the maximum ecological benefit to the bay is not achieved with existing funds spent. Water quality improvement, toxic clean-up, and habitat conservation are generally managed and accounted for separately even when objectives overlap. There is a need to promote projects that achieve multiple public objectives even though funding and accounting for success under each set of regulations is conducted separately. Examples are the beneficial, local use of dredge material for habitat restoration; treatment wetlands which improve habitat as well as treat water; and stormwater management or infrastructure plans which are integrated with other needs.

Projects that achieve multiple public objectives need to be promoted.

8. *Key biological indicators that link natural resources to water and sediment quality are not defined (See 5.0 Monitoring and Research).* A quantifiable means to link natural resources and indicators of water and sediment quality is essential to making meaningful decisions on bay improvements. This reflects a knowledge gap that extends far beyond San Diego Bay and even the SCB. The result is an inability to achieve as much benefit as possible for natural resources from the regulatory programs for water and sediment quality through an integrated approach, common objectives, adaptive management cues, and communication about status and trends. To meet Navy requirements for a key indicator, a way to monitor the indicator must be addressed.

9. *Lack of adequate mapping of habitat subsets, conditions and functions is preventing some progress (See 4.3 Strategy for Habitat Management).* The value of existing habitat is not mapped in sufficient detail to support design criteria for project proposals when they come along. The 2000 INRMP (Chapter 4 and Appendix G) recommended enhanced guidance for unvegetated shallow subtidal habitat (mudflats). While projects impacting this habitat are infrequent, there appears to have been a range of interpretation and enforcement when they do occur, with emphasis on site- and project-specific decisions, dependence on perceived availability of sites and ability to identify alternatives, reliance on limited funding available for a specific project, and reliance on what is thought to be a reasonable permit requirement based on the size of the project. The lack of descriptive or quantitative information about the functions at stake in intertidal and shallow areas has hindered its regulatory protection.

1.7 Summary of INRMP Objectives

Table 1-5 summarizes the INRMP objectives that are detailed in Chapters 4 through 6.

Table 1-5. Integrated Natural Resources Management Plan Objectives. Strategies for attaining goals and objectives are described in the text of Chapters 4 through 6.

The INRMP Goal is: To ensure the long-term health, restoration, and protection of San Diego Bay's ecosystem in concert with the bay's economic, Naval, navigational, recreational, and fisheries needs .

Topic Area	Objective
Ecosystem approach	4.1 Protect bay natural resources and their function by planning and acting at ecologically meaningful, hierarchical scales and time frames.
Mitigation and enhancement	4.2 Improve the success of mitigation and enhancement projects based on regulatory (avoidance and minimization measures), functional, and ecosystem criteria.
Protected sites	4.2.1 Ensure effective protection of a minimum quantity and quality of the remaining marine and coastal habitat in San Diego Bay, targeting a mix of habitat types that maximizes ecosystem function and carrying capacity.
Deep subtidal	4.3.1 Retain sufficient deep subtidal habitat to support safe navigation, good water quality, and physical and biological functioning in balance with the need for other habitat types in the bay.
Moderately deep subtidal	4.3.2 Conserve and enhance the attributes of moderately deep habitat that support diverse and abundant invertebrate forage for fishes and birds, as well as needed exchanges of energy, materials, and biota among habitats, in balance with the need for shallow and intertidal habitats.
Unvegetated shallows	4.3.3 Conserve and enhance the attributes of vegetated shallow subtidal sites that sustain a diverse and abundant invertebrate community, fish and wildlife foraging, nursery function for numerous fishes, as well as an ecological role in detritus-based food web support.
Vegetated shallows	4.3.4 Conserve and enhance the attributes of vegetated shallow subtidal sites that sustain a diverse and abundant invertebrate community, fish and wildlife foraging, nursery function for numerous fishes, as well as an ecological role in detritus-based food web support.
Intertidal flats	4.3.5 Achieve a long-term net gain in the area, function, value, and permanence of intertidal flats, and the physical conditions that support this habitat.
Salt marsh	4.3.6 Ensure no net loss of existing structure and function of salt marsh habitat, and achieve a long-term net gain in its quantity, quality, and permanence.
Artificial shoreline structures	4.3.7 Through engineering solutions, minimize the use of shoreline stabilization structures that impact or replace natural intertidal habitats, and maximize the value and function that necessary artificial structures contribute to the bay ecosystem.
Salt ponds	4.3.8 Protect and enhance the important wildlife functions of the salt ponds, with emphasis on special status birds, shorebird foraging and roosting, and sea bird nesting.
Upland transitions	4.3.9 Ensure no net loss of availability, structure, and function of high value adjacent uplands, and achieve a long-term net gain in their quantity, quality, and permanence.
River mouths and floodplains	4.3.10 Allow river mouths and floodplains to fulfill or at least mimic their natural ecological function as an intermittent and episodic source of sedimentation, organic matter, and freshwater input for the bay.
Invasive species	4.4.1 Minimize the harmful ecological, economic, and human health impacts of aquatic invasive species in San Diego Bay.

Table 1-5. Integrated Natural Resources Management Plan Objectives. Strategies for attaining goals and objectives are described in the text of Chapters 4 through 6. (Continued)

The INRMP Goal is: To ensure the long-term health, restoration, and protection of San Diego Bay's ecosystem in concert with the bay's economic, Naval, navigational, recreational, and fisheries needs (Continued).

Topic Area	Objective
Plankton	4.4.2 Identify and manage the physical and chemical factors in the bay that contribute to plankton productivity, and use of the bay by zooplankton from coastal waters.
Benthic algae	4.4.2.1 Identify and then conserve the food web and other functions of algal functional groups that reflect bay ecosystem health.
Invertebrates	4.4.2.2 Identify and conserve the abundance, biomass, and diversity of invertebrate functional groups that reflect health in each habitat and the ecosystem as a whole. Ensure that harvested invertebrate species are safe for human consumption.
Fishes	4.4.3 Conserve and enhance fish population abundance and diversity, with priority to those using the bay as a nursery or refuge, and to indigenous bay species.
Harvest management	4.4.3.1 Foster harvest management that can support viable, self-sustaining populations and promote native species richness within the San Diego Bay ecosystem.
Artificial propagation	4.4.3.2 Explore the potential for enhancing the numbers of fish species that are in decline through artificial propagation in San Diego Bay while protecting the bay ecosystem.
Birds	4.4.4 Maintain, enhance, and restore habitats on San Diego Bay aimed at providing for the health of resident and migratory populations of birds that rely on the bay to complete their life cycle. Foster broader public knowledge and appreciation of the functional, aesthetic, recreational, and economic values of the bird resources of the bay.
Marine mammals	4.4.5 Maintain a healthy balance of marine mammal species inhabiting or visiting San Diego Bay.
Threatened or Endangered Species and Critical Habitat Requirements	
Green sea turtle	4.4.6.1 Contribute to the recovery of the listed green sea turtle population consistent with the USFWS Recovery Plan through conservation measures in San Diego Bay.
California least tern	4.4.6.2 Contribute to the recovery of least tern numbers based on population size, distribution, and secure nesting site numbers by providing clear benefit to the species in a cost-effective manner.Manage predators of the California least tern to maximize colony success as measured by fledgling productivity and pair numbers.
Light-footed clapper rail	4.4.6.3 Protect the listed light-footed clapper rail population inhabiting San Diego Bay and seek to contribute to its recovery.
Western snowy plover	4.4.6.4 Due to a local decline in western snowy plovers, identify and correct the problem related to water quality, invertebrates, and sick or dying snowy plovers. Protect the listed western snowy plover population inhabiting San Diego Bay and seek to contribute to its recovery.
Salt marsh bird's beak	4.4.6.5 Seek the recovery of the salt marsh bird's beak population through habitat protection and enhancement.
Climate Change	5.1.1 Offset the adverse impacts of climate change through annual goal setting based on science-based scenarios, targets, collaborative planning, adaptive management, and joint pilot projects.
Sustainable Resource Use and Development	5.1.2 Sustain natural resources and Port and Navy institutional missions into the future without decline to natural resource assets or compromising the ability to grow those assets, by enabling innovation in planning, design, project management, and implementation.
Dredge and fill projects	5.2.1 Conduct necessary dredging and dredge disposal in an environmentally and economically sound manner.
Ship and boat maintenance	5.2.2 Manage the maintenance of boats and ships in San Diego Bay in a manner that achieves significantly improved water and sediment quality, healthier marine organisms, and economic good sense.
Shoreline construction	5.2.3 Seek improved habitat value of developed shorelines and marine structures and their functional contribution to the ecosystem.
Water surface use and shoreline disturbance	5.2.4 Properly balance the various surface uses of the bay as a navigable waterway and associated shorelines with conservation priorities for waterbirds and shorebirds.
Industrial	5.3.2.1 Reduce and minimize stormwater pollutants harmful to the bay's ecosystem from entering the bay from watershed users.
Freshwater inflow management	5.3.3 Encourage water managers within the bay watershed to manage freshwater inflows to help maintain the natural salinity and nutrient levels of the bay's wetlands and intertidal zone.
Remediation of contaminated sediments	5.4.1 Ensure that San Diego Bay finfish and shellfish are safe to eat, that the food web is not adversely altered and that risks are minimized to recreational and commercial water contact users from the effects of contaminated sediment.
Oil spill prevention and clean up	5.4.2 Prevent spills of oil and other hazardous substances, and ensure the effectiveness of prevention and response planning.
Cumulative effects	5.5 Minimize adverse cumulative effects on habitats and species of the bay ecosystem.

Table 1-5. Integrated Natural Resources Management Plan Objectives. Strategies for attaining goals and objectives are described in the text of Chapters 4 through 6. (Continued)

The INRMP Goal is: To ensure the long-term health, restoration, and protection of San Diego Bay's ecosystem in concert with the bay's economic, Naval, navigational, recreational, and fisheries needs (Continued).

Topic Area	Objective
Outdoor recreation and environmental education	5.6 Establish a culture of conservation for the bay as an ecosystem, including the relationship to its watershed.
Long-term monitoring	6.2.2 Provide monitoring that enhances bay managers' understanding and capacity to respond to a changing San Diego Bay and make better decisions regarding natural resource conservation and sustainable uses.Detect the extent and spatial scale of trends in critical ecosystem structural and functional attributes that contribute to the bay's important role as nursery for juvenile fish and invertebrates, as a major migratory stopover for shorebirds and waterfowl, as a breeding/nesting ground for wildlife, and for supporting endemic and rare species. Determine the cause of detected trends, separating management effects from natural availability. Use the trends to assess the relationship between physical and chemical factors and biological factors.
Water and sediment quality research to support management needs	6.2.3 Improve the ability to build on existing and new project monitoring experience to make the bay healthier and more sustainable.
Research to Support Management Decisions	6.2.4 Support management decisions by conducting research on the mechanisms and processes that provide value to the bay as an ecosystem.
Data integration, access, and reporting	6.3 Ensure the most effective integration, analysis, and dissemination of monitoring and research on San Diego Bay, and communication of this information to all concerned, so resources are targeted effectively for bay ecosystem health.

2.0 State of the Bay—Ecosystem Resources

This chapter describes what we understand about the physical and living resources that inhabit San Diego Bay. The elements that make up the ecosystem are discussed one by one—climate, hydrology, water, sediment, then the habitats and biotic communities. Finally, the condition of the ecosystem as a functional whole is presented, along with an assessment of the gaps in our understanding about the state of the bay.

2.1 Ecoregional Setting

A natural, nearly enclosed embayment, San Diego Bay is an exceptional harbor because of its deep entrance and sheltered waters. It originated from the alluvial floodplains of the Otay, Sweetwater, and San Diego Rivers. The bay is part of the Pacific Ocean's SCB (or "the Bight"), a curve in the southwestern California coastline that extends from Point Conception to just south of the Mexican border (as shown on Map 1-1). This ecological region is very productive and diverse for several reasons. First, for marine animals, it is the northern end of the range of many tropical species, and the southern end for many temperate species. Point Conception marks a sharp break in sea temperatures. Points north are cooler and just south of the Mexican border temperatures become warmer.

Second, the Bight is the landfall terminus of the very complex, Pacific Ocean underwater topography—especially when compared to the long, flat shelf extending seaward from the south Atlantic coast. A system of 13 large and 19 smaller submarine canyons, as well as offshore islands, provides habitat for a full range of species with different depth and temperature preferences. Special communities such as kelp beds add habitat structure in shallow water, fostering a rich species assemblage.

Third, the SCB contains both cool and warm water due to ocean currents mixing from subarctic and equatorial regions. Sea temperatures fluctuate regularly due to the changing strengths of these currents. These changes are reflected most by plankton and to a varying degree are transferred up the food chain.

Finally, the Bight's embayments, including San Diego Bay, contain shallow and intertidal habitat required by a number of species, and which is naturally scarce in southern California (compared to the east and gulf coasts). These ecological "edges" are even more limited today due to commercial development in other harbors, ports, marinas, and estuaries of the Bight.

2.2 Climate and Climate Change

2.2.1 Climate and Climate Cycles

Coastal San Diego County's mild, year-round climate is characterized as subtropical Mediterranean, with dry, warm summers and wet, cool winters. The average annual temperature is 60.4 degrees Farenheit (°F) (15.8 degrees Celsius [°C]), with an average high temperature of 67.3°F (19.6°C) and an average low temperature of 53.4°F (11.9°C). Temperatures of freezing or below have rarely occurred at the National Weather Service station at downtown San Diego since the record began in 1871, but hot weather, 90°F (32°C) or above, is more frequent. Along the coast, fog is common in the spring and summer. The annual average precipitation downtown, based on a continuous and homogeneous 146-year record from July 1850 through June 1996, is 10.02 inches. The current and official 30-year average (1978–2007) is 10.77 inches (National Oceanic and Atmospheric Administration [NOAA] 2008), falling between November and March. Upstream in the coastal drainages the mean annual precipitation is closer to 19 inches. Annual precipitation is extremely variable in this region. For example, over the past century annual precipitation has ranged from 3.02 to 26 inches at the San Diego gauge (City of San Diego 2001). The 3.02 inches of rainfall received in San Diego between July 1, 2001 and June 30, 2002 represents the driest year on record (NOAA 2004).

Winds over the bay are usually breezy (about 10 knots), but these have certain strong seasonal and diurnal cycles. Throughout most of the year, westerly winds pick up in the afternoon as cool air moves inland; evening and early morning easterly winds occur primarily in winter and are less than 10 knots (Wang *et al.* 1998). Stronger winds may occur in winter, associated with cold fronts moving through the region. Easterly Santa Ana winds may be quite strong in the fall, driven by high pressure over inland deserts. Winds are generally greater south of the Coronado Bridge than north of it, with greatest wind speeds in central south bay, west of Sweetwater Channel (Lapota *et al.* 1993).

Climatic cycles related to El Niño and La Niña events can alter the region's precipitation for a given year. During El Niños, sea-surface temperatures over a large part of the central Pacific climb above normal and stay high for many months. This large pool of warm water coincides with a change in wind patterns, which alters where evaporation takes place, and hence, where storms form and travel. Most of the time, strong El Niños bring wet winters to the Southwest and dry conditions to Indonesia and northern Australia. They generally occur every two to seven years. During La Niñas, water temperatures in the central Pacific drop below normal, and rainfall patterns shift in the other direction. El Niño typically lasts from 12-18 months and produces significantly more rainfall in southern California. La Niña, which usually but not always follows El Niño, has the opposite effect locally, causing less rainfall and cold ocean surface temperatures. Taken collectively, the El Niño/La Niña cycle is known as the El Niño Southern Oscillation (ENSO).

The ENSO cycle is just one of many atmospheric oscillations, or fluctuations, going on around the globe. The Pacific Decadal Oscillation (PDO), which involves, as the name implies, decade-long shifts is sea-surface temperatures in the Pacific, can also be charted on a multi-decadal time scale, usually about 20 to 30 years. The PDO is detected as warm or cool surface waters in the Pacific Ocean, north of 20°N. During a "warm" or "positive" phase, the west Pacific becomes cool and part of the eastern ocean warms; during a "cool" or "negative" phase, the opposite pattern occurs. The PDO was named by Steven R. Hare, who noticed it while studying salmon production patterns. While the ENSO and PDO have similar spatial climate fingerprints, they have very different behavior in time, and the climatic fingerprint of the PDO is most visible in the North Pacific/North American sector rather than the tropics. The opposite is true for ENSO. Causes for the PDO are not currently known. These cycles combined with nutrient sources, vertical nutrient gradients, warm spring–summer temperatures, and the attenuation of light with depth in San Diego Bay are fundamental to its productivity.

2.2.2 Global Warming and Sea Level Rise

There is now broad consensus among coastal managers that climate change will have far-reaching and long-term adverse impacts on coastal areas. Those impacts could devastate the bay's living resources with disruption and long-term damage to shallow, intertidal, and upland transition habitats, species, public access, commercial and residential development, and public facilities and infrastructure. The economic impacts could be enormous, considering that a National Ocean Economics Program study in 2005 valued California's "ocean economy" at $43 billion.

Rare 20 years ago, links between global warming and changes in terrestrial and marine ecosystems are now commonplace (Barry 2008). Using the work of the Intergovernmental Panel on Climate Change (IPCC) and the United States Global Change Research Program, the increasing sophistication of climate change models is allowing managers to make reasonable inferences about potential changes in regional and local climates. Some of the general changes in ecosystems globally are (as summarized by Brown and Thorpe 2008):

- Warming will be greatest over land, and at high northern latitudes
- Contraction of snow cover, increases in thaw depth over permafrost regions, and decreases in sea ice extent
- Very likely increase in frequency of hot extremes, heat waves, and heavy precipitation events
- Likely increase in tropical cyclone intensity
- Poleward shift in extra tropical storm tracks
- Very likely precipitation increases in high latitudes and decrease in dry regions in midlatitutdes and tropics
- High confidence that many semiarid regions (including western United States) will see decreases in water resource availability.

Carbon dioxide emissions also impact ocean chemistry with potential consequences for ocean ecosystems. If carbon dioxide concentrations in the atmosphere, as predicted, continue to increase at the current rate, then the oceans will become relatively more acidic than they have been in millions of years (Caldeira and Wickett 2003). This lower pH is eroding the mineral building blocks for the shells and skeletons of shellfish and other organisms (Kuffner and Tihansky 2008). Oceanographers are attempting to identify the possible consequences of changing ocean conditions on phytoplankton productivity and marine food chains.

More regionally, for southwestern United States and California, the following changes are expected (IPCC 2007; Archer and Predick 2008): fewer frost days; warmer temperatures; greater water demand by plants, animals, and people; increased frequency of extreme weather events (heat waves, deeper droughts, and higher flood peaks); warmer nights, reduced snowpack, and earlier spring snow melt sufficient to reduce water supply, lengthen the dry season, create conditions for drought, disease, and insect outbreaks, and increase the frequency and intensity of wildfires. Temperatures considered unusually high will occur more frequently. Because of the profound influence on the fire regime and hydrology, nonnative plants in arid lands might trump direct climate impacts on native vegetation. Lenihan *et al.* (2005) also surmised these impacts, predicting increased summer monsoons; increased fire weather, fuels, and wildfire frequency and intensity (aggravated by warmer springs and summers); decreased biodiversity; and decreased utility of multi-species conservation reserves without a significant redesign. Migration patterns of terrestrial and marine species will shift.

For San Diego, the climate-model analyses also show that wet areas will get wetter and dry areas will get drier, with all models predicting warmer temperatures, ranging from 2-4°F from conservative models to 8-10°F in higher-impact models (Cayman Institute 2007). Temperature change increases in the western United States have tracked those globally, especially in winter and spring. The number of days that exceed thresholds of 95°F ("heat waves") will increase; that is, there will be more hot days and longer summers. Future downtown San Diego temperatures could be like today's temperatures in La Mesa.

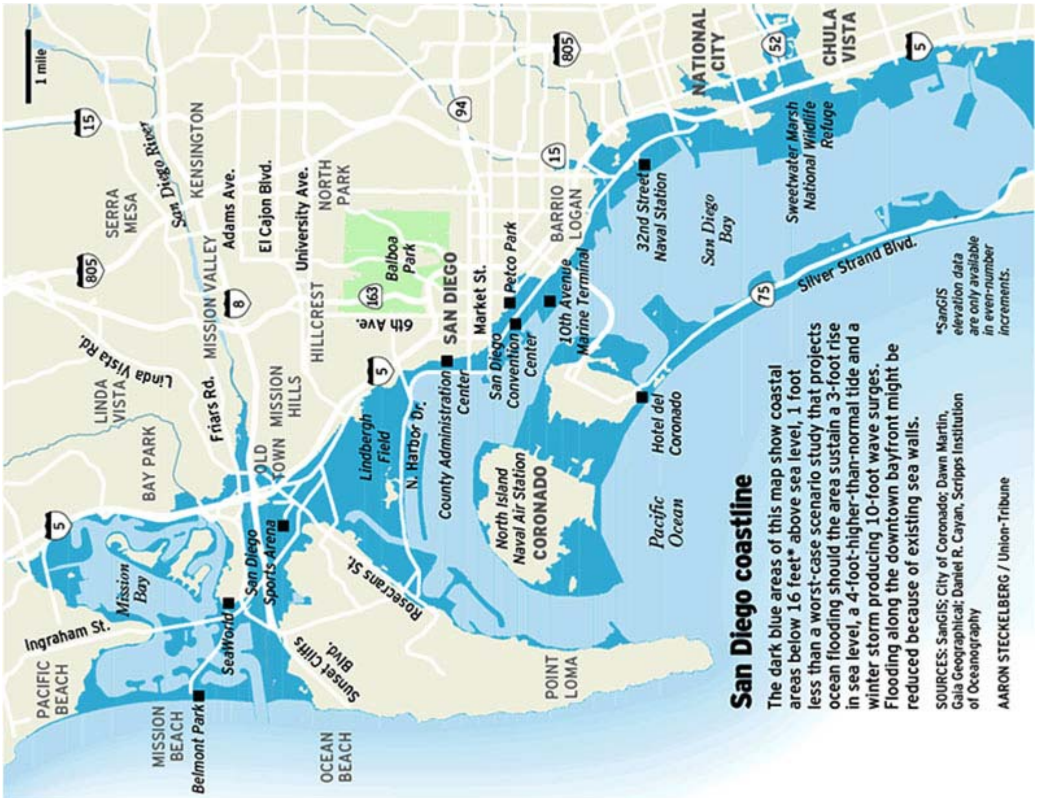
Sea level has been rising globally and along the west coast (about 10-20 centimeters [cm] or about 7 inches over the last century) (Cayman Institute 2007). The co-occurrence of "high" high tides with extreme storm-forced sea levels magnifies local coastal impacts. Modeling that incorporates the thermal expansion of the oceans and the melting of polar ice due to global warming suggests a substantial increase in the rate of sea-level change over the coming 100 years, with sea level rise ranging from 9-90 cm (to about 35 inches) above the current condition (United Nations Framework Convention on Climate Change 2007; Cayan *et al.* 2006). This large range in the predicted sea level rise reflects alternative scenarios of greenhouse gas emissions, from low to high (Cayan *et al.* 2006). A recent white paper analysis of potential coastal impacts funded by the California Energy Commission and the California EPA indicates that as sea levels rise, the likelihood of extreme storm events also escalates (Cayan *et al.* 2006).

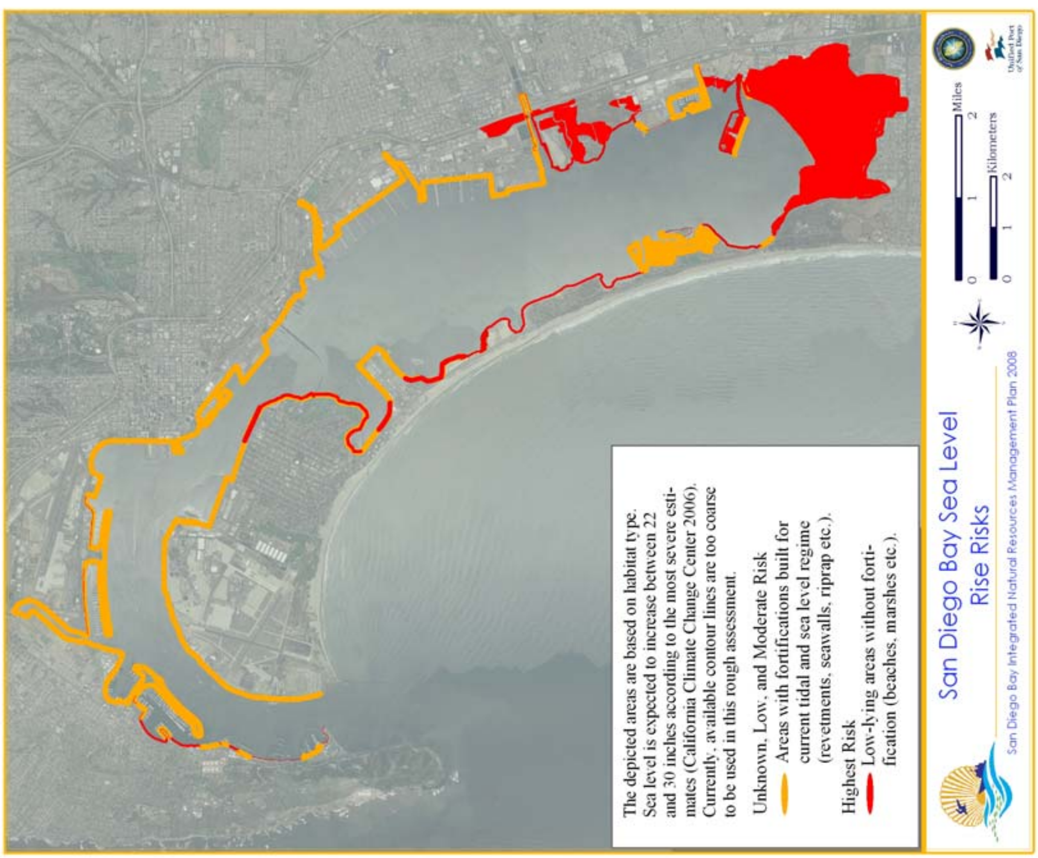
Since all models contain some error, various government agencies are using a range of predictions for coastal planning, with a number of State agencies requiring assessment for climate change scenarios for grant or permit approval (see Chapter 4 for examples). The U.S. Geological Survey (USGS) is conducting a survey of all coastal USFWS Refuges to assess the impact of sea-level rise. Their model assumes that the long-term rate of sea level rise would continue to be about 3 millimeters (mm) per year (about 6 inches in 50 years). Increments this small can have profound impacts on wetland surfaces. The National Wildlife Federation considers a moderate scenario to be 5- to 27-inch sea level rise in this century, with a mean sea level rise projection of 15 inches by 2100.

Marginal bay habitats are at risk from storms and tides, which can decrease prey availability up the food chain.

The effects of climate change over the next century will impact San Diego Bay in a variety of ways. Most notably will be the effects of sea level rise and increased tidal surges on natural resources and shore infrastructure, and a diminution of freshwater inputs. Eelgrass beds may shift or contract because of changing water clarity, depth, and temperature. High tide refugia for avian species may be depleted, and there may be a loss of intertidal habitat, such as occurred in cordgrass habitat occupied by light-footed clapper rails in the Tijuana Estuary, decimating the bird's population. Those marginal bay habitats without protective buffers are most at risk, especially those that require special salinity conditions, intermittent inundation, or light penetration. Storms and tides with the highest amplitude of the year can cause losses due to storm surges, or the overgrowth of vegetation at higher tidal elevations. When this happens, prey availability decreases sharply and shorebirds may no longer feed in the area (Baird 1993). Changes in water temperature affect mud temperature, which has been correlated with the concentration of certain prey species (Goss-Custard 1979), and thus the availability of prey to shorebirds. New species arrivals and departures of species historically evident are expected. The list of at-risk species is expected to increase.

Map 2-1 shows two climate change scenarios for San Diego Bay. One shows a worst case scenario with an increase of 22-30 inches by 2100, the other one adding high tide and storm surges, along with an unprotected shoreline, for the same time period.





Map 2-1. Two climate change scenarios for San Diego Bay.

2.3 Physical Conditions of the Bay

2.3.1 Current and Historical Bathymetry and Shorelines

The bay is 15 miles (24 kilometers [km]) long and varies from 0.2 to 3.6 miles (0.4 to 5.8 km) in width. It is 17 mi^2 (43 km^2 or about 11,000 acres).

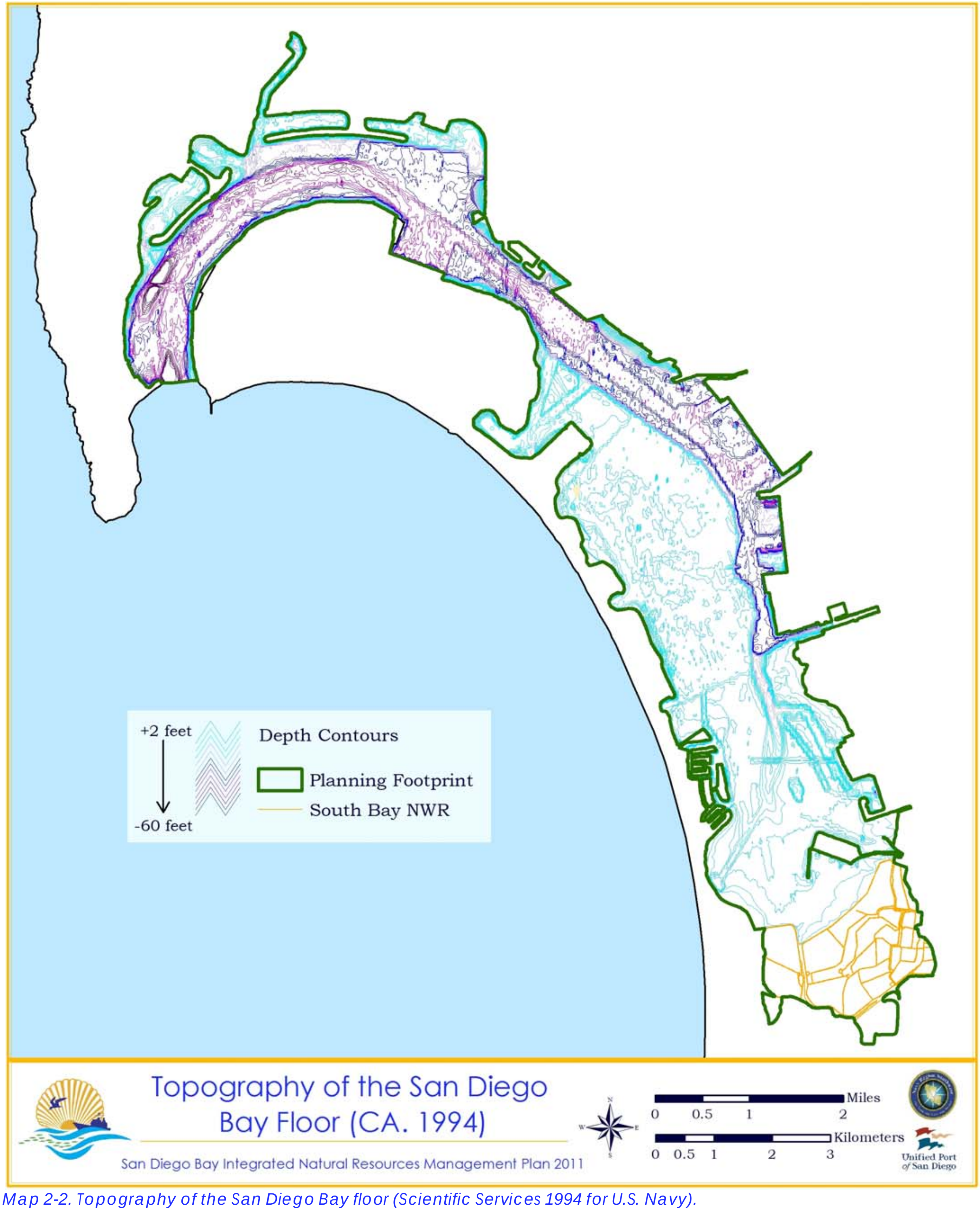
The bay is 15 miles (24 kilometers [km]) long and varies from 0.2 to 3.6 miles (0.4 to 5.8 km) in width. It is 17 mi^2 (43 km^2 or about 11,000 acres) in area at mean lower low water (MLLW) (Wang *et al.* 1998). A sand spit, deposited by a northward-bound eddy of the coastal current on the west, separates the bay from the sea. Historically, the sand transported was laid down from deposition emanating from the Tijuana River. However, since the damming of the river in 1937, the sand supply has been cut off and northern beaches have undergone severe erosion (Peeling 1975). Zuniga Jetty, which runs parallel to Point Loma at the bay's inlet, was built to control erosion near the inlet, changing the bay's hydrodynamic characteristics by diverting both northward-bound sediment and currents (Wang *et al.* 1998). Broad lowlands extend about 1.5 miles (2.4 km) south and east from the bay, before rising up into the coastal terrace, or mesa, that supports urban San Diego. Rugged Point Loma hooks around the north side, cutting off the ancient floodplain of the San Diego River, which throughout its evolution alternatively drained into San Diego or Mission Bays.

With a water volume of about 230,000 cubic meters (m^3) (Peeling 1975), the bay's depth ranges from 59 feet (18 meters [m]) near the mouth to less than 3 feet (1 m) at the south end. It has an average depth of 21 feet (6.5 m) measured from mean sea level (Wang *et al.* 1998). There has always been a narrow, natural channel deepening at the mouth, possibly cut by river floods at a time when sea level was much lower (Peeling 1975). This channel has been and continues to be deepened by dredging for safe passage of ships seeking sheltered anchorage at port. Prior to major filling activities, which began in 1888 and intensified just before and during World War II, the bay had an area of 21 to 22 mi^2 (54 to 57 km^2), as defined by the mean high tide line of 1918. About 6 mi^2 (15.5 km^2) of the bay has been filled based on this high tide line, or about 27% (Smith 1976).

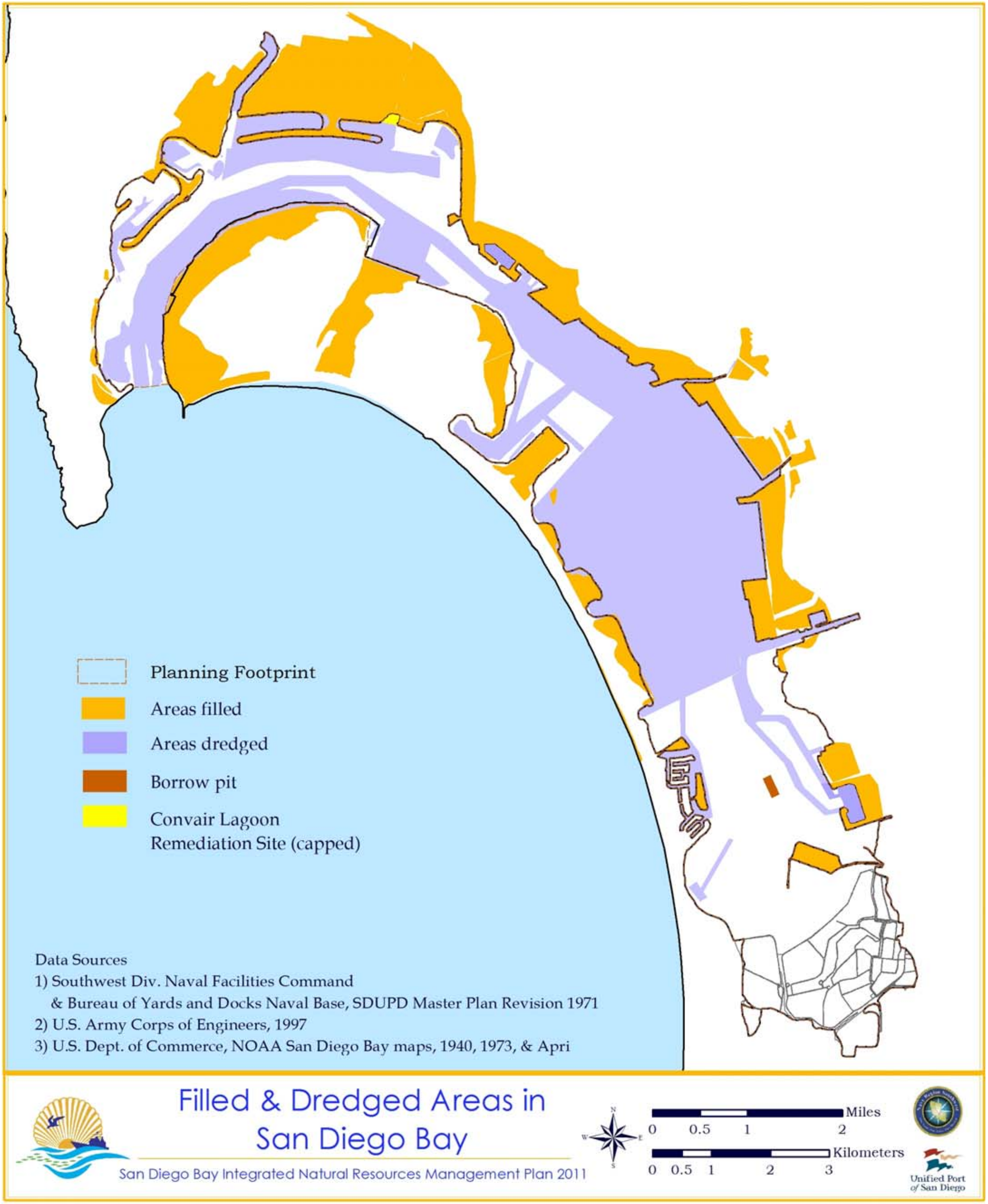
Map 2-2 shows the recent topography of the bay floor, while Map 3-1 (in Chapter 3) shows the historic habitat breakdown, based on an 1859 chart shown here in Figure 2-1 (other historical maps may be found in Appendix G). Note the natural channel in Map 3-1. Map 2-3 shows the cumulative history of dredge and fill activity. Only 17 to 18% of the original bay floor remains undisturbed by dredge or fill (Smith 1976).

2.3.2 Hydrology

Freshwater contribution to the bay comes primarily from the Otay and Sweetwater Rivers and secondarily from several creeks: Telegraph Canyon (south of Sweetwater River Basin), Chollas (north end of Naval Depot south of National Steel and Shipbuilding Company [NASSCO]), Switzer (Tenth Avenue Marine Terminal [north end]), Paleta (7th Street Channel, south of Naval Repair Base), and Paradise (south of Paleta), as well as some minor drainage groups (See Map 1-3). The first major reduction of freshwater input occurred when the USACE diverted the San Diego River to Mission Bay in 1875. Later construction of dams and extensive groundwater use in the Sweetwater and Otay drainages reduced the already ephemeral input from those rivers by 76% (USACE 1973). Freshwater input is now limited to surface runoff from urban areas (e.g. the over 200 storm drains and intermittent flows from several rivers and creeks after storms). For about nine months of the year, the bay receives no significant amount of fresh water. Evaporation approximately balances the freshwater input from all sources over the course of the entire year (Lackey and Clendenning 1965). During the summer, however, the evaporation rate of 62.7 inches/year in south bay is higher than precipitation and freshwater inflow (Peeling 1975; Lenz 1976). This can cause south bay to become hypersaline, or saltier than seawater, in excess of 35 parts per thousand in dry seasons (Wang *et al.* 1998).



Map 2-2. Topography of the San Diego Bay floor (Scientific Services 1994 for U.S. Navy).



Map 2-3. Cumulative history of dredge and fill activity in San Diego Bay.

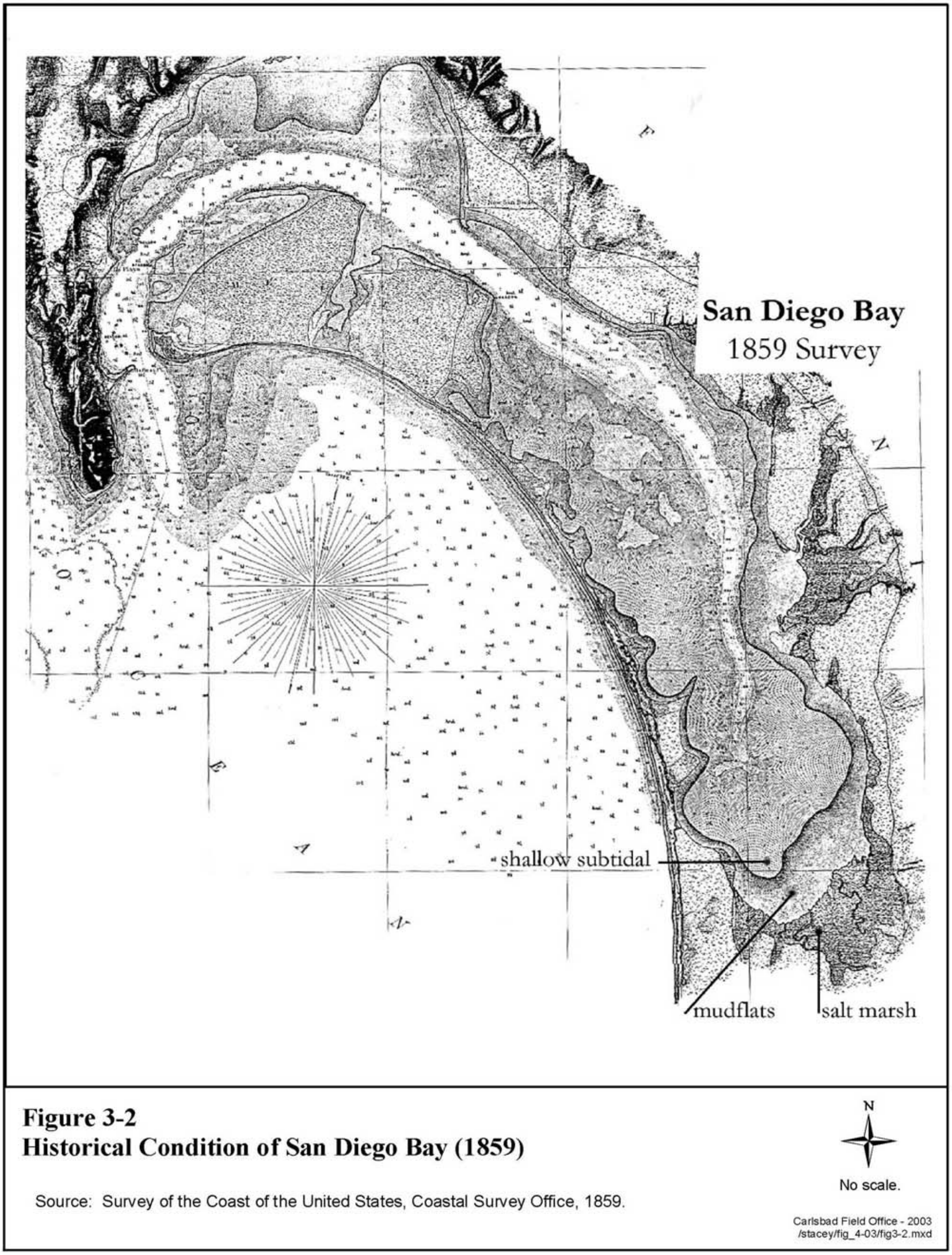


Figure 2-1. Map of San Diego Bay based on 1859 survey of the coast of the United States (Coastal Survey Office 1859).

Salinities near the bay entrance approach those of the nearby open ocean. In contrast, salinities in south bay are greater than in the ocean in late summer, but can be lower in the winter following rain. This summer occurrence of hypersalinity in south bay may lead to stratified, density-driven flushing in the fall. This process moderates the build up of hypersaline conditions in south bay (Largier 1997).

2.3.3 Circulation, Temperature, and Salinity

The tidal conditions in San Diego Bay are measured using a long-term harmonic tide gage station at Navy Pier near downtown San Diego. This gage has been in operation since 1900 and is operated by National Oceanic and Atmospheric Administration (NOAA). Benchmarks tied to the Broadway station are located at Point Loma, Quarantine Station, and National City. Tidal measures collected over a previous tidal epoch (19-year period from 1960–1978) have been statistically reduced to obtain long-term average values of MLLW, Mean Lower Water, Mean Tidal Level, Mean Higher Water, and Mean Higher High Water (MHHW). The highest observed water level in the bay, 8.35 feet MLLW, was recorded on January 27, 1983, and the lowest observed water level, -2.88 feet MLLW, was recorded on December 17, 1973 (NOAA 2003).

Circulation of ocean currents outside the bay affects organisms having access and entry to the bay. The ebb and flood of tides within the bay circulate and mix ocean and bay waters, and also transport organisms, especially plankton, in and out of the entrance. Tides produce currents, induce changes in salinity, and alternately expose wet portions of the shoreline. Tidal flushing and mixing are important for dispersing pollutants, maintaining water quality for marine life, and moderating water temperature that has been affected by exchange with the atmosphere or heating, such as by the South Bay Power Plant.

Tidal exchange in the bay exerts control over the flushing of contaminants, transport of aquatic larvae, salt and heat balance, and residence time of water.

Bay circulation may be driven by wind, tides, temperature, and density gradients associated with seasonal, tidal, and diurnal cycles. In San Diego Bay, circulation is primarily related to tides, because winds are of mild magnitude and there is a low fetch area (Wang *et al.* 1998). Tidal patterns off this coast are mixed, with two unequal highs and lows each day. The diurnal difference in MHHW and low MLLW tides is 5.6 feet (1.7 m), with extremes of 9.8 feet (3 m) (Largier 1997). The tidal prism, or the volume of water contained between the tides, is about 73 x 10^6 m^3 (Gautier 1972). Highest tides are in January and June.

Tidal exchange in the bay exerts control over the flushing of contaminants, transport of aquatic larvae, salt and heat balance, and residence time of water (Chadwick 1997). Tidal current velocities range from 0.6 to 2.7 feet/sec. (0.2 to 0.8 m/sec.) at the mouth (Gartner *et al.* 1994) to much lower in central and south bay. Velocities at depth lead velocities at the surface during flood tides by 30 to 90 minutes (Chadwick *et al.* 1996). Variations in velocity are due to variations in depth and width of the bay as the tidal prism moves southward, the presence of side traps such as marinas and basins, and the general reduction in velocity with distance from the entrance (Largier 1997). Longitudinal tidal currents will still, however, exceed the strength of wind and wave action, except during periods of high winds (San Diego Gas & Electric Company [SDG&E] 1980).

Temperature and density gradients, both with depth and along a longitudinal cross-section of the bay, drive tidal exchange of bay and ocean water beginning in the spring and continuing into fall. The seasonal thermal cycle has an amplitude of about 46 to 48°F (8 to 9°C) (Smith 1972). Maximum water temperatures occur in July and August, and minimums in January and February. In the winter, thermal gradients are absent, with cooler air temperatures and higher winds causing the bay to be nearly isothermal (Smith 1972). During 1993 surveys, the warmest temperature was 84.7°F (29.3°C) in south bay, and the coolest temperature, 59.2°F (15.1°C), was just north of the Coronado Bridge in January (Lapota *et al.* 1993). The average surface temperature is estimated to be 63.3°F (17.4°C) (Smith 1972). Smith (1972) also found maximum vertical temperature gradients of about 0.3°F/feet (0.5°C/m) during the summer. Typical longitudinal temperature range is about 45 to 50°F (7 to 10°C) (about 0.3 to 0.5°C/km) over the length of the bay (Largier 1995) during the summer. Temperature inversions also occur diurnally due to night cooling.

Salinities near the bay entrance approach those of the nearby open ocean (31.2 to 31.4 practical salinity units [psu] [Largier 1997]). In contrast, south bay evaporation and poor flushing produce salinities as high as 37 psu in late summer (Ford 1968; Ford and Chambers 1973), decreasing to lows of 22 psu following heavy rains (Largier 1997). This summer occurrence of hypersalinity in south bay may lead to stratified, density-driven flushing in the fall. This process moderates the build up of hypersaline conditions in south bay (Largier 1997).

Within tidal cycles, the temperature stratification builds up during the flood tide and weakens with the ebb tide. The thermal exchange that occurs at the mouth of the bay when sea water is mixed with warmer bay water is complicated by salt gradient-driven flows of south bay water seaward, beneath the less dense water of the surface. As described above, the importance of this stratification depends on the state of the tide, the strength of the wind, and time of year. Estimates of the tidal exchange ratio at the bay entrance (the proportion of water coming in the bay with the flood tide that is new oceanic water versus recycled bay water) range from 0.5 to 0.7 (Fischer *et al.* 1979; Largier 1995; Chadwick and Largier 1997).

The marked reduction in area of the bay from its historical dimensions has reduced the volume of the tidal prism by roughly 25%, and it is probably this reduction combined with increased depth that has reduced the flushing rate (Smith 1976). Another estimate of this reduction is 30% (Browning *et al.* 1973), while Largier (1997) places it as 33% the volume of the tidal prism. It is also likely that the bay's circulation pattern has been modified by this change in geometry (Smith 1976).

2.3.4 Residence Time of Water

Residence time is the rate at which water enters or leaves a water body divided into the volume of the water body.

Flushing rates change drastically as one moves away from the bay entrance. Longest residence times are observed in the summer, apparently related to the density stratification of the bay at that time (Chadwick 1997). The amplitude of the tidal cycle also affects the flushing rate. During a *strong* tidal cycle, up to 40% of the mean volume of the bay passes Ballast Point during the ebb flow, at least temporarily residing outside the bay. During an *average* tidal cycle, the volume of water leaving the bay is about 13%. This bay water mixes with ocean water. During the next flood tide, this mix gets pulled back into the bay. While the residence time of water near the northern inlet of the bay is short except for side basins where commercial and marina activities are located (Largier 1995), it can take from ten to 100 days for water in the bay as a whole to be exchanged, depending on the tidal amplitude. Residence times in south bay may be months, ranging from 20 to 300 days (Chadwick 1997).

Taking into account this mixing, Map 2-4 shows the half-life of water residing in the bay with different tidal amplitudes. The actual process is somewhat more complicated, with warm, less dense water moving out of the bay as a jet near the surface. Colder, denser water moves in as a front at greater depths. The data are based on a two-dimensional hydrodynamic model (depth is not considered), validated with salinity and temperature correlations (data and graphics provided by Don Sutton and John Helly of the San Diego Supercomputer Center).

2.3.5 Hydrodynamic Regions of the Bay

Based on the factors described above, Largier (1996, 1997) described four hydrodynamic regions of the bay:

1. **Marine Region.** Circulation in the marine region is dominated by tidal exchange with the ocean. In San Diego Bay, this area of efficient flushing is within perhaps 3 to 4 miles (5 to 6 km) of the entrance, reaching almost to downtown. Residence time of bay water is just a few days. The net result of these circulation patterns in the bay is the presence of cold, clean ocean water at depth, explaining the Mussel Watch Project result that mussels at the mouth of the bay are the cleanest in the county (Largier 1996, 1997).
2. **Thermal Region.** In the thermal region, still in north bay but extending to approximately Glorietta Bay, currents are driven primarily by surface heating. The vertical exchange of water results from entry of a cold, oceanic plug at depth with the flood tide, then the receding of warm, bay surface water with the ebb tide.
3. **Seasonally Hypersaline Region.** Between about Glorietta Bay and Sweetwater Marsh Unit of the South San Diego Bay NWR is a seasonally hypersaline region. Water is stratified by salinity gradients induced by evaporation.
4. **Seasonally Estuarine Region.** South of Sweetwater Marsh is a seasonally estuarine region receiving occasional inputs of freshwater discharge from the mouth of the Otay and Sweetwater Rivers. Residence time of bay water can exceed one month and may approach much longer times.

2.3.6 Turbidity

Turbidity is a measure of the clarity of water based upon suspended matter.Clay, silt, and organic matter, as well as some dissolved substances, cause cloudiness. Microscopic organisms such as phytoplankton and zooplankton also contribute to turbidity. When light passes through this cloudy water, it is scattered, reflected, and attenuated rather than transmitted in straight lines; the higher the intensity of the scattered or attenuated light, the higher the value of turbidity.

Natural, or ambient, turbidity comprised of both organic and inorganic suspended particles is distinguished here from turbidity caused by dredging or other human activities. Ambient turbidity varies spatially and over time, with waters of the bay becoming more turbid, or less transparent, as distance increases from the entrance. In the shallow, wider south end of the bay, where a longer wind fetch is possible over the narrow Silver Strand, persistent wind and wave action cause a marked increase in turbidity during the winter and early spring. Shallow areas are more affected than deep waters. The wind is able to scour up the finer sediments of this region at that time of year. Water is then clearer in the fall months (Lapota *et al.* 1993). Turbidity also varies through the day with both wind and tides. Figure 2-2 shows spatial variation on the water surface of turbidity measured as total suspended solids (TSS), based on averages from 29 boat cruise transects 1992-1995 (K. Richter, Space and Naval Warfare Command [SPAWAR], unpublished data).

Turbidity also varies with water depth, and this can make a difference to bay managers concerned about avian and fish foraging and other issues. Photo 2-1 shows three types of turbidity, one natural and two induced by construction of a habitat enhancement island. The natural turbidity associated with a mudflat occurs throughout the water profile, whereas the construction is causing separate surface and subsurface sediment plumes.

Suspended particles have a central portion in marine food webs (there are two types - plankton-based, and detritus-based) (Little 2000). A large pool of dissolved organic matter is created by macrofauna and phytoplankton, and this fuels a “microbial loop.” Bacteria attached to the sediment particles use the dissolved organic matter, and are then in turn eaten by micro flagellates who are then eaten by ciliates. The “loop” provides an extra food supply for zooplankton, and returns dissolved organic matter to the main food chain. Suspended material does sink slowly to the bottom, and this “rain” is important to benthic organisms in deeper waters (Little 2000).

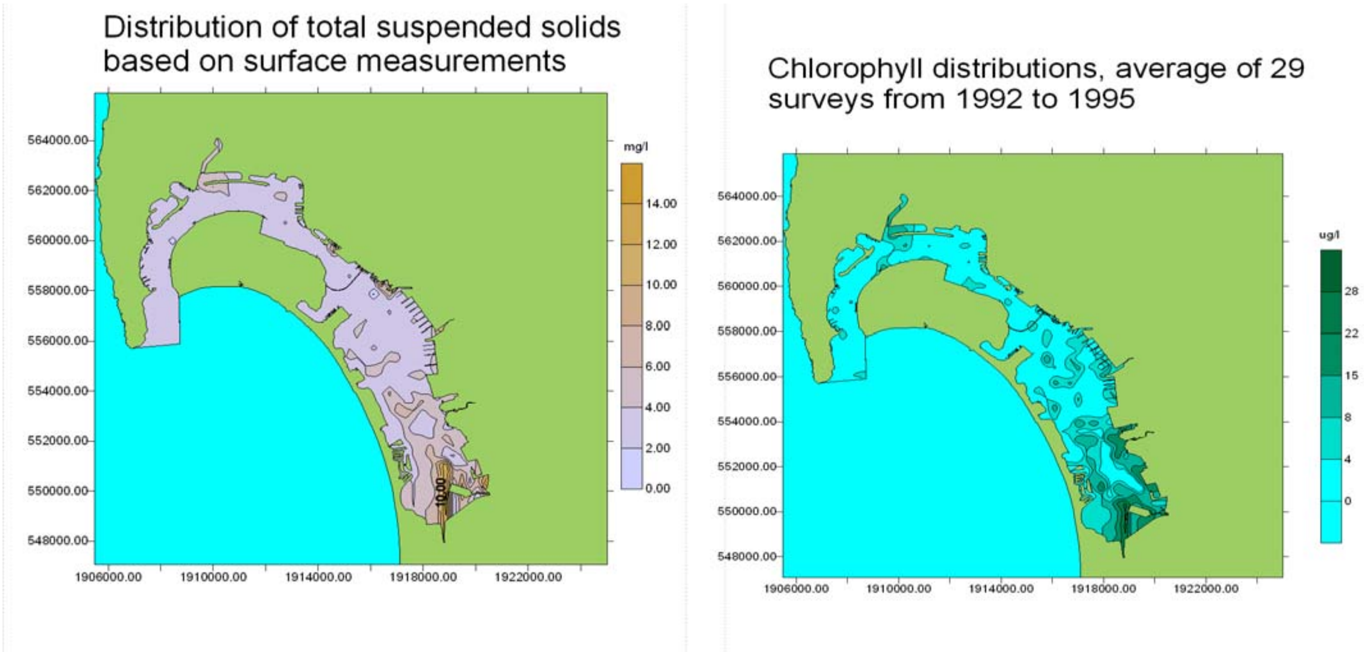


Figure 2-2. Calculated total suspended solids in milligrams per liter at the water surface taken from 29 cruises between 1992 and 1995. Also shown are surface chlorophyll results (micrograms per liter) from the same cruises. Data and graphics provided courtesy of K. Richter, Space and Naval Warfare Command.

Photo 2-1. March 2001 oblique aerial of creation of Homeport Island as part of Navy nuclear carrier homeporting project. The photo shows three types of turbidity managers separate: ambient turbidity throughout the water profile as evident adjacent to the mudflat in the photo's center-left; water surface turbidity (lighter color in water nearest island construction); and subsurface turbidity plumes, shown closest to the photo foreground.

Estuarine organisms tend to be adapted to higher turbidity levels than those of the open coast. For example, the well-known paucity of suspension feeders such as tunicates, hydroids, and sponges in many estuaries may be due to clogging of the feeding apparatus with silt. The more turbid estuaries are known to have very few suspension feeding species, whereas less turbid estuaries are covered by bryozoans, tunicates, and sponges (in rocky subtidal areas) (Little 2000).

2.3.7 Sediment

Without human intervention, San Diego Bay may have eventually (in geologic time) filled up with sediment delivered by the San Diego, Otay, and Sweetwater Rivers. In 1842, M. Duflot de Mofra, an attaché of the French legation to Mexico, visited the area and spoke of the port: “Certain areas are shallow, and some parts are so covered with sand that ships can easily run aground on the silt that the tiny San Diego River brings down from the mountains in the rainy season. Within the last few years the river, through the negligence of the inhabitants has returned to its former channel and now empties into the waters of San Diego harbor.” The wandering river was threatening to choke up San Diego Bay as it had already done to False Bay, once a good deep port as reported by Viscaino in 1602 (San Diego Historical Society 2007).

In addition, it is likely that the northward drift of beach sand that connected Coronado Island with the mainland, and Coronado and North Islands together, eventually would have blocked or nearly blocked the harbor entrance. Breakwaters, channel maintenance, and tidal action prevent this from occurring (Norris and Webb 1990). Mud layers on top of sand and sandy-silt along the eastern margins are removed during dredging, causing the sandier layers to be exposed.

The diversion of the San Diego River and the damming of the Sweetwater and Otay Rivers have significantly reduced sedimentation sources into the bay.

Historically, the bay floor and margins were characterized by sand, silt, clay, mud (silt and clay less than 62 microns in diameter), and mudstone. Sands were most common at the mouth and along the western margins, while finer mud deposits characterized the eastern margins and southern extremity of the bay (Peeling 1975). According to studies in 1980 by the SDG&E, thickness of bay floor muds average 0 to 7.8 feet (0 to 2.4 m). The mud sits upon layers of sand and sandy-silt, then on older semi-consolidated sediments. Dredging exposes these sandier layers. The diversion of the San Diego River and the damming of the Sweetwater and Otay Rivers has significantly reduced natural sedimentation sources into the bay.

Present contribution of sediment from all potential sources is minimal. As described above for freshwater inflow, the major historic contribution of sediment was from the three major rivers plus smaller streams, which drained an area of about 900 mi^2 (2330 km^2). The current drainage area is 433 mi^2 (1122 km^2), since diversion of the San Diego River (Table 2-1). The total fluvial sediment delivered to the bay was on the order of 0.8 to 1.1 x 106 m^3 per year (Smith 1976). The San Diego River, alone, was estimated to have delivered about 3.8 to 5.3 x 105 m^3 to the bay annually. As evidenced from the prominence of the San Diego River and other deltas, fluvial sediment was gradually filling the bay until the late 1800s. The diversion of the San Diego River ended all sediment deposition from that river, and damming of the Sweetwater and Otay Rivers reduced sediment delivery by 75%. The present-day sediment contribution from the undammed portions of the remaining drainages is estimated to be about 1.4 to 1.9 x 105 m^3 per year (Smith 1976).

Table 2-1. Estimated trends in total fluvial sediment delivery to San Diego Bay (Smith 1976).

Drainage Extent	Drainage Area (km^2)	Annual Volume Sediment Delivery (m^3)
Original	2,330	800,000 – 1,100,000
Current (with San Diego River diverted, dams on Sweetwater, Otay, and other drainages)	1,122	140,000 – 190,000

Some sedimentation would be expected from wave erosion of the bay's shorelines. However, well over half of the shoreline is protected by piers, docks, bulkheads, revetments, and riprap. The remaining unprotected shoreline is predominantly on the lee side of prevailing winds (the western shoreline). As a result, only about 18 to 20% of the unprotected shoreline and 7% of the overall bay shoreline appears subject to significant erosion; therefore, unprotected shoreline is a minimal potential contributor of sediment to the bay (Smith 1976).

During the century prior to the 1960s, when more rigorous regulation went into effect, the annual dredging rate averaged 3.3 to 4.7 x 106 m^3, which is three to six times the former (background) yearly sediment input. This annual dredging rate was roughly 17 to 34 times the current yearly sediment input to the bay. The severely reduced sediment input to the bay is further confirmed by the unusually low volume of maintenance dredging conducted in interior channel areas (Smith 1976).

As a result of all the above, the bay's sediment composition and distribution is highly altered. Map 2-5 shows the present pattern of fine sediments (as represented by percent silt and clay) on the bay floor (compiled by SPAWAR from several sources). Such characteristics of the bay's sediment can help explain the distribution and abundance of organisms that are closely tied to substrate. Reflecting the present hydrodynamic regimes, grain size can also explain the fate and loading of sediment contamination (Schiff *et al.* 2006).

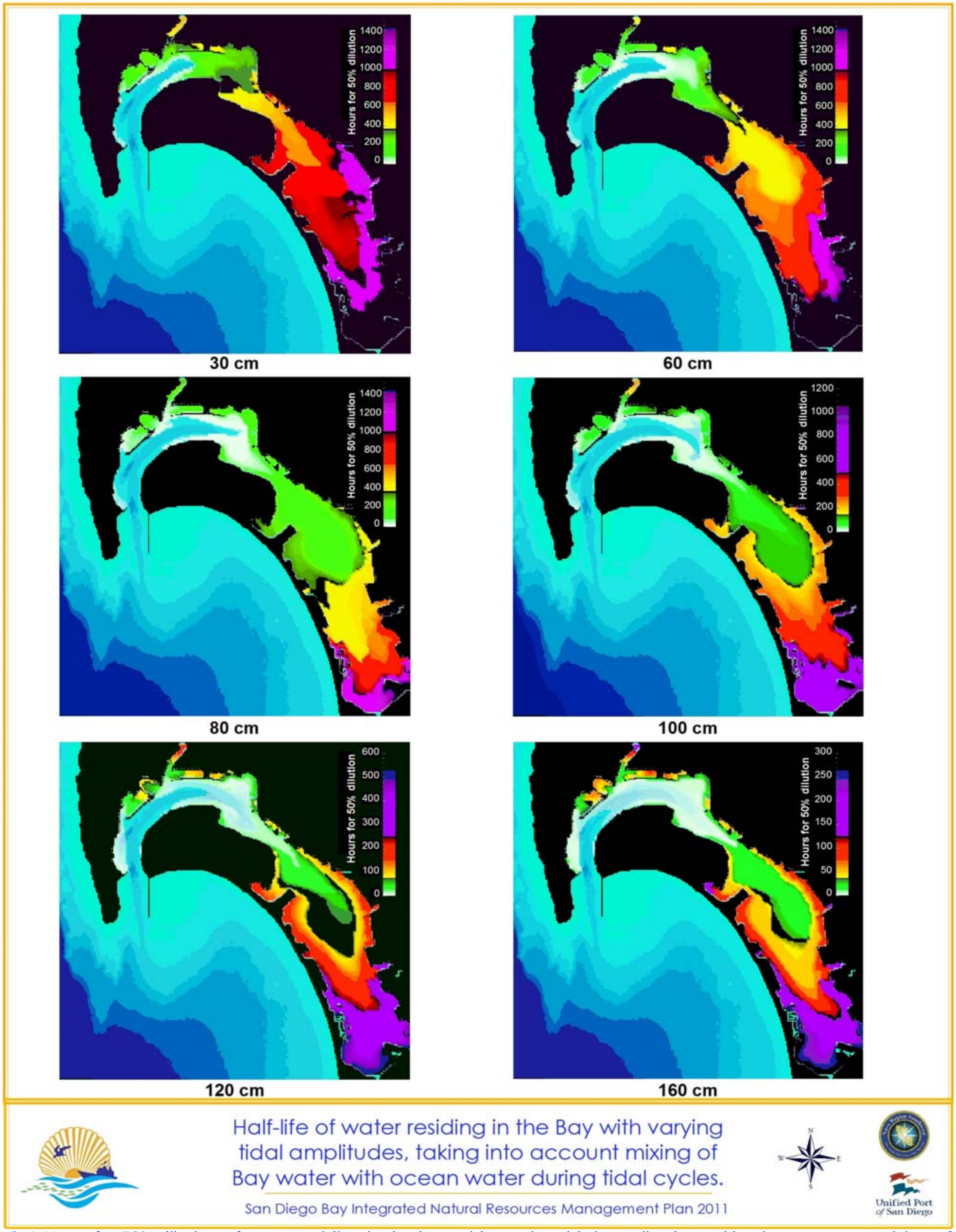
2.4 Water and Sediment Quality

San Diego Bay's water and sediment quality represents the ecosystem's chemical and physical properties that reflect the effects of natural and human influences. How this quality has changed over time, what the current quality is, and the ecological effects of this change, are the topics of this section.

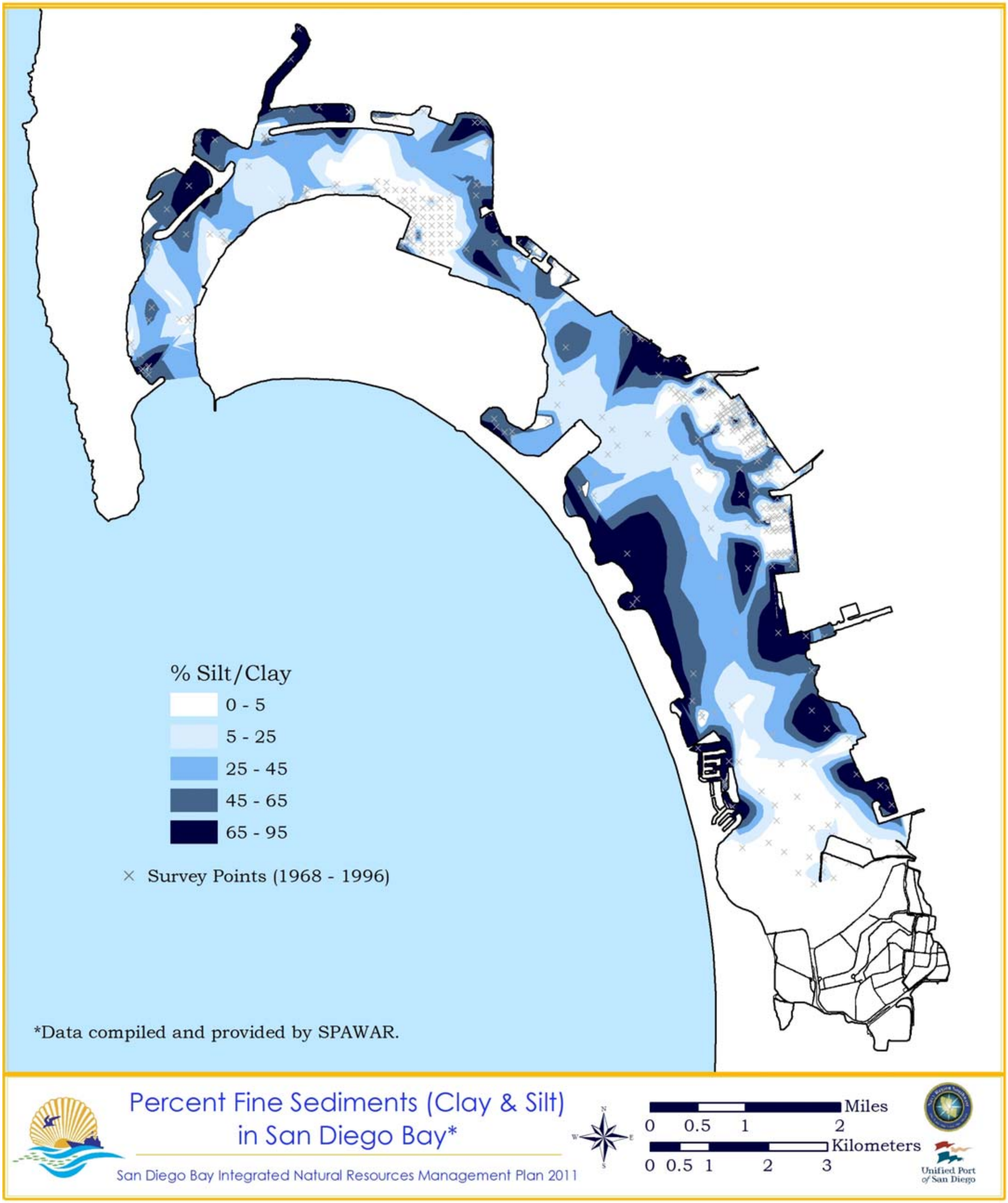
2.4.1 Historical Change in Water Quality Condition

San Diego Bay's water quality impacts most likely began upon its becoming a harbor in the late 1700s. Until the mid-20th century, its waters were seen as the solution for the disposing of bilge water, garbage, and sewage. Waste disposal of collected sewage into the bay was first attempted in 1887–1888 when the City's population was less than 16,000 (San Diego Regional Water Pollution Control Board [SDRWPCB] 1952). Industrial wastes were mainly from the food processing industry in the early part of this century. In 1924, high bacterial levels were detected in a zone near the city sewer outfalls but did not extend beyond the pier head into the navigation channel. Before the first sewage treatment plant was constructed by the City of San Diego in 1940, high coliform counts indicated sewage contamination in all parts of the bay. However, rapid population growth during and after World War II overwhelmed the capacity of the few sewage plants, which used primary treatment and usually no chlorination.

By 1952, at least 50 million gallons of sewage and industrial wastes were disposed of daily into San Diego Bay (SDRWPCB 1952). The SDRWPCB, a newly formed state agency at that time, undertook a comprehensive pollution survey of the bay that was the first one of its kind on the west coast (Delaney 1966). It identified principal waste discharges to be from three municipal sewage plants' primary effluent, four industrial sources of untreated wastes, and two military sources of crude sewage. In addition, 4,000 vessels used the harbor every month.



Map 2-4. Hours for 50% dilution of water residing in the bay with varying tidal amplitudes, taking into account mixing of bay with ocean water. The data are based on a two-dimensional hydrodynamic model (depth not considered), validated with salinity and temperature correlations.



Map 2-5. Percent fine sediments (silt and clay) on the San Diego Bay floor.

Water quality conditions in the early 1950s were indicative of such a large waste loading (SDRWPCB 1952). Visually, the color of the bay's water varied from green to brown, with widespread oil slicks commonly found, and transparency as low as 2.5 to 5.9 feet (0.76 to 1.8 m) at the industrial east shore. Solid wastes dumped into the south bay were deposited by wind onto western beaches of the bay and sewage solids were frequently observed along Coronado's bayside shore. Coliform bacteria densities were 70 mpn (most probable number)/ml along the east shore and 24 to 70 inches (70 to 178 cm) in the central bay, exceeding California Department of Public Health (CDPH) standards; all recreational areas had high bacterial densities. Dissolved oxygen levels were frequently found to be under 5.0 parts per million (ppm) over most of the south and central areas of the bay, approaching the then minimum allowable level of 4.0 ppm.

Benthic animal life was almost completely absent from a 372 acre zone between the U.S. Coast Guard (USCG) station and the south end of the U.S. Naval Supply Base due to the lethal effect of up to 3 feet (1 m) of sludge deposits on marine invertebrates. Toxic wastes were not measured at the time, though industrial operations were known to discharge cyanide, chromium, and other toxic materials and had probably caused a die-off of some birds and cockles in the south bay in spring 1952. Hydrogen sulfide was dominant in and around Chollas Creek, symptomatic of depleted oxygen levels.

By 1955, the CDPH found that the waters of the central portion of the bay had deteriorated since 1951 and were now "sufficiently contaminated by sewage wastes to be hazardous to public health," particularly for recreational uses (CDPH 1955). In December, CDPH placed a quarantine on the beaches and shorelines in the central bay area (SDUPD 1995b). The SDRWPCB adopted its first water quality criteria for San Diego Bay that same year. By 1963, dissolved oxygen levels had dropped to 4.0 ppm in all parts of the bay except at the entrance, with some samples recording 1.0 ppm (Terzich 1965). Finally, in August 1963, the San Diego Metropolitan Sewerage System went into operation and by February 1964, all domestic sewage discharges and those from the NAB were connected (Delaney 1966). Treated effluent from this system was, and continues to be, discharged through an ocean outfall off of Point Loma.

Once the sewage discharges stopped, water clarity improved to 15 feet (5 m) by March 1964 (SDUPD 1995b). By 1966, SDRWPCB staff were noticing large schools of fish and occasionally seals in the central bay (Delaney 1966). By way of the return of dissolved oxygen levels in excess of 5 milligrams per liter (mg/l) throughout the bay, agency staff claimed that about 9,600 acres (3,885 hectares [ha]) or 80% of the bay had returned to being suitable habitat for marine life. Sportfishing and clamming were once again a popular activity. Sludge deposits over 11.8 inches (30 cm) deep were seldom found in the original "dead zone," then shrunken to about 8,999 feet (2,743 m) by 299 feet (91 m) in size. Only a few sites had coliform densities occasionally approaching 10 mpn/ml. The biological oxygen demand, suspended solids, phosphate, and nitrogen loadings showed great improvement due to the significant decline in wastes discharged into the bay, as shown in Table 2-2 below (Delaney 1966).

Table 2-2. Comparison of known wastes discharged into San Diego Bay, 1955 and 1966.

Year	Volume (million gallons /day)	Biological Oxygen Demand (kg/day)	Suspended Solids (kg/day)	Phosphate (kg/day)	Nitrogen (kg/day)
1955	44.28	35,834	45,995	6,305	7,394
1966	2.87	16,352	22,770	240	576
% reduction	93.5	54.5	50.5	96.2	92.2

After this success, attention became focused on the impacts of wastes discharged from vessels and from industrial sources (Terzich 1965; Delaney 1966; U.S. Federal Water Pollution Control Administration 1969). Vessel discharges from the bay's commercial and government ships, as well as party boats and pleasure craft, were specifically evaluated in a comprehensive federal study, which determined that their wastes created conditions “hazardous to health, aesthetically offensive and damaging to ecological balances in San Diego Bay” (U.S. Federal Water Pollution Control Administration 1969). The Naval Station (Naval Base San Diego [NBSD]) area had the highest coliform levels in the bay, which were twice the standard. Oil spills, primarily from Naval fueling and fuel transfer operations, were noted as another problem. After 1967, industrial dischargers were required to reduce the amount of biological oxygen demand and settleable solids to meet SDRWPCB discharge requirements. Storm drains were also identified as sources of chemical and bacteriological contaminants to the bay in 1965, but no estimate was made of their discharge volume or content.

By 1969, water quality conditions for turbidity, salinity, transparency, nutrients, and associated plankton populations were generally within the limits set forth by the State-Federal Water Quality Standards (WQS) in most parts of the bay (U.S. Federal Water Pollution Control Administration 1969). In 1971, San Diego Bay was reportedly considered “one of the world’s cleanest metropolitan bays” (SDUPD 1995b). The Navy began eliminating vessel discharges in the early 1970s and ceased all ship sewage and industrial waste discharges into the bay by 1980 (SDUPD 1995b).

San Diego Bay’s bacterial contamination from sewage discharges overshadowed the issue of other possible contaminants for decades. In the 1970s, staff from the RWQCB, San Diego Region, began to take notice of industrial wastes and high levels of heavy metals and toxicants (Mathewson 1972; RWQCB 1972). Much of the chemical pollution was found in the bay’s sediment rather than in the water column. A series of studies showed San Diego Bay to have serious problems with chemical pollution, even though the conditions were similar to other urbanized bays (SWRCB 1976; RWQCB 1985; Kennish 1997).

Copper ore spills and associated discharges at a copper loading facility at the 24th Street Marine Terminal caused concentrations in bottom sediments in the spill area to be 25 times higher in the mid-1980s than pre-spill levels (RWQCB 1985). Copper was later dredged at the site in the early 1990s to 1000 ppm. In that same decade, tributyltin (TBT) levels were found to be very high in marinas and commercial and Naval ship basins where antifouling hull paints were concentrated (Valkirs *et al.* 1991). In 1984 the National Status and Trends Program for Marine Environmental Quality measured very high levels of polychlorinated biphenyls (PCBs) in San Diego Harbor and polycyclic aromatic hydrocarbons (PAHs) near Harbor Island (NOAA 1987 in Kennish 1997). Overall, San Diego Bay was ranked 5th in the nation for total PCBs in mussels and 10th for PAHs in mussels during the 1986-1988 national Mussel Watch Project out of about 145 in estuaries, embayments and open coastal sites (Kramer 1994; NOAA 1989 in Kennish 1997). Sediment quality had also changed due to the influx of upstream sediments from the Sweetwater and Otay Rivers during very large storm events. In the winter of 1980, a large amount of sediment was flushed into the south bay because of spillovers at upstream reservoirs. Total organic nitrogen concentrations generally decreased over the area’s sediments, along with an increased coarseness in grain size (Lockheed 1981 in Macdonald *et al.* 1990).

As part of California's ongoing Bay Protection and Toxic Cleanup Program, San Diego Bay's sediment was evaluated for chemical and biological conditions between October 1992 and May 1994 (Fairey *et al.* 1996 and Addendum Fairey *et al.* 1998). Results indicated chemical pollution based on established sediment quality indicators, developed by NOAA and the State of Florida and used as a substitute for absent EPA and California guidelines. The study used a weight-of-evidence approach. Sediment quality indicators were exceeded at all San Diego Bay stations and the number of exceedences was high at most stations. Chlordane, PAHs, and PCBs were the pollutants most often found at elevated concentrations. Copper, lead, mercury and zinc were often found at elevated levels in the Naval Shipyard areas, although the data indicate the probability of metal toxicity is low. This is consistent with previous results demonstrating elevated chemical concentrations at several of these stations.

Seven stations (representing four sites) were given ranking based on toxicity, chemical and benthic community data. High Priority was assigned to one site at the station located at the mouth of Switzer Creek where a concrete culvert empties into the bay (Fairey *et al.* 1998). Historically this area served as a PAH waste dump site for a SDG&E coal gasification plant. Prior to that the site served as one of the original garbage dumps in the San Diego region (SDUPD 1996). Pesticide residues and organic matter were prevalent in the sediment samples and indicate a probable link to urban and storm runoff. Three stations were assigned to a moderate priority category based on elevated chemical levels and one measure of biological effect. Each of these stations is in an area of current or past ship repair operations. One Naval Shipyard station, just north of the Coronado Bridge and near Continental Maritime, is an area which has served as a ship repair facility and prior to that was the location of a tuna cannery. PCBs are the principal pollutant at this site. At the Naval Shipyard between Pier 5 and Pier 6, near the mouth of the Graving Dock, ship repair activities are a likely source of PAHs, PCBs and copper. A station located just south of the Coronado Bridge, near Southwest Marine, where industrial and shipping activities have been in operation for many years, was also tagged a moderate priority. Sources of elevated PCBs and PAHs in samples may be from commercial activities or from fill material that was added along the shoreline in the past. One Naval shipyard station was assigned a moderate priority category based on an inconclusive measure of biological effects (Fairey *et al.* 1998).

The findings of the study (Fairey *et al.* 1998) supported the selection of a reference station at Fiddler's Cove as representative of current background chemical conditions in San Diego Bay. Based on the use of chemical summary quotients that allow comparisons to be made among regions within California, the report concluded that the San Diego Bay region often falls within the upper end (most polluted) of the range of bays in California, compared to more pristine settings in northern and central California. This is to be expected because the north coast and central coast are not as heavily populated or industrialized as the urban areas of southern California (Fairey *et al.* 1998). San Diego Bay's watershed was also identified as an Area of Probable Concern by the National Sediment Quality Survey in 1997 because 32 sampling stations showed sediment contamination where associated adverse effects to aquatic life were probable (Tier 1) (EPA 1997).

In the 1998 Bight survey, chemical contamination was still widespread in the bay's sediments, but at lower levels for most of the "contaminants of concern" (COC) than in previous decades (Bay *et al.* 2000). While San Diego Bay ranked high in average sediment contaminations for antimony, copper, mercury, and PAHs, the bay had the lowest levels of pesticides of all other bays in the region (City of San Diego 2003). Areas of concern continued to be shipyards, marinas, and the outlets of creeks.

2.4.2 Current Water Quality Condition

Present day water quality concerns for San Diego Bay focus mainly on the quantities of contaminants found in the water, sediments, and biota (such as shellfish, and other marine organisms) (Lapota *et al.* 1993; Zeng *et al.* 2002; Allen 2006). Monitoring studies and research are continuing to seek answers to the many questions about the bay's water and sediment quality condition.

Many areas of San Diego Bay's shoreline have been listed as impaired water bodies under CWA §303[d] by the SWRCB due to identified pollutants. The most recent list was approved by the EPA in June 2007 (see Table 2-3 below). Pollutants include bacteria, pesticides, heavy metals, and organic compounds while areas of concern continue to be marinas, shipyards, and outlets of creeks. As a result of these listings, the RWQCB and SWRCB are required to prepare a total maximum daily load (TMDL) technical report and action plan for each site and pollutant. In addition, the San Diego RWQCB has identified five of these listed sites to be "toxic hot spots" due to multiple pollutants and toxic effects that require immediate clean-up (San Diego RWQCB 2000). Management actions are discussed in Chapter 5.

Table 2-3. Areas of San Diego Bay and tributaries listed as impaired on Clean Water Act § 303(d) List – 2006 (San Diego Regional Water Quality Control Board 2007) .

Project Name	Pollutant/Stressor
Chollas Creek	Diazinon
Chollas Creek	Metals:copper, lead, zinc: Indicator bacteria
SD Bay Shoreline, near Chollas Creek	Benthic community effects: sediment toxicity
SD Bay Shoreline, vicinity of B Street and Broadway Piers	Benthic community effects, Indicator bacteria, sediment toxicity
SD Bay Shoreline, Shelter Island Park, G Street, B Street Pier, Tidelands Park	Indicator bacteria
SD Bay Shoreline- 7th St. Channel / Paleta Creek*	Benthic community effects: sediment toxicity
SD Bay Shoreline, near Switzer Creek *	Chlordane, Lindane/hexachlorocyclohexane, PAHs
SD Bay Shoreline - Downtown Anchorage	Benthic community effects, sediment toxicity
SD Bay Shoreline, near Navy SubBase	Benthic community effects, sediment toxicity
SD Bay Shoreline- Naval Station San Diego. 32nd St.	Benthic community effects, sediment toxicity
SD Bay Shoreline, near Coronado Bridge	Benthic community effects, sediment toxicity
SD Bay Shoreline, north of 24th St. Marine Terminal	Benthic community effects, sediment toxicity
SD Bay	PCBs
SD Bay Shoreline, Chula Vista Marina	copper
SD Bay Shoreline at Glorietta Bay	copper
SD Bay Shoreline at Harbor Island (east and west basins)	copper
SD Bay Shoreline at Marriot Marina	copper
SD Bay Shoreline, between Sampson and 28th Streets*	copper, mercury, PAHs, PCBs, zinc, sulfates, total dissolved solids (TDS)
SD Bay Shoreline at America's Cup Harbor	copper
SD Bay Shoreline at Bayside park (J Street)	Indicator bacteria
SD Bay shoreline at Coronado Cays	copper
SD Bay Shelter Island Yacht Basin	copper
** Also identified as a "toxic hot spot" by the San Diego RWQCB*	

Sources that appear to be contributing pollutants to the bay's environment include surface runoff from urban watersheds, industrial facilities, power generating station, vessel activities from Navy operations, recreational marinas and commercial ports, aerial deposition, hazardous material spills, storm drains, and sewage spills, among others. With the long history of industrial, marina, and military use of the bay, "legacy" pollutants continue to remain from past practices despite curtailment of new discharges. Even with increased urbanization and population growth over the past 30 years in the southern California region, contaminant inputs to these coastal waters have reduced 70% from all sources, primarily because of improved wastewater treatment (Schiff *et al.* 2000).

Today, urban runoff is the largest source of pollutants in the region, contributing more heavy metals than all other sources combined. Besides chemical and bacterial pollution, debris from human activities (such as plastic, metal materials, bottles, and cans) is becoming more common in bays and harbors (Allen 2006). With its large watershed, the bay receives drainage from the cities of San Diego, National City, Chula Vista, Lemon Grove, El Cajon, Bonita, Imperial Beach, and Coronado, and from surrounding communities as far east as the Cuyamaca Mountains. Storm drains and streams deliver pollution from many nonpoint sources: automobile oil and grease that build up on roads and parking lots, fertilizer runoff from lawns, illegal dumping of chemicals, yard debris, garbage, and soil erosion.

How the chemical contaminants are delivered to the "hot spots" of sediment toxicity around the bay is the focus of several studies. University of California (UC) Davis's Marine Pollution Laboratory (2003) described a "generic site conceptual model" for San Diego Bay to help clarify the potential linkages between sources, exposure pathways, and receptors (Figure 2-3). At the mouth of creeks like Switzer Creek, upland watershed sources can be contributed through the stream's drainage. Stormwater contributes also through storm drains and direct runoff. The bay's sediment and water column provide a vertical connection, as well as air deposition of contaminants (e.g. PAHs). Such a depiction can aid in developing models for predicting the role of contaminants in the environment if levels at the sources increase or decrease, for example.

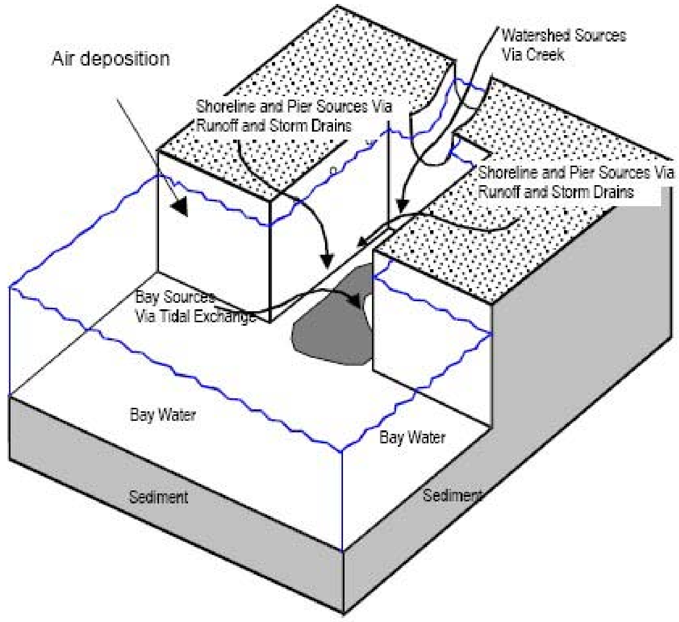


Figure 2-3. Conceptual site description of how chemical contaminants might be delivered to San Diego Bay via bay, watershed, and air sources (University of California Davis 2003).

2.4.2.1 Chemical Contaminants

Chemical contaminants that are currently of concern in San Diego Bay include heavy metal and organic (chlorinated and petroleum hydrocarbon) pollutants. Discussion needs to be distinguished for their presence by location: (1) sediment, and (2) water column. Better information for the bay is becoming available through more advanced and frequent levels of chemical monitoring through such programs as (See also Chapter 6):

- Regional Harbor Monitoring Program (RHMP) for San Diego Bay, Mission Bay, Oceanside Harbor, Dana Point Harbor
- National Pollutant Discharge Elimination System (NPDES) permit monitoring by 22 dischargers (including Navy, Port, County, Cities) (annual reports)
- Bight Monitoring Program by Southern California Coastal Water Research Project (SCCWRP) (1994, 1998, 2003, 2008)

The recently released 2003 Bight survey has assessed sediment toxicity, sediment chemistry, and benthic macrofauna as an indicator of environmental stress (Bay *et al.* 2005; Schiff *et al.* 2006; Ranasinghe *et al.* 2007; SCCWRP 2007). As in the previous survey, San Diego Bay's marinas, ports and harbors had the highest concentrations of pollutants. More specific results are discussed below.

Heavy metals of concern in the bay are primarily copper, lead, mercury, and zinc. Other metals have been detected but are not identified to be of priority concern. One metal, TBT, was formerly a serious problem in the bay's marinas but levels have decreased significantly after this component of antifouling paints was phased out for recreational, commercial, and navy vessels (Valkirs *et al.* 1991; Fairey *et al.* 1996). Excessive concentrations of metals in sediment and the water column can be toxic to marine organisms; copper is in fact applied as a coating on vessel surfaces because it is a biocide that inhibits fouling organisms.

Copper is the dominant metal found at many marinas. For the water column, one recent study evaluated the extent and magnitude of copper contamination at 20 San Diego Bay marina sampling sites (Schiff *et al.* 2006). It found that about 86% of the surface water in the marinas exceeded the state water quality threshold for dissolved copper, with the highest concentrations associated with greatest vessel density and lowest water circulation. However, toxicity (i.e. abnormal embryo development) was observed at only 21% of the marina area, with the disparity between predicted and actual toxicity remaining unexplained. Measuring dissolved copper contributions from recreational vessel antifouling coatings, another study found that roughly 95% of the copper is emitted during passive leaching in comparison to hull cleaning activities on a typical 30 foot power boat (Schiff *et al.* 2003).

Copper and other metal concentrations in the bay's sediment were evaluated in the 2003 Bight survey (Schiff *et al.* 2006). As shown in Map 2-6, many shoreline sites that year had levels in the highest category for copper (37 to 362 milligrams per kilogram) and zinc (109 to 822 milligrams per kilogram). Similar results were found for lead and mercury (not depicted here).

Organic COCs are primarily PAH and PCB compounds.

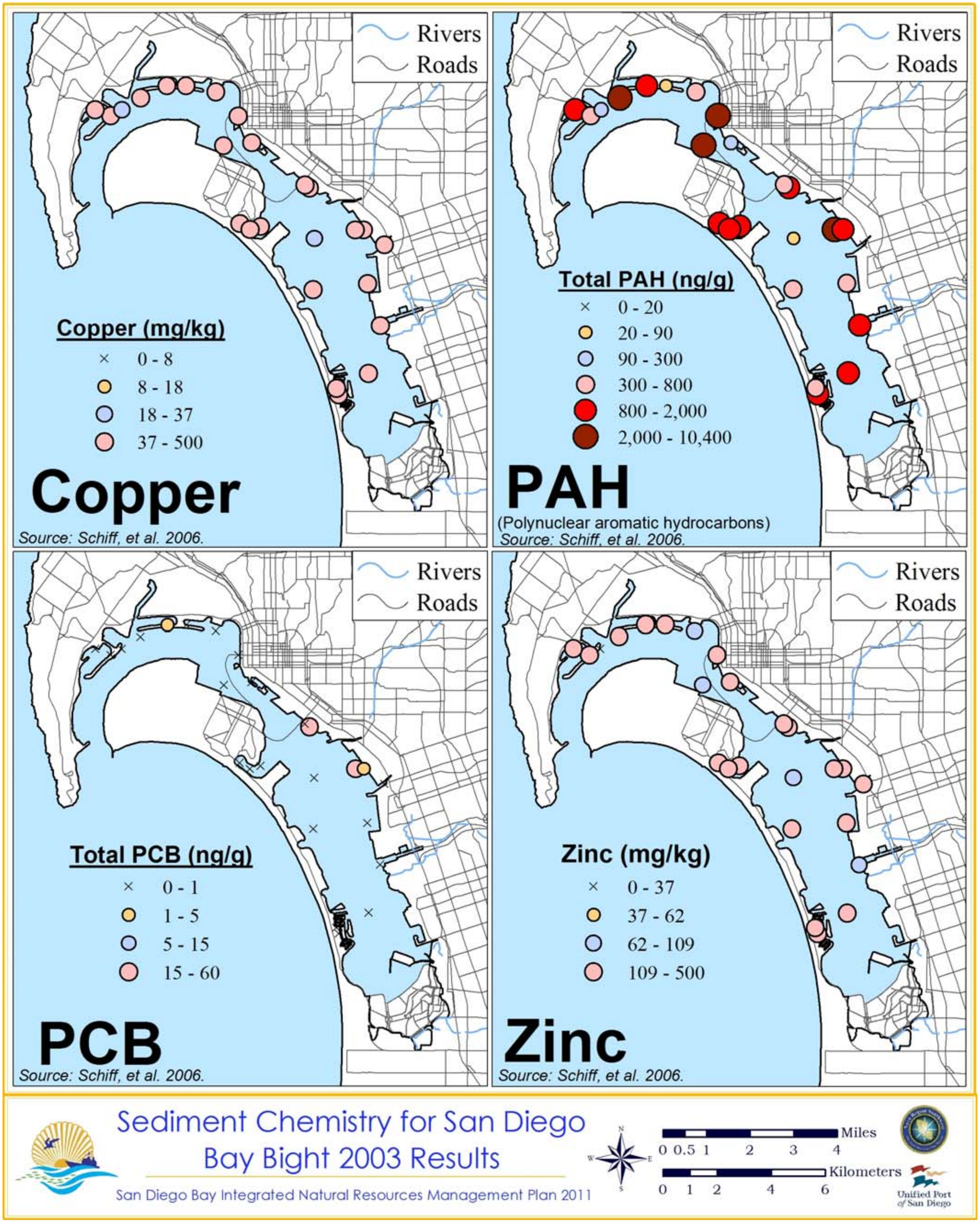
PAH pollutants are organic compounds that are among the heaviest molecular fraction of petroleum hydrocarbons (Woodward-Clyde 1996). Because they are not very soluble in water and tend to accumulate as particulates in aquatic systems, they can become persistent as well as concentrated within the aquatic food chain. Commonly found at high levels in estuarine and marine sediments near industrial centers, they serve as a continual source of contamination for biotic communities (Kennish 1997). PAHs are released through fossil fuel combustion, asphalt production, leaching of creosote oil, and spills of oil, gasoline, diesel, and other petroleum products.

Earlier studies evaluated the sources of PAH contaminant for San Diego Bay: the leaching of creosote from pier pilings in the bay (61%), followed by in-place sediments introduced to the water column, mainly through dissolved molecules (27%) (PRC Environmental Management 1996; Woodward-Clyde 1996). The Navy measured PAH and copper concentrations in 1997 to assess the effects of its recent changes in bilge water operations and the removal of creosote impregnated pier pilings at Naval Station (Navy 1998). PAH levels were the lowest measured in the bay up to that time, and significantly lower by a factor of nine at Naval Station sites, which was attributed to the operational changes by the Navy there.

Recent studies are shedding more light on the PAH issue. Urban storm water contains PAHs, which were found to be predominantly derived from aerial deposition and subsequent wash-off of PAHs associated with combustion by-products in the Los Angeles region (Stein *et al.* 2006). Arid regions like Los Angeles and San Diego, can deliver high concentrations where high daily traffic is combined with intense rainfall and high surface runoff from impervious surfaces. The 2003 Bight Survey found high concentrations of total PAH at several sites in the bay (See Map 2-6).

PCBs are extremely persistent in the environment and can cause various carcinogenic and adverse effects to marine life and people. Sources include paints, electronics, and plastics. All of San Diego Bay is listed as impaired for PCBs, unlike the more limited areas listed for other contaminants (Table 2-3). In 2003, the Bight Survey found moderately high total PCB concentrations at only one site and lower levels at 3 other sites in the bay (See Map 2-6).

Until recently, no studies focused on measurements of PCBs within the water column. In 2002, such a project collected samples and found the highest concentrations of water column PCBs in the Central Bay, similar to previous monitoring results for sediments (Zeng *et al.* 2002). One theory is that some PCBs are redistributing from the sediment to the water column and transported out of the bay through tidal exchange.



Map 2-6. Sediment chemistry for San Diego Bay from Bight '03 Results.

Pesticides of concern include chlordane (total), diazinon, and lindane.

Diazinon is a pesticide that was once commonly used but has been phased out in the past decade. While contamination was significant enough in Chollas Creek to require a TMDL action plan (adopted in 2002 by the San Diego RWQCB), its presence in water quality sampling appears to be significantly reduced. No diazinon has been detected in wet weather samples in Chollas Creek's drainage since the 2003-2004 season and it has recently been moved from a high priority pollutant to a COC (San Diego Bay WURMP 2007).

Chlordane, an insecticide discontinued in the mid-1970s, has caused extensive contamination along the north shore of the bay and in areas receiving storm runoff (Fairey *et al.* 1996). In the 1998 Bight survey, no chlordane was found at any of the sampling sites in San Diego Bay (City of San Diego 2003). However, it remains as a listed pollutant for the shoreline near Switzer Creek (Table 2-3).

Dichloro-diphenyl-trichloroethane (DDT), another discontinued pesticide, was not found in the bay during the 2003 Bight survey, despite previous records of its presence and its prevalence in other parts of the Bight (Schiff *et al.* 2006).

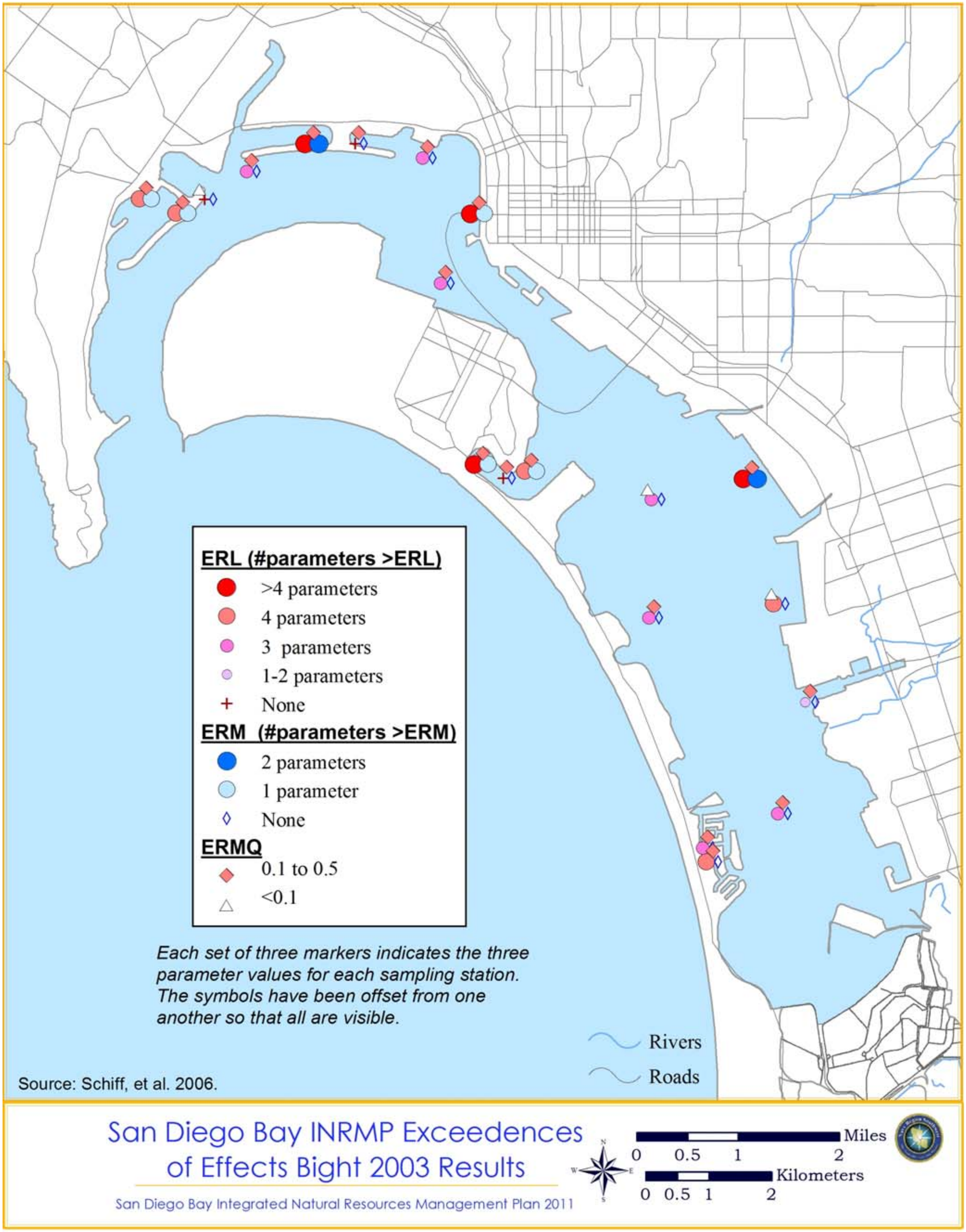
The Bight '03 monitoring program looked at two approaches in evaluating the potential for adverse biological impacts from the measured levels of contaminated sediment (Schiff *et al.* 2006). One looks at the areal extent of individual chemicals: effects range low (ERL) and effects range medium (ERM). Concentrations below the ERL describe sediment quality with low probability of resulting in adverse biological effects (i.e. toxicity) while concentrations above the ERM represent sediments having a high likelihood of adverse biological effects. For San Diego Bay, Map 2-7 shows quite a few sites where the number of parameters exceeds the ERL. However, far fewer sites exceed the ERM.

The second approach assesses the areal extent of sediment contamination based on a composite of several constituents. In this case, a sediment quality quotient (effects range-median quotient) is used to account for potential for additive toxic effects of chemical mixtures in sediments. As shown in Map 2-7, the for San Diego Bay shows lower levels than the ERM, mainly indicating sediment quality effects at low to moderate risk of adverse biological impact.

2.4.2.2 Bacteria Contamination

Coliform bacteria from fecal matter is used as an indicator of human pathogens, which can cause illness in recreational water users and shellfish consumers. Bacterial contamination of the bay, historically caused by lack of sewage treatment, can still become a problem near stormwater outfalls and streams following rain storms. The first major rainfall (“first flush”) of the season tends to contribute high levels of bacteria, as well as chemical contaminants (Macdonald *et al.* 1990; SDUPD 1995b). Sources of this contamination most likely include leaking or broken sewer lines, illegal dumping of sewage, and domestic animal feces. The County of San Diego has monitored recreational sites in the bay for indicator bacteria for several years, with many exceedences of state recreational water contact standards near storm drains and in poor circulation areas (San Diego Interagency Water Quality Panel 1998).

The City of San Diego's Public Health Department has had to close beaches due to sewage spills ranging from 1,300 to 3,000 gal (Rodgers 1997). Sewage from broken lines enters storm drains and contaminates the bay during dry weather as well as wet. As the result of improved management and maintenance, the City of San Diego has steadily reduced the number of sewage spills from 365 in 2000 to 71 in 2006 (City of San Diego 2007). Similarly, a focus on urban runoff prevention to beaches had reduced the percentage of beach advisories and closures since 2000 to a low of 0.44% of “total beach mile days possible.”



Map 2-7. Exceedences of effects (ERL, ERM,) at San Diego Bay from Bight 2003 Results.

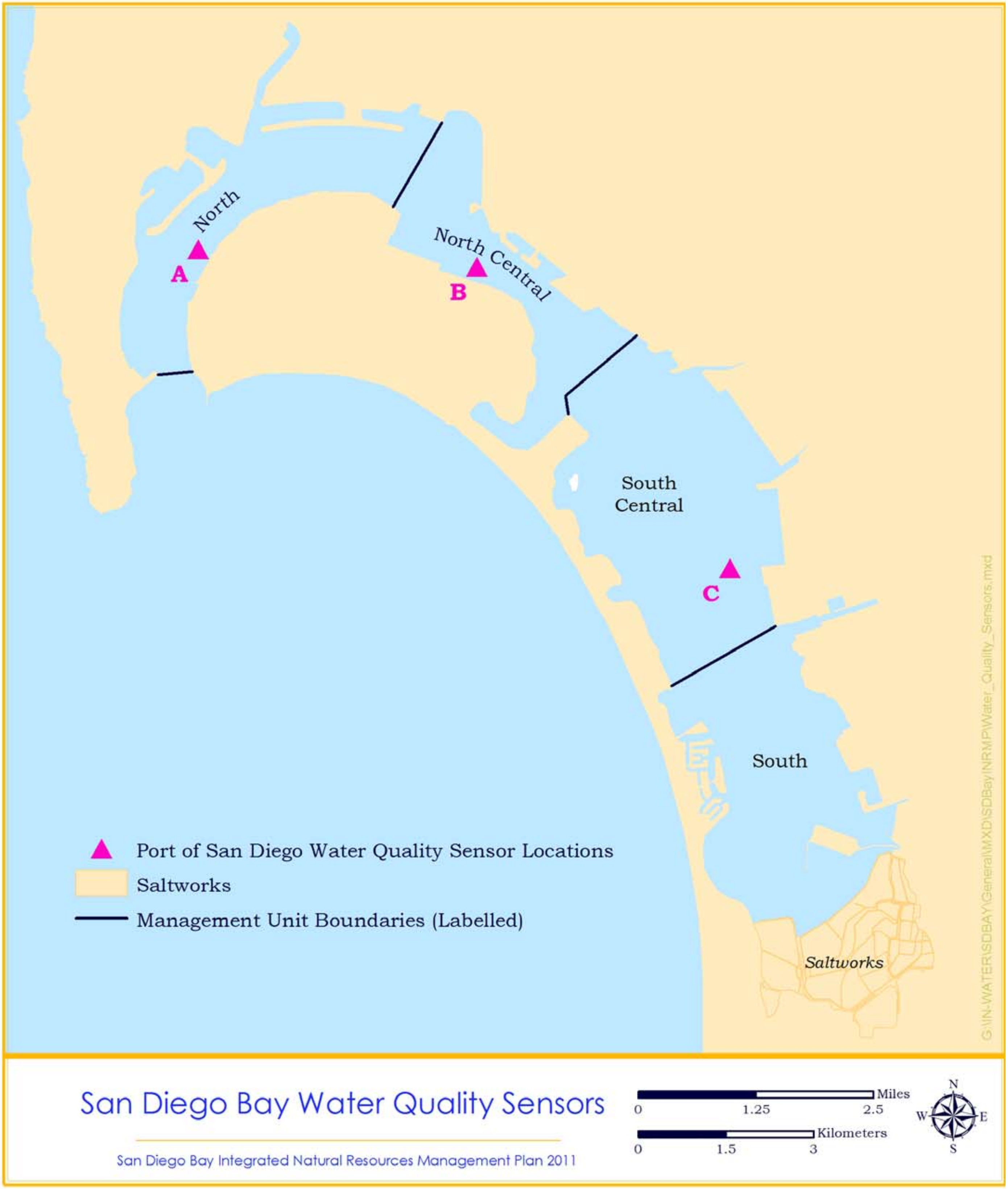
A Bacterial TMDL action plan is in progress for San Diego Bay's shorelines (Shelter Island Park, G Street, B Street Pier, Tidelands Park) by the San Diego RWQCB because bacterial densities at these locations exceed its Basin Plan's numeric water quality objectives for one or more of the indicator bacteria. Based on recent monitoring for urban runoff, bacteria is also the only high priority pollutant for the entire San Diego Bay WMA. All three watersheds draining into the bay were found to contribute fecal and total coliform bacteria during 2005-2006 monitoring, most likely contributed by wildlife, failed septic systems, sewer spills, and pet waste (San Diego Bay WURMP 2007).

2.4.2.3 Other Water Quality Conditions

Nutrient levels compared favorably in 1993 to those from 1980 (Lane 1980; Lapota *et al.* 1993). January had the highest concentrations of phosphate (0.2 to 3.1 micrograms [μg] technical atmosphere per liter [at/l]), nitrate (12.0 to 31.9 μg-at/l), and ammonia (3.5 to 9.3 μg-at/l). Chlorophyll concentrations ranged from 1.8 to 18.9 μg/1 at their highest in January. These levels correlate with maximum algal production that month, with measured nutrients higher in south bay than north bay. High chlorophyll levels in 1993 were thought to be the result of increased nutrient loading from the freshwater runoff into the bay. The 2003 Bight Survey measured Total Nitrogen and found three sites on the east side of the bay with high levels (0.15 to 2.14%) (Schiff *et al.* 2006). Total Organic Carbon (TOC) was high at only one site.

In 2007 the Port environmental program funded the design and establishment of a cost-effective strategy for characterizing the spatial and temporal variation of turbidity and physical water quality characteristics within the bay. The study examined the feasibility and use of existing Port equipment and methods previously utilized during the 2001 Port water quality pilot study to collect continuous physical water quality measurements at predetermined locations within the bay (Tierra Data Inc. [TDI] 2010). At the conclusion of the study continuous data collected at the two monitoring stations displayed notable trends in several physical water quality parameters with respect to season, tidal exchange, and rainfall. Data collected during this evaluation displayed spatial variability for several measured parameters which supported previous hydrographic studies (Chadwick 1997), documenting San Diego Bay as a partitioned estuary with complex circulation and stratification components. The study was funded again in February 2010 incorporating recommended changes and new instruments to strengthen the long-term data set and evaluate the relationship between turbidity and chlorophyll a and correlations with biological productivity. Long term physical water quality data sets provide valuable temporal information within the bay that supplements intermittent evaluations and supports related scientific investigations. Instruments were reinstalled in April 2010 in three distinct regions of the bay to collect continuous physical water quality measurements through Fall 2011 (Map 2-8).

Bay and harbor floating debris, often consisting of plastics and cans, is another form of contamination (Allen 2006). Some is derived from in-bay boating sources while streams and storm drains deliver debris collected from the bay's watershed. In a recent Creek to Bay Cleanup, an estimated 9.25 tons of debris were removed from the San Diego Bay WMA to keep the debris from flowing into the bay through runoff (San Diego Bay WURMP 2007).



Map 2-8. Long term physical water quality sensors collecting continuous temporal information within the bay.

2.4.3 Regional Comparisons

Within the SCB, a review of the long-term findings reveals that most contaminants increased during the 1950s and 1960s, but decreased during the 1970s and 1980s (Mearns 1992). Metal concentrations in fish have declined since the 1980s. Pesticide levels are 100 times lower today, although certain long-lived "legacy" inputs like DDT contamination continue to be widely dispersed in the Bight's ocean sediments and some fish. Overall, the levels of most pollutants in the open coastal zone are now declining compared to their levels of 30 to 40 years ago (Schiff *et al.* 2000).

Regional comparisons of San Diego Bay with other bays have changed over time. In a 1987 regional survey, PAHs in sediments collected at southern California stations between Santa Monica Bay and San Diego Bay found the Seventh Street (Paleta Creek) and Chollas Creek stations to contain the highest levels of these hydrocarbons of all stations sampled (Anderson and Gossett 1987). Comparing ten coastal sites in southern California, a 1988 study revealed samples from San Diego Bay to have the highest concentrations of metals, PAHs, and hydrocarbons of all stations sampled and were the most toxic in two out of three toxicity tests used (Anderson *et al.* 1988). The 1997 National Sediment Quality Survey determined that San Diego Bay, San Francisco Bay, and offshore areas around San Diego and Los Angeles appear to have the most significant sediment contamination in the EPA's Region 9 (EPA 1997).

The Bight '98 survey found San Diego Bay's relative rank among other bays in the Southern California region in average sediment concentration as the following: among the top 3 for antimony, mercury, copper, and PAHs; 4th for PCBs, 5th for chromium, and 6th for zinc. It had the lowest levels of pesticides of all the bays (City of San Diego 2003). In the 2003 Bight monitoring effort, the relative rankings among the various southern California bays and ports were not reported in the same way (SCCWRP 2007). However, San Diego Bay was singled out for mention in the 2003 results under sediment toxicity because of the "dramatic" increase in toxicity over the '98 survey: from 0% to 44% toxic area for marinas, and 13% to 50% for ports/bays/harbors (Bay *et al.* 2005). See Figure 2-4. San Pedro Bay's ports/bay also had a significant increase (from 21% to 42%) while Newport bay's marinas showed a minor increase (though their percent toxic area was highest at 81- 88%). Too few stations were sampled in other embayments in Bight '98 and Bight '03 to make similar comparisons.

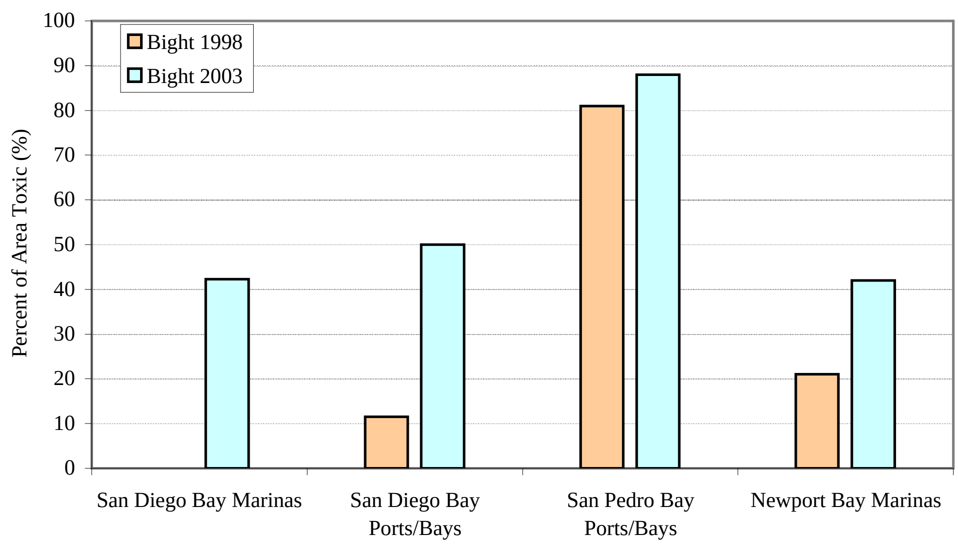


Figure 2-4. Percent of area toxic 1998 and 2003, from Bight 2003 Results.

For sediment chemistry, Bight '03 found metals to be enriched in almost all marinas in the region, and to a lesser extent, for ports/bays/harbors (Schiff *et al.* 2006). On the other hand, high levels of antimony and nickel in the Channel Islands “suggest their natural high abundance” in the region. For trace organics, San Diego Bay did not show significant total DDT concentrations in contrast to the high levels of the coast off of Palos Verdes Peninsula and in Los Angeles/Long Beach Harbor.

2.4.4 Ecological Effects of Contamination

By 1952 only sturdy rough fish survived in the bay. Most others had disappeared. In 1963 with the ocean disposal outfall, life almost immediately returned to the bay.

The effects of the historically high sewage pollution levels on the bay’s flora and fauna were partially documented in the 1950s and 1960s (SDRWPCB 1952; Terzich 1965). The CDFG and the Federated Sportsmen of San Diego County reported great changes in the numbers and types of fish and wildlife using the bay. By 1952, the bay only supported a few of the “particularly sturdy rough fish,” with no evidence of croaker, corvina, sand bass, halibut, or sea trout and few bait fish. Razor clams, cockles, and scallops had disappeared and migrating waterfowl only used the bay occasionally for a brief stopover. A die-off of hundreds of ducks, gallinules, cormorants, and other shorebirds, and large numbers of cockle clams and fish in the south bay in the spring of 1952 was attributed to the discharge of toxic metal processing wastes (SDRWPCB 1952). A zone of about 373 acres (151 ha) on the east shore was devoid of benthic invertebrates due to the toxic effects of thick sludge deposits. Laboratory tests by CDFG showed that crabs were more susceptible to the toxic effects than molluscs or worms.

After the regional sewage treatment plant, with its ocean disposal outfall, became operational in 1963, the effect of improved water quality on fish and wildlife in the bay became apparent almost immediately. Observers noted in April 1964 the return to its waters of sculpin, sole, sand bass, octopus, shark, seal, porpoise, bonito, and other fish while returning birds included cormorants, “bluebills,” scoters, and mergansers (Terzich 1965). A 1968 study described the south bay as supporting a diversity of marine species representative of the inner sections of relatively undisturbed bays and estuaries in California and Baja California (Ford 1968). However, central bay and its shoreline still showed the ecological effects of sludge deposits with bottom organisms reduced to only a few of the most pollution tolerant species; a polluted site was indicated by less than five kinds of organisms or more than 200 polychaete worms per square foot (Parrish and Mackenthun 1968).

By 1973, the CDFG noted that “healthy fish and invertebrate populations again flourish in many areas,” with eelgrass beds becoming reestablished on dredged sites and ecologically desirable marine plants beginning to grow on pilings and rock structures (Browning *et al.* 1973). The “ecologically undesirable” algal mats that had previously covered the bottom of portions of the central and south bay areas were also greatly reduced.

Thermal pollution from the South Bay Energy Facility’s discharge was found to cause adverse effects on marine life within 1,801 to 3,901 feet (549 to 1,189 m) of the discharge point (Ford *et al.* 1970). Only marine invertebrate and algae species tolerant of the temperature conditions were found in this zone, although adverse effects to the bay outside the cooling channel were determined to be minimal, mainly affecting decapod crustaceans and gastropod molluscs. Impacts were apparently greatest from the late summer cooling water discharge, with additional species occupying the channel area during cooler periods. Beneficial effects of the thermal plume included significant biomass increases for several major groups and the creation of favorable year-round habitat for the endangered eastern Pacific green sea turtle (Macdonald *et al.* 1990). Ecological effects of the thermal effluent on certain marine species at the site were also studied in several master’s theses at San Diego State University (SDSU) (Kellogg 1975; McGowen 1977; Merino 1981).

The effects of copper at high (>3.0 ppb) and low (<1.0 ppb) levels on phytoplankton communities in San Diego Bay were studied for one year (Lane 1980). Phytoplankton samples taken from high copper level areas showed less species diversity but maintained high biomass and productivity. The effects of excessive copper levels have been evaluated nationally for various marine organisms: sea anemones, mussels, softshell clams, snails, zooplankton, amphipods, crabs, sandworms, algae, and topsmelt (Eisler 1998).

The relative quality of the bay's benthic (bottom-dwelling) invertebrate community was analyzed from 1992-1994 as an indicator of sediment quality and toxicity (Fairey *et al.* 1996). These data, combined with toxicity and chemical data, were used to recommend priority areas for more intense evaluation as "toxic hot spots" (see discussion above). To test for short-term toxicity of copper and other metals, the embryos of the native mussel, *Mytilus galloprovincialis*, are being used in certain San Diego Bay studies (Schiff *et al.* 2006). Abnormal embryo development is an indicator of toxicity effect. Other benthic invertebrate species are also used for sediment toxicity testing to evaluate survival or growth rates, following EPA standard protocols (e.g. SWRCB 2005).

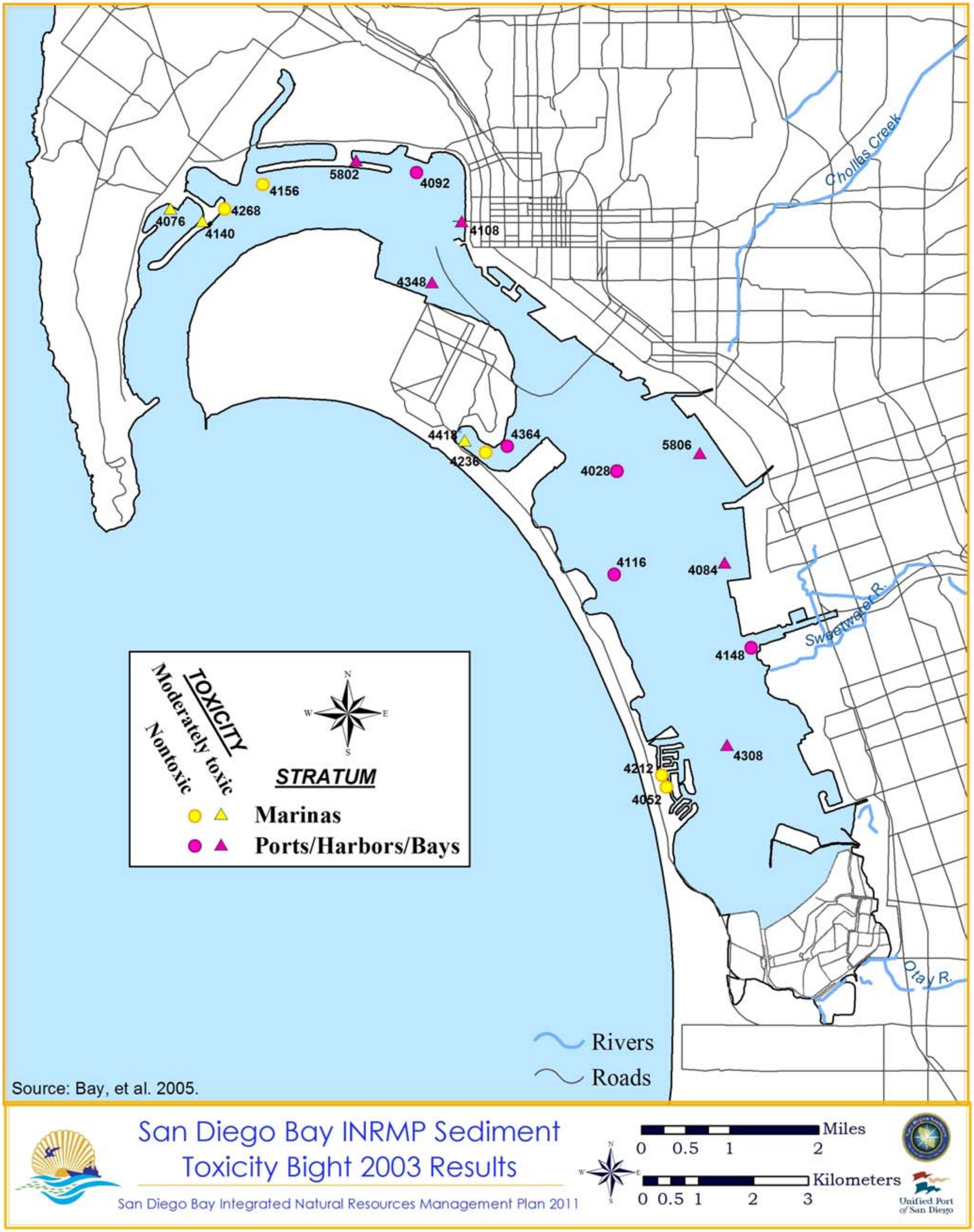
Sediment toxicity to marine organisms was evaluated for the region and San Diego Bay in the 2003 Bight survey (Bay *et al.* 2005). Tests were conducted in part I of the survey using one benthic invertebrate species, the amphipod *Eohaustorius estuarius*. Of the 19 samples collected in the bay, 53% were nontoxic, 47% were moderately toxic (amphipod survival was > 50% and < 83%), and none were highly toxic. These sites were primarily located in marinas (Map 2-9). These results need to be compared to the sediment chemistry results found at the same sites in the survey (Schiff *et al.* 2006). As noted above in the discussion and in Map 2-6, high levels of copper (a known biocide) and other metals and trace organics were also found in marina sediments.

The health of the benthic organism community was also evaluated in another Bight '03 assessment through the use of a "biointegrity" index, SQO26, developed and validated for marine bays and estuaries as part of the 2003 survey (Ranasinghe *et al.* 2007). All species of benthic macrofauna collected in each grab sample were identified and counted. The SQO26 combines four benthic indices to evaluate benthic condition, which is rated in four categories. San Diego Bay's benthic condition for the sites sampled revealed the following (Table 2-4).

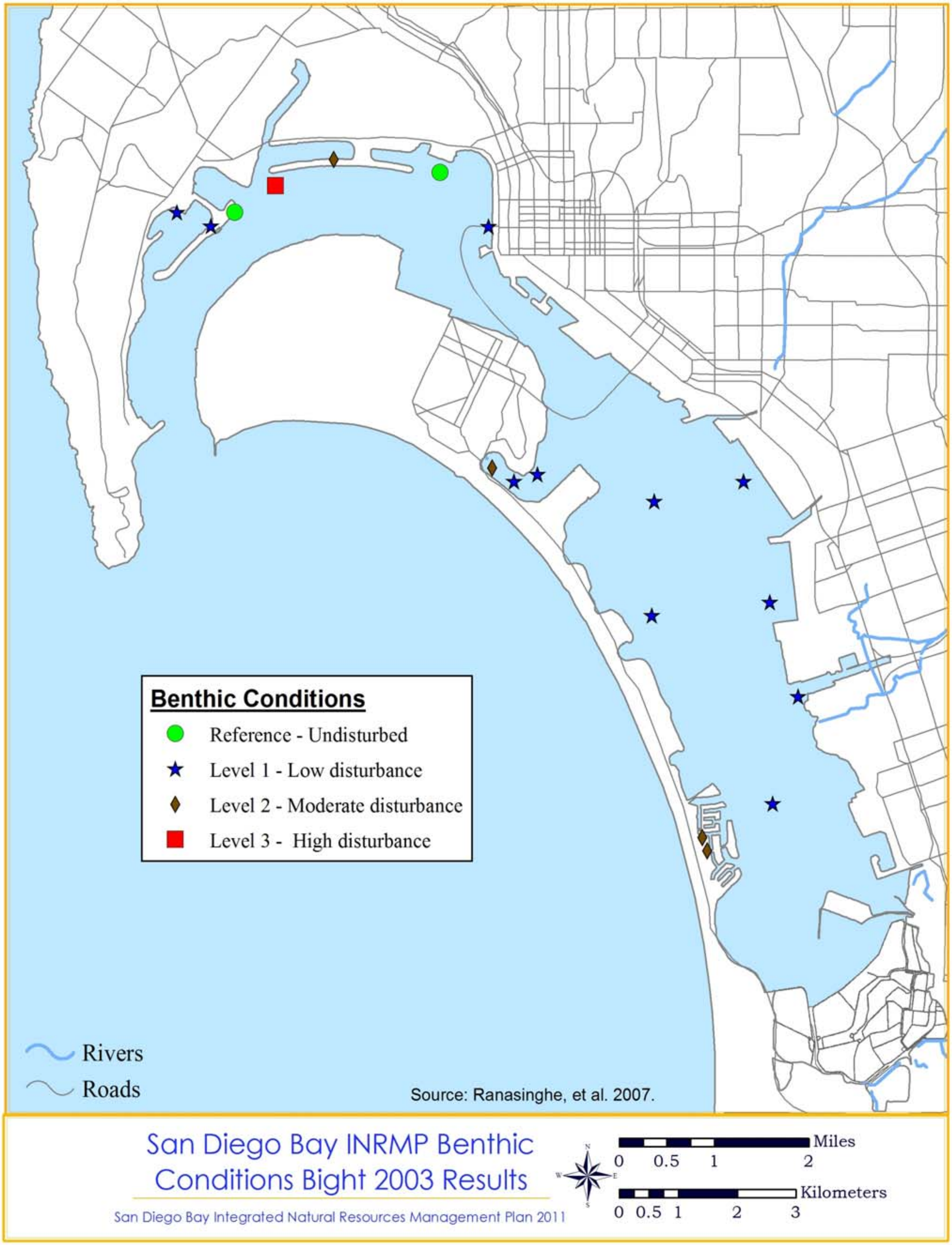
Table 2-4. Benthic condition at sites sampled in 2003 for Bight 2003 in San Diego Bay (Ranasinghe et al. 2007).

Benthic Condition	Number of Sites	% of Sites
Reference-Undisturbed	3	16%
Level 1 - Low Disturbance	11	58%
Level 2- Moderate Disturbance	4	21%
Level 3- High Disturbance	1	5%

Map 2-10 also depicts the distribution of these sites of benthic condition. In contrast to the sediment toxicity results evaluating a single sensitive species, the benthic condition assessment noted moderate to high disturbance at 26% of the bay's sites while 74% were at undisturbed to low disturbance levels. Having the data further stratifed by location, such as marinas, may help to better correlate these separate assessments. Since benthic macrofauna "integrate the effects of multiple types of stress and insults over time," the survey recommends that benthic macrofauna are one of the most relevant measures of sediment quality (Ranasinghe *et al.* 2007).



Map 2-9. Sediment toxicity for San Diego Bay from Bight 2003 Results.



Map 2-10. Benthic conditions for San Diego Bay from Bight 2003 Results.

Bioaccumulation of potentially toxic chemicals by organisms in the food chain is a concern that continues to be studied (see Allen 2006 for a recent summary). One study compared the bay to non-urban sites and found high concentrations of PCBs in liver tissues of white croaker (*Genyonemus lineatus*), barred sand bass, and black croaker (*Cheilotrema saturnum*) from several sites (McCain *et al.* 1992). Barred sand bass showed symptoms of fin erosion. Mercury and chlorinated hydrocarbons (DDT and PCB) tend to increase up structured food webs while other trace metals do not (Young *et al.* 1980, in Allen 2006). Health advisories are posted for fish consumption when contaminants exceed the State of California's screening values, which are lower and more conservative than EPA's (Allen 2006). A health risk study of the bay in 1990 determined that mercury and PCB levels in selected fish species could pose a limited health risk, if significant quantities of fish were consumed (San Diego County Department of Health Services 1990). As a result, health advisory signs were posted at public fishing piers to warn about eating fish caught in the bay.

Contaminants of uncertain concern in regard to bioaccumulation include tin, cadmium, silver, lead, and organotin.

Since several pollutants are known to bioaccumulate in the tissues of marine species, a tissue contamination study was recommended for PCBs, chlordane, and possibly methylmercury to determine potential human health problems associated with consuming resident species of finfish and shellfish (Fairey *et al.* 1996). Contaminants of uncertain concern in regard to bioaccumulation include tin, cadmium, silver, lead, and organotin. Of these, tin, cadmium, and lead have all been detected at elevated levels in San Diego Bay's sediments (Mearns 1992). PAHs are known to be absorbed and to accumulate in marine organisms and have the potential to cause cancer, mutations, and abnormal growth (Kennish 1997). TBT is linked to endocrine disruption in shellfish and snails, but is no longer a contaminant of concern in the bay (Manahan 2000).

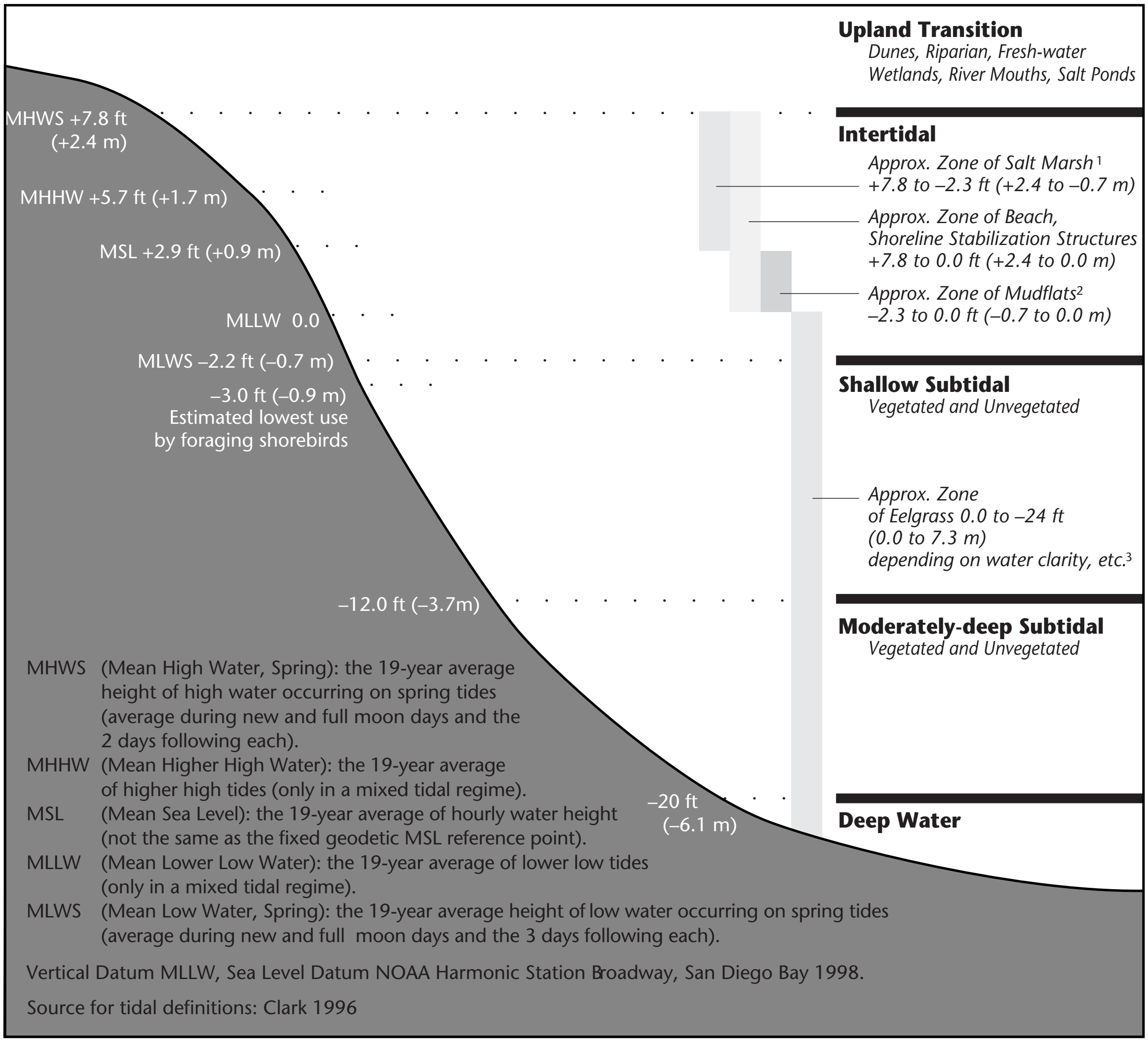
The 1998 regional Bight study found health improvements in the fish community, finding no fin erosion or other physical abnormalities compared to 1984-1988 when fin erosion was prevalent in black croaker and barred sea bass (City of San Diego 2003). Benthic invertebrates were again an indicator of the most highly polluted areas of the bay, with low abundance and few taxa (diversity of species) correlated with sampling stations having the highest concentrations of contaminants. Complicating comparisons with past studies is the increasing presence and dominance of a few non-native bivalve clam and polychaete worm species. See Section 4.4.1: Invasive Species for more information.

Linking the water quality and sediment quality conditions of San Diego Bay with the bay's many habitats (Section 2.5: Bay Habitats) and the abundance and diversity of the bay's Species Assemblages (Section 2.6: Species Assemblages) needs to be done for successful adaptive management of the bay's many human uses (Chapter 3). How to measure this linkage is discussed under Section 6.1.1: Key Management Questions.

2.5 Bay Habitats

The habitat descriptions that follow are arranged by depth with respect to the tides, then by substrate, water clarity, and other factors. The approximate positioning of the habitats are shown in Figure 2-5, as defined in this INRMP, in relation to tidal elevation, using the tidal station at Broadway Pier as a reference. These habitats are linked together ecologically by the transport of energy and other resources. These relationships are discussed in Section 2.8: The Ecosystem as a Functional Whole. The water column as a habitat is treated under Deep Water, although the water column extends to shallower depths. Also, the benthos as a habitat is discussed under Unvegetated Shallow Subtidal, even though it extends to deeper depths.

The shallower habitats and the bay's natural shoreline have been severely depleted or modified, beginning with the first pier at the end of Market Street in 1850, and the first dredging in 1914. See Map 2-11 for changes 2000-2007. Table 2-5 shows the habitat losses, comparing an 1859 geodetic chart and a 1995 aerial photo, as updated in 2007.

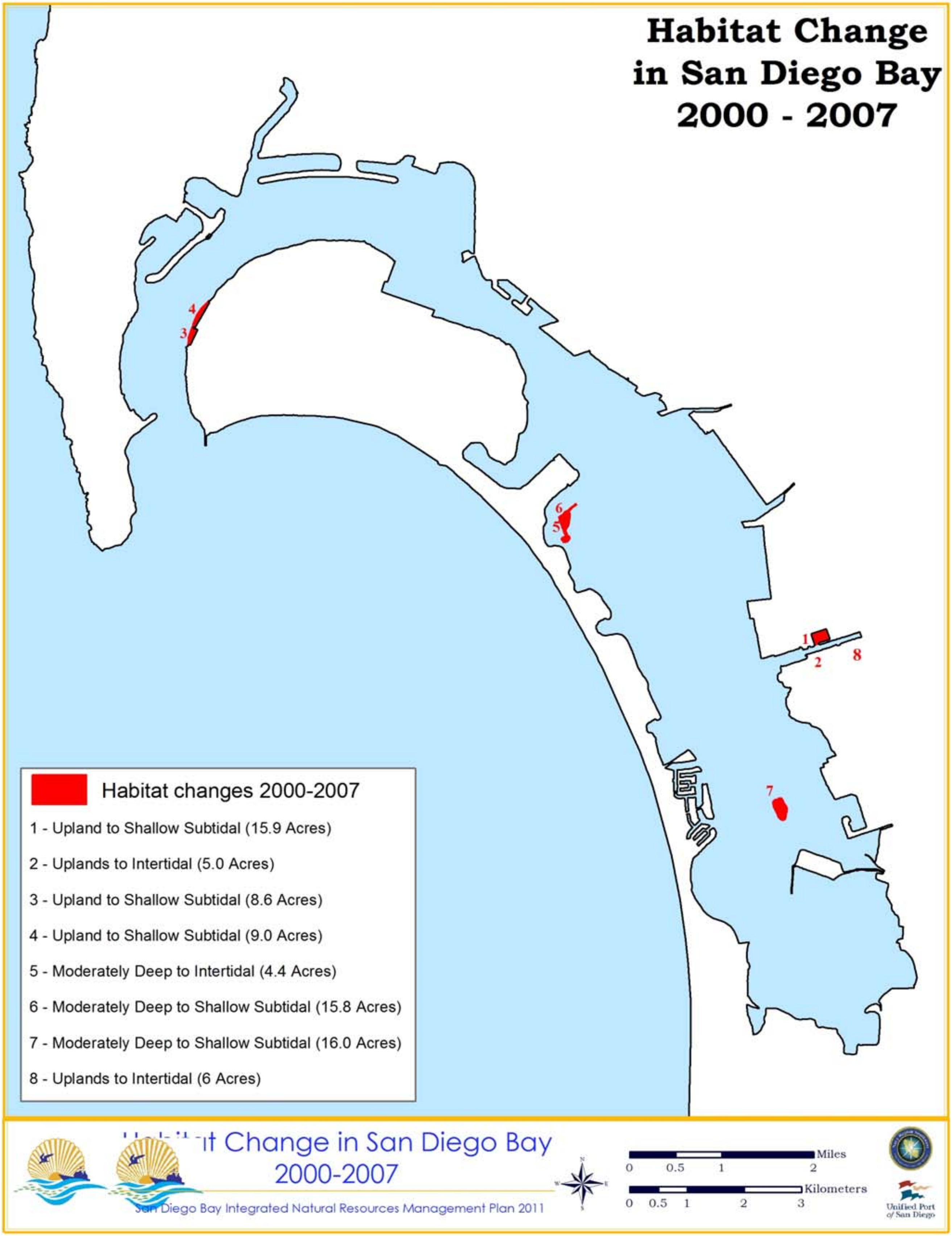


[1] Lower limit of salt marsh is defined by lower limit of cordgrass (*Spartina foliosa*). These tidal elevations are estimated based on salt marshes neighboring those of San Diego Bay. This is as low as 0.7 m (+2.3 ft) MLLW in Mission Bay (Levin *et al.* unpubl. data). In Tijuana Estuary and Anaheim Bay, lower limits range from +1.1 to +1.6 m (+3.5 to +5.25 ft) MLLW (Zedler *et al.* 1982; Massay and Zembal 1979).

[2] Mudflat zone derived from lower limit of cordgrass to upper limit of eelgrass (0.0).

[3] In San Diego Bay, depth of eelgrass varies with Bay regions as follows: south Bay 0.0 to 1.8 m (0.0 to –6 ft) MLLW; central Bay 0.0 to –2.4 m (0.0 to –8 ft) MLLW; north Bay 0.0 to –3.7 m (0.0 to –12 ft) MLLW. Near the mouth in north Bay, there is a different form (wider blades) that extends down to –5.5 to 7.3 m (–18 to –24 ft) (Hoffman, pers. comm.)

Figure 2-5. Habitats in relation to tidal elevation.



Map 2-11. Projects in 2000-2007 that have changed habitat conditions in San Diego Bay.

Table 2-5. San Diego Bay: Comparison of 1999 (Integrated Natural Resources Management Plan 2000), 2007, and historic[a] habitat acreages.

Habitat (depths in feet)[b]	1999 Acres/Hectares (% of total)	1859 Acres/Hectares (% of total)	1999 % Loss or Gain	Change since 2002 INRMP[f]	2007 % Loss or Gain Since 1859
Deep Subtidal (>–20)	4431/1798 (28%)	2212/895 (12%)	+100%	-36.2 acres	+99%
Moderately Deep Subtidal (–12 to –20)	2219/898 (14%)	954/386 (5%)	+133%		
Shallow Subtidal (–2.2 to –12)	3734/1511 (24%)	6400/2590 (35%)	–42%	+33.5 acres	-41%
Vegetated Shallow Subtidal[c]	1065/431 (7%)	Unknown	Unknown		
Intertidal excluding Salt Marsh (+2 to –2.2, high tide line to –3 on 1859 coverage)	979/396 (6%)	6148/2488 (33%)	–84%	+5 acres	-84%
Artificial hard substrate[d,e] (riprap and seawall; piers, wharves)	45.4 miles / 73.1 km	0	+74% of shoreline		
Salt Marsh	823/333 (5%)	2785/1127 (15%)	–70%	+ 20[f]	-69.7%
Upland Transition	2313/936 (15%)	Unknown	Unknown	-5 acres	Unknown
Riparian	7/3 (<1%)	Unknown	Unknown		
Freshwater Marsh	1/0.4 (<1%)	Unknown	Unknown		
Salt Works					
Crystallizer	121/49	N/A	N/A		
Pickling	59/24	N/A	N/A		
Primary	462/187	N/A	N/A		
Primary/Intertidal	106/43	N/A	N/A		
Secondary	366/148	N/A	N/A		
Dikes	62/25	N/A	N/A		
Total	15694/6351	18500/7487			

a. *Historic figures are based on an 1859 chart. Current figures are based on a 1995 aerial photo taken at MLLW and bathymetry from 1859 versus current chart.*

b. *All depths based on MLLW.*

c. *Vegetated shallows is a subset of shallow subtidal, so is not included in the totals.*

d. *Plus 131 acres (53 ha) horizontal surface structures (piers, etc.).*

e. *Artificial hard substrate is a subset of subtidal and intertidal habitats, so is not included in the totals.*

f. *In 2001 the U.S. Navy dredged approximately 500,000 cubic yards of sand at NASNI. In 2001, dredging began for a new intertidal mudflat and eelgrass enhancement site in the bay. The completed homeport Island has an area of 15 acres. Upland was excavated to intertidal along Sweetwater Channel. Upland excavated to subtidal marina at National City. Borrow pit filled in to change from deep subtidal to shallow subtidal in 2003. Addition of six acres planted to cordgrass and annual pickleweed for National City wharf extension project, plus 14 acres expansion of Lovett Marsh in National City for placement of USS Midway/San Diego Aircraft Carrier Museum.*

2.5.1 Deep Subtidal (>-20 feet [-6 m] MLLW)

Habitat Description

Deep subtidal habitat includes the surface water, water column and sediments for areas greater than 20 feet (6 m) in depth, constituting about 4,440 acres (1,797 ha) (34%) of bay surface area. It is associated primarily with navigational channels. Except for a few areas in north bay that have no dredging record, all deep subtidal habitat has been dredged since the 1940s; most was dredged in the 1960s or more recently.

Use of the Habitat

Deep subtidal habitat is used by a wide variety of vertebrate and invertebrate species. Some specifically inhabit the open water areas, some spend only part of their life cycle in the open water, and others use the open water to access coastal areas. Within the water column are microscopic species of phytoplankton and zooplankton (see also Section 2.6.1: Plankton). Their movement and distribution are completely dependent on currents and they are continually flushed out to sea by tides. Phytoplankton are an important primary producer in the bay. Their bloom appears to be driven seasonally by stormwater runoff, peaking in January (Lapota *et al.* 1993). Feeding on the phytoplankton and with a potentially completely different seasonal cycle are the zooplankton, including abundant meroplankton or "temporary plankton," the larval forms of invertebrates that later settle to the bottom and become benthic juveniles and adults.

These forms occur together with species called holoplankton, which are zooplankton that spend their entire lives in the open water environment in planktonic form. The density and diversity of holoplankton are greater in north bay, which is closer to coastal ocean water (Ford 1968). Some zooplankton migrate vertically through the water column at night, as well as horizontally with tidal movement.

Bird abundance and diversity appears lower in deep water habitats than in shallow habitats (USFWS 1995a; Ogden 1995; TDI 2008). However, many different waterbirds use the open water for feeding and resting. The California least tern and the California brown pelican (*Pelecanus occidentalis californicus*) forage in the open water, but especially along the bay margins where schooling fish concentrate. In addition to foraging, brown pelicans use these areas for staging fall migration, roosting, and for juvenile pelicans to scatter in search of new territory (USFWS 1997). Ogden (1994) reported many elegant and other terns using the open water habitat. Surf scoters make more use of deep water than other birds (Ogden 1995). California sea lions (*Zalophus californianus*) use buoys in deep water areas for hauling out, and California bottlenose dolphins (*Tursiops truncatus*) may be seen regularly in the deep water of north bay. Occasionally, gray whales (*Eschrichtius robustus*) visit near the mouth of the bay.

Organisms that live in the deep water benthos have a patchy distribution due to changes in sediment particle size on the bay floor and to their own reproduction and dispersal mechanisms which have a clumped pattern.

Fish species that can be found in the water column in San Diego Bay are listed in Table 2-6 (Robbins 2006). The water column encompasses all waters beyond the littoral zone and deeper than one meter.

Table 2-6. Fish species found in the water column (Robbins 2006).

Species	Common Name	Species	Common Name
Embiotoca jacksoni[1]	black surfperch	*Engraulis mordax*[6]	northern anchovy
Sphyraena argentea	California barracuda	*Sarda chiliensis*	Pacific bonito
Leuresthes tenuis	California grunion	*Scomber japonicus*[7]	Pacific mackerel
Scorpaena guttata[2]	California scorpionfish	*Sardinops sagax*	Pacific sardine
Pleuronichthys decurrens[3]	curlfin sole	*Seriphus politus*	queenfish
Trachurus symmetricus[4]	jack mackerel	*Cymatogaster aggregata*[8]	shiner surfperch
Atherinopsis californiensis	jacksmelt	*Citharichthys stigmaeus*[9]	speckled sand dab
Paralabrax clathratus[5]	kelp bass	*Atherinops affinis*	topsmelt
Gillichthys mirabilis	longjaw mudsucker		

1. In San Diego Bay, black surfperch appear seasonally, usually during the month of April, when the young-of-year recruit to the bay after the females give birth (Allen 1999; SWRO NMFS 1992).
2. California scorpionfish eggs are pelagic and float in masses near the surface (McCain 2003).
3. Curlfin sole spawn from April to August and release pelagic eggs (McCain 2003).
4. Juvenile jack mackerel school over shallow and deep rocky reefs, in kelp beds, and along rocky shorelines (Allen 1985; Mason 2001).
5. Kelp bass forage mid-water (Allen and Hovey 2001).
6. Young-of-year northern anchovy recruit to the mid-water of the nearshore and channel in San Diego Bay during July (Allen 1999). Northern anchovies typically school near the surface (Bergen and Jacobson 2001).
7. There is an apparent inshore-offshore migration, with Pacific mackerel being inshore between July and November (Konno and Wolf 2001). Juveniles reside along open coast sandy beaches, and in kelp beds, bays, and estuaries (Konno and Wolf 2001).
8. shiner surfperch appear seasonally in San Diego Bay, with young-of-year arriving in April after the females give birth (Allen 1999; SWRO NMFS 1992). They reside mid-water over soft-bottom, along open coast sandy beaches, and in bays and estuaries (Allen 1985).
9. Speckled sand dab larvae are pelagic and remain near the surface (Allen and Leos 2001).

Function

An important function of the deep water environment is the transport of plankton into and out of the bay for coastal species that depend on access to the warm, sheltered, and shallow waters during early life cycle stages. This includes the larvae of many fishes and crustaceans.

The food web in deep water is dependent upon detrital “rain” from sunlit surface waters. Fungi, bacteria, and protozoans of the benthos help break down coarser organic matter, making it available to higher organisms. As this organic matter is progressively consumed by larger and larger organisms, protein becomes increasingly concentrated up the food chain, creating higher quality food. While most of the deep water benthic habitat is not accessible to birds, benthic organisms do provide forage to rays and flatfishes. They also release planktonic larvae, which frequently undergo diurnal vertical migrations.

2.5.2 Moderately Deep Subtidal (-12 to -20 feet [-4 to -6 m] MLLW)

Habitat Description

Approximately 2,219 acres (898 ha) (17%) of bay surface area falls into the moderately deep category, primarily in south-central bay off the coast of the NAB and in inlets of north bay. The habitat extends from the approximate lower depth of most eelgrass to the approximate edge of the shipping channel. It represents areas that generally have been dredged in the past but are not maintained as navigational channels. The most recent dredging record at these depths off of NAB is dated 1941–1945. Sediment texture varies widely, from 5 to 95% fines.

While it generally supports similar communities to deeper habitat, moderately deep water habitat is distinguished in this INRMP because it represents potential enhancement sites for shoring up to shallower depths, which are more representative of historical habitat conditions.

Due to their potential for enhancement, moderately deep water habitats are distinguished from deep water in this INRMP.

Use of the Habitat

Moderately deep water is favored over other bay locations by several kinds of birds, including bottom feeding diving birds, especially rafting surf scoters, scaups, and buffle heads (*Bucephala albeola*), and plunge divers, such as terns and brown pelicans (USFWS 1995a; Ogden 1995). The endangered California least tern and the brown pelican forage in these areas.

Function

Other than the fact that these areas have been left undisturbed by dredging for longer periods than deeper water, any ecological differences between deep and moderately deep habitats have not been quantified.

2.5.3 Shallow Subtidal (-2.2 to -12 feet [-0.7 to -4 m] MLLW)

Continually submerged, these shallow habitats extend from the low tide zone (2.2 to –12 feet [0.7 to –4 m] MLLW). Shallow, soft bottom areas, with their associated fauna and flora, were the primary subtidal habitat in San Diego Bay prior to its development. About 3,734 acres (1,511 ha) (28%) presently dominate south bay, portions of south-central bay, and narrow strips along the shoreline of north and north-central bay. About 29% of the existing shallow waters are vegetated with eelgrass. This represents an overall loss of 41% from historic proportions due to filling in of the bay margins and dredging to deeper depths. The Port filled in over 10 acres of a deep subtidal borrow pit to allow an addition of shallow subtidal in 2003. South bay has comparatively little disturbance from dredging, having last been dredged off NAB in 1941–1945. Exceptions are the Emory Cove channel, Chula Vista Marina and the navigation channel leading to this marina. Sediment grain sizes tend to be very coarse (0 to 5% fines) to coarse (5 to 25% fines), except off the coast of NAB where fine sediments (up to 95% fines) accumulate.

Bird abundance and diversity is also higher at these depths, possibly due to the higher abundance of fish (Ogden 1994; USFWS 1995a). Shallow waters support many thousands of resident and migratory birds every year for foraging and resting. While all waterbirds are more abundant in shallow waters close to the shoreline, the groups that appear to use these areas preferentially are bottom feeding divers such as scoter and scaup, black brant (*Branta bernicla nigricans*), plunge divers such as terns, and the surface-foraging black skimmer (*Rynchops niger niger*) (Ogden 1994; USFWS 1994a).

Waterbirds and fishes are more abundant in shallow waters close to the shoreline.

2.5.3.1 Unvegetated Shallows (-2.2 to -12 feet [-0.7 to -3.7 m] MLLW)

Habitat Description

Soft bottoms of unconsolidated sediment are unstable and shift in response to tides, wind, waves, currents, human activity, or biological activity, such as feeding by bottom fishes or bat rays excavating pits to reach buried clams (Figure 2-6). It is known that fauna differ between fine sediments and sand in these areas, but it is not certain how much of this difference is due to particle size versus the effects of water flow characteristics, which in turn influence oxygen supply, nutrients, food, and larval settlement (Little 2000). Few plants and animals have adapted to this instability. Because animals and plants lack attachment sites in this environment, they must burrow into the substrate to prevent from being washed away by currents; these species are called "infauna." Competition for space is ameliorated partly by organisms occupying various depths within the substrate. Invertebrates such as sponges, gastropod molluscs, and some larger crustaceans and tunicates live on the surface.

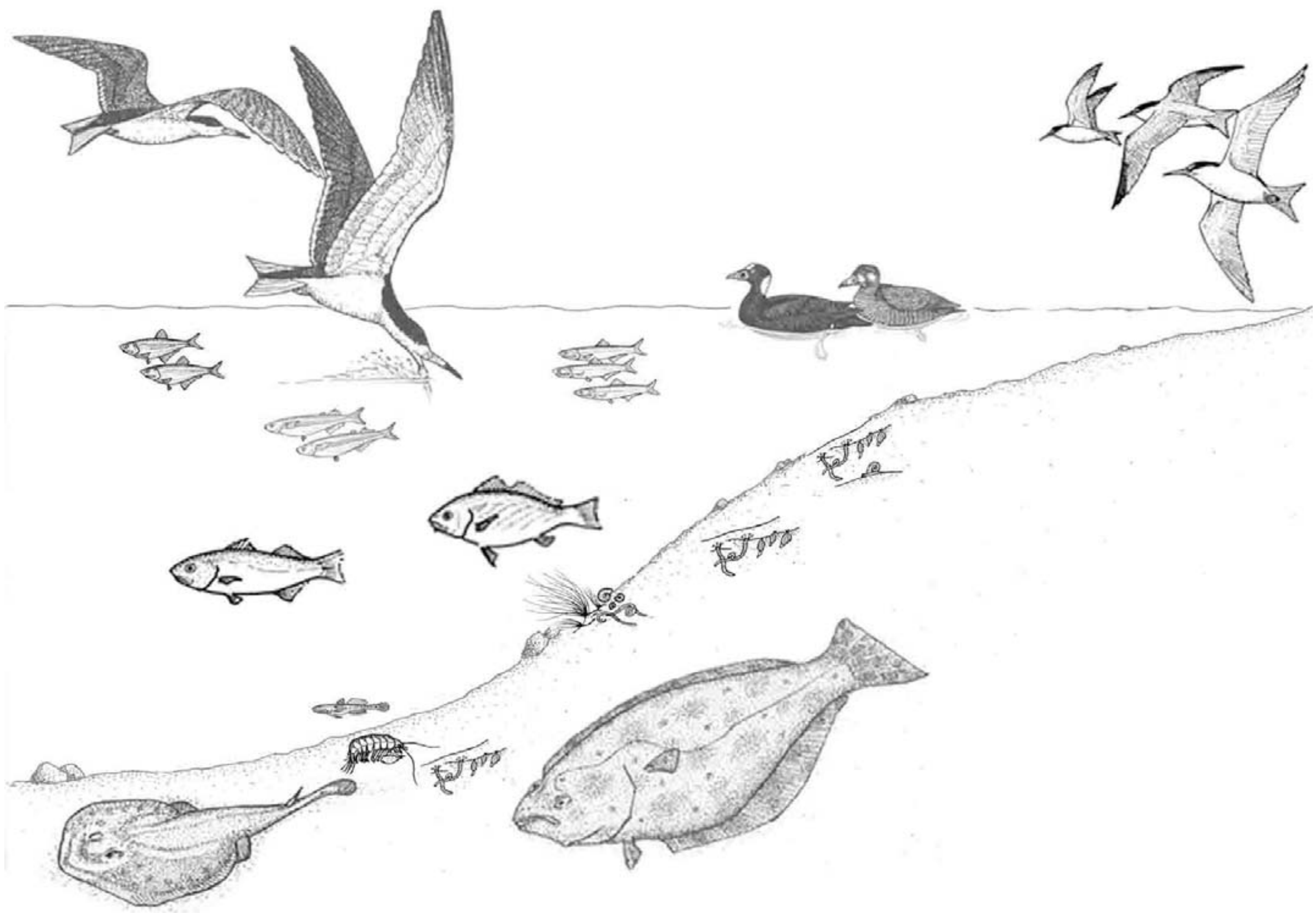


Figure 2-6. Unvegetated shallows.

Deposit feeding species tend to predominate in soft bottom sediment areas, where they glean live and dead plankton.

Various areas within this habitat have different species composition and abundance, generally depending on time since last disturbance and composition of the substrate. The CDFG (1973) reported subtidal substrates of fine mud, silt, fine and coarse sand, shelly sand, and a few areas of pebbles and cobbles. Deposit feeding species, those that glean detritus once it has settled, tend to predominate in soft bottom sediment areas with large amounts of silt and clay. The main reason for this relationship is that more detritus accumulates in the interstitial spaces among fine sediment particles than among those of larger grain size. In contrast, suspension feeders, those that filter material from the water column, are more common in areas where sandy sediments predominate, such as in portions of north bay and on the bay side of the Silver Strand.

Underwater observations indicate that algal mats provide cover from predators for many species of motile invertebrates and fishes, much like marsh vegetation does for birds.

An important structural component of unvegetated shallows is the presence of extensive masses or mats of living algal or bryozoan material interspersed with areas of exposed sediment that may extend into the intertidal zone (Ford 1968; Ford and Chambers 1974). The dense, heavily branched red alga, *Gracilaria verrucosa,* forms the bulk of this mat, which also includes the red algae *Hypnea valentiae* and *Griffithsia pacifica.* Some of these plants are loosely anchored in the sediment, while others drift just above the bottom. Mats can be 1 to 2 feet (0.3 to 0.6 m) thick during the warmest months of the year. Underwater observations indicate that these algal mats are an important microhabitat feature, because they provide cover or refuge from predators for many species of motile invertebrates and fishes, much like marsh vegetation does for birds. The algae also appear to serve as a food source for some invertebrates. The living plant material and detritus constitute a primary food source for California killifish (*Fundulus parvipinnis*) and other fish, crabs, isopods, gastropod molluscs, and some aquatic birds (Macdonald *et al.* 1990). A CDFG report (1972) also reported bryozoan mats as a distinct habitat type in south bay. See Photo 2-2.

Photo 2-2. Sponge, bryozoan and foliose red algae in south San Diego Bay. Photo courtesy of Merkel & Associates.

Use of the Habitat

Demersal fishes of unvegetated shallow areas of soft sediment feed on benthic invertebrates.

Unvegetated shallows support species assemblages of benthic invertebrates and demersal fishes that are both distinct from and overlap with vegetated areas of the same depth (Kramer 1990; Takahashi 1992a; Allen 1997). Many of the invertebrates serve as food sources for the demersal fishes that occur primarily in these unvegetated areas of soft sediment. Several demersal species use shallow unvegetated areas as grounds for spawning and/or nurseries. An important example is the California halibut, a flatfish species of commercial and recreational value. The small juvenile halibut are restricted primarily to unvegetated shallows of unconsolidated sediment in bays and estuaries (Allen 1982; Kramer 1990), where they feed on invertebrate fauna (Drawbridge 1990). Other species of demersal fishes that appear to depend primarily on invertebrates of unvegetated shallows as their food source include the diamond turbot (*Hypsopsetta guttulata*), round stingray (*Urobatis halleri*), and several species of gobies. Many fishes that occur in eelgrass and other vegetated habitats feed in unvegetated areas as well (Allen 1998a).

Not surprisingly, studies in the south bay have shown that many of the fishes that occur in shallow subtidal habitats of south bay also occur intertidally (Ford and Chambers 1973, 1974). Sediment characteristics at a given location are much the same both intertidally and subtidally. However, the number of intertidal species present generally appears to be much smaller than the number of subtidal species (Ford and Chambers 1973, 1974; Macdonald *et al.* 1990).

Table 2-7 lists fishes found in unvegetated shallows (Robbins 2006).

Table 2-7. Fish found in unvegetated shallows as summarized by Robbins (2006).

Species	Common Name	Species	Common Name
Clevelandia ios	arrow goby	*Heterostichus rostratus*[6]	giant kelpfish
Syngnathus exilis	barcheek pipefish	*Mustelus californicus*	grey smoothound
Syngnathus auliscus	barred pipefish	*Pleuronichthys verticalis*	hornyhead turbot
Paralabrax nebulifer	barred sand bass	*Atherinopsis californiensis*	jacksmelt
Myliobatis californica	bat ray	*Paralabrax clathratus*[7]	kelp bass
Hypsoblennius gentilis	bay blenny	*Syngnathus californiensis*	kelp pipefish
Lepidogobius lepidus	bay goby	*Triakis semifasciatus*[8]	leopard shark
Syngnathus leptorhynchus	bay pipefish	*Engraulis mordax*	northern anchovy
Hippoglossina stomata	bigmouth sole	*Scomber japonicus*	Pacific mackerel
Embiotoca jacksoni	black surfperch	*Leptocottus armatus*	Pacific staghorn sculpin
Mustelus henlei	brown smoothound	*Porichthys notatus*	plainfin midshipman
Pleuronichthys coenosus	CO turbot	*Seriphus politus*	queenfish
Sphyraena argentea	California barracuda	*Urobatis halleri*	round stingray
Gymnura marmorata	California butterfly ray	*Quietula y-caula*	shadow goby
Menticirrhus undulatus	California corbina	*Cymatogaster aggregata*	shiner surfperch
Leuresthes tenuis	California grunion	*Cynoscion parvipinnis*	shortfin corvina
Hyporhamphus rosae	California halfbeak	*Rhinobatos productus*	shovelnose guitarfish
Paralichthys californicus[1]	California halibut	*Anchoa delicatissima*	slough anchovy
Fundulus parvipinnis	California killifish	*Citharichthys stigmaeus*	speckled sand dab
Synodus lucioceps	California lizardfish	*Porichthys myriaster*[9]	specklefin midshipman
Strongylura exilis	California needlefish	*Roncador stearnsii*	spotfin croaker
Scorpaena guttata[2]	California scorpionfish	*Paralabrax maculatofasciatus*	spotted sand bass
Symphurus atricauda[3]	California tonguefish	*Pleuronichthys ritteri*	spotted turbot
Tridentiger trigonocephalus	chameleon goby	*Atherinops affinis*	topsmelt
Ilypnus gilberti	cheekspot goby	*Hyperprosopon argenteum*	walleye surfperch
Pleuronichthys decurrens[4]	curlfin sole	*Genyonemus lineatus*	white croaker
Anchoa compressa	deepbody anchovy	*Atractoscion nobilis*	white sea bass
Pleuronichthys guttulata	diamond turbot	*Phanerodon furcatus*	white surfperch
Micrometrus minimus	dwarf perch	*Umbrina roncador*	yellowfin croaker
Pleuronichthys vetulus[5]	English sole	*Acanthogobius flavimanus*	yellowfin goby
Xysteurys liolepsis	fantail sole		

1. California halibut use San Diego Bay and its eelgrass as a nursery area (Allen 1999; Hoffman 1986; Kramer and Sunada 2001; SWRO NMFS 1992). Larger fish reside over nearshore soft-bottom and in the channel (Allen 1985; Allen 1999).
2. California scorpionfish spawn near the bottom at depths between 3 and 120 meters (Love 2001). They reside over hard-bottom and soft-bottom Love 2001; NMFS Northwest Region 2004).
3. California tonguefish reside on soft-bottom (Allen 1985; Allen 1999). Their eggs are located on the benthos of bays (MBC Applied Environmental Sciences 1994).
4. Curlfin turbots reside over soft-bottom (Allen 1985; Anchor Environmental 2003). They are most common at depths less than 90 meters (McCain 2003).
5. English sole can be found in the northern portion of San Diego Bay (Allen 1999). English sole move inshore during the summer months and can be found in eelgrass, along the open coast, and over sand and mud (McCain 2003; Pearson and Owen 2001).
6. Giant kelpfish inhabit the eelgrass and soft-bottom habitats of San Diego Bay (Allen 1999; Hoffman 1986; SWRO NMFS 1992). Young-of-year recruit to the bay during the months of July and October (Allen 1999).
7. Kelp bass larvae can be found in shallow water among drift algae (Allen and Hovey 2001).
8. Leopard sharks are most common at depths ranging from 0 to 5 meters in muddy bays (Smith 2001). They reside in estuaries, bays, and kelp beds over soft and hard bottoms, as well as along open coast sandy beaches (NMFS NW Region 2004; Smith 2001; Smith 2005). Leopard sharks spawn and pup in shallow water (Smith 2005). Seasonally, pups are along sandy beaches and in protected bays (Smith 2005).
9. Specklfin midshipman reside over soft-bottom (Allen 1985).

Factors Affecting Composition of the Soft Bottom Community

As summarized in Pister (2007), benthic marine environments are notoriously patchy. Understanding the processes that generate and maintain patchiness in these environments has been one of the primary goals of ecologists for a long time (e.g. Baker 1909; Huntsman 1918; Hewatt 1935; Hatton 1938; Doty 1946). Scientists have long suspected that substrate plays an important role in the variation of marine communities (Zobell & Allen 1935; Hatton 1938; McDougall 1943; Pomerat and Weiss 1946; Wisely 1958). As in the deeper water environment, the patchiness of benthic organisms in shallow areas in space and time is due to such variables as substrate composition, environmental disturbances, the nonrandom settlement and growth of larvae, productivity of the overlying water in terms of phytoplankton, life history strategies of organisms, competitive strategies, and predation by larger, active predators such as the round stingray and flatfishes.

The stability of the soft bottom community depends upon the relative importance of physical factors versus biological ones in structuring it. The major physical and chemical factors that determine the structure of a soft bottom community and affect the population dynamics of its epifaunal and infaunal species involve a variety of characteristics of the sediment. They include grain size distribution, degree of grain compaction and porosity, water content, drainage (that is, whether it is stagnant or flushed at low tide), dissolved oxygen levels, levels of suspended and deposited organic material, and the short-term and long-term stability of the sediment. These characteristics are affected by depth, slope of the bottom, wave action, currents, and other physical and chemical characteristics of the water above the bottom.

A stable, healthy community will support larger infauna and a greater diversity of infaunal life-styles.

Biological activity can also dominate community structure. For example, a relatively long-lived species, such as a sea cucumber, can dominate a shallow-water benthic community partly by modifying its physical environment through a series of stable mounds and unstable intermediate areas to favor organisms compatible with itself. In that way, the sea cucumber-based community can remain stable for years. A stable, healthy community will tend to support larger infauna (ghost shrimp, clams, etc.), and a diversity of infaunal life-styles such as suspension feeders, burrowers, tube builders etc. (L. Levin, Scripps Institute of Oceanography, *pers. comm.*). Invasion of a community by invasive species can completely change the relative dominance of species. Sometimes, physical and biological factors alternate in controlling residents in an area, such as before and after storms (Nybakken 1997).

Merkel & Associates (2008) found a high diversity of fish (but lower than artificial reefs) in both sand and eelgrass habitats. The sand habitat ranked high along with the eelgrass. The report suggests that this may be partially due to improved visibility in open sandy areas during sampling. Bare sand is relatively rare in San Diego Bay and occurs where sedimentation rates are low preventing the accumulation of silt, and where depths are too great for eelgrass growth. Sand also occurs on the edges of navigational channels where dredge cuts reveal buried sand. Similar to mud bottom, invertebrate filter and deposit feeders dominate this habitat and serve as a food base for flat fishes and rays, many of which are commercially or recreationally important.

The distribution of organisms in the subtidal sand ecotype is spatially and temporally patchy. For example, sand dollars (*Dendraster excentricus*) occur in large clustered beds in areas where wave action and sediment type permit. Communities that persist for long periods of time and then disappear exemplify temporal fluctuations in the distribution of subtidal sand species. For example, research indicates that entire sand dollar beds, which appeared stable over a period of six years, could totally disappear over a period of 19 years (Davis and VanBlaricom 1978).

Typical animal assemblages of sand bottom habitats include a variety of invertebrates. Tube-building polychaete worm (*Diopatra ornata*) communities are commonly found in shallow, relatively sandy habitats. Other shallow sand bottom species include sea pens (e.g. *Stylatula elongata*), the bivalve *Tellina modesta*, tube dwelling anemones (*Pachycerianthus fimbriatus*), and the gastropod *Caecum crebricinctum*. Key predators in sandy subtidal habitats are expected to be armored sea stars (*Astropecten* spp.), bat rays (*Myliobatis californica*), round stingrays, leopard sharks (*Triakis semifasciata*), and flatfish (e.g. halibut and turbot). Ephemeral occurrences of floating algae are common, as are algae and invertebrates that require hard substrate that are attached to smaller pebbles or shells on the sand surface. In 2008 (Merkel & Associates 2008) divers characterized common species of sandy subtidal areas with: tube-dwelling anemone; sea pen (Photo 2-3); the sponges *Aplysina fistularis* and *Tetilla mutabilis*; the bryozoan *Thalamoporella californica*; and fishes California halibut, diamond turbot, bat ray, and round stingray.

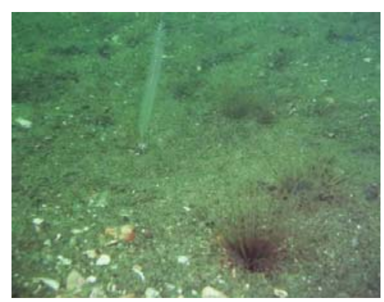


Photo 2-3. Sea pen and tube-dwelling anemone. Photo courtesy of Merkel & Associates.

Differences between sand habitats in north and south San Diego Bay were observed during the same study. The influence of tidal flushing was observed in the north bay with the sandy habitat being of a coarser grain sand. More open coast species were observed in this habitat such as the red sea urchin (*Strongylocentrotus franciscanus*). Sandy habitat in the south bay was covered by a layer of fine silt and could be characterized as muddy sand. The decreased tidal action was evident with the presence of scattered floating algae and bryozoan colonies. Although a greater abundance of fish has been found in vegetated versus non-vegetated sites in San Diego Bay (Hoffman 2006; Allen *et al.* 2002), some fish species depend upon non-vegetated areas and may prefer sand. Allen *et al.* (2002) found that California halibut and diamond turbot both occurred in order of greatest abundance at deep non-vegetated sites, shallow non-vegetated sites, and vegetated sites. The managed species Pacific sardine and northern anchovy were both caught in greater abundance in non-vegetated sites than vegetated sites when in nearshore areas.

Function

Invertebrate fauna of unvegetated shallows in San Diego Bay is important to ecological functioning of the bay, both because it serves as the main food source for a wide variety of demersal fishes that occur in this habitat and because it is a major species assemblage in its own right.

While not studied separately for shallow waters, bay sediments are the sites of key ecological functions such as decomposition, nutrient cycling, and nutrient production (Levin *et al.* 2001). Infaunal invertebrates in these sediments increase percolation of water and oxygen levels through bioturbation and suspension feeding. Shredders such as gastropod mollusks break up large pieces of organic matter, while deposit feeders both transform and bury or bring up organic matter. Dominant suspension feeders are often bivalve mollusks, but some polychaetes, crustaceans, and sponges also perform this function. These animals can increase water clarity and light levels and reduce pollutants (Alpine and Cloern 1992).

Infaunal and epifaunal invertebrates serve as the major food base for many species of fish and larger invertebrates including shrimp, crabs, lobster, halibut and croaker, which transfer this production across habitats (Levin *et al.* 2001). Feeding by nematode and polychaete worms, gastropod molluscs, brittlestars, crabs, isopods, and a wide variety of smaller crustaceans serves to transform detritus and small invertebrates into usable food for larger invertebrates and fishes; the latter, in turn, are eaten by other large fishes (some of sportfishing value) and aquatic birds. Bivalve molluscs and other suspension feeders serve a similar function in transforming plankton and suspended detrital material into food for fishes and birds. The less conspicuous molluscs, polychaete worms, small crustaceans, and other invertebrates mineralize organic waste as it accumulates, consume macroalgae, and return essential chemicals and organic matter to the water column.

2.5.3.2 Vegetated Shallows (0.0 to -24 feet [0.0 to -7.3 m] MLLW)

Habitat Description

Eelgrass covers most of the available nearshore area in San Diego Bay (Allen 1999). An important and productive benthic habitat in San Diego Bay is formed by beds of eelgrass (*Zostera marina*), a type of seagrass and a native marine angiosperm (Figure 2-7). Eelgrass habitats rank among the most productive habitats in the ocean (Nybakken 1997), and are an important component of the San Diego Bay food web. As has occurred in bays and estuaries all along the Pacific coast and elsewhere in the world, eelgrass beds in San Diego Bay have suffered substantial losses and impacts due to their location in sheltered waters where human activity is concentrated. However, these losses were historic due to bay fill and deepening. Today, eelgrass is protected under the CWA and other laws, and any impacts are fully mitigated. The potential area for eelgrass growth in the bay may be saturated such that these beds currently exist to the extent that bathymetric regime, water clarity for sunlight, water temperature, and characteristics of the sediment allow. In San Diego Bay, these beds have stabilized, ranging from zero MLLW to depths of at least 23 feet (7 m) below MLLW, depending on levels of light and water turbidity. In south bay the range is from 0 to –7 feet (0 to –2 m) MLLW, central bay 0 to –10 feet (0 to –3 m) MLLW, and north bay 0 to –13 feet (0 to –4 m) MLLW. Near the mouth in north bay, a different form of eelgrass (wider blades) grows from –16 to –23 feet (–5 to –7 m) MLLW (R. Hoffman, NMFS, *pers. comm.*).

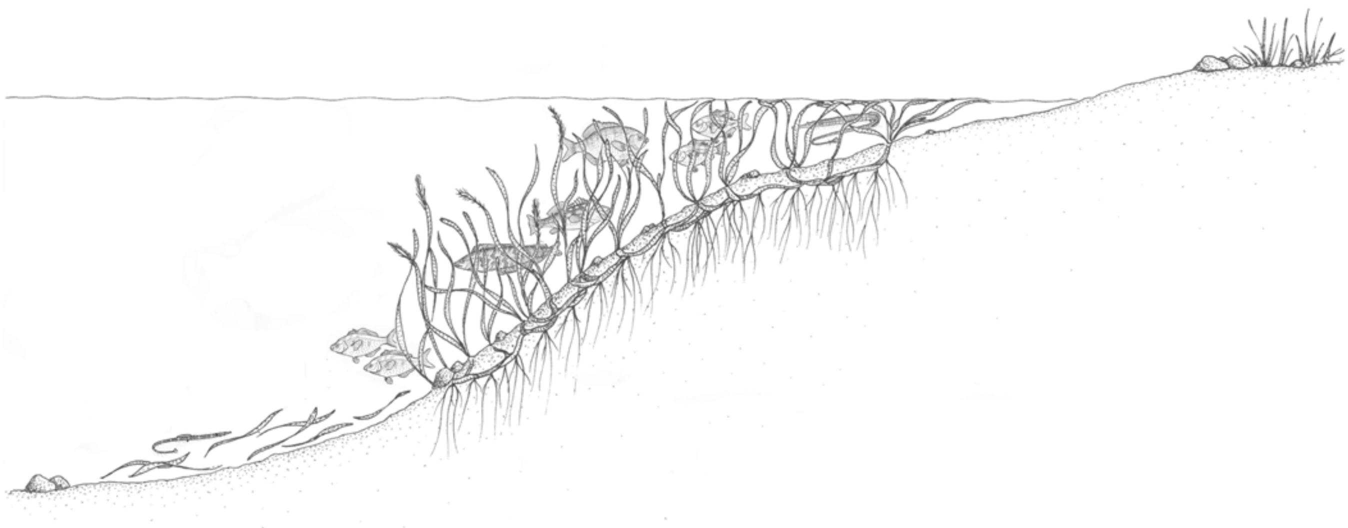
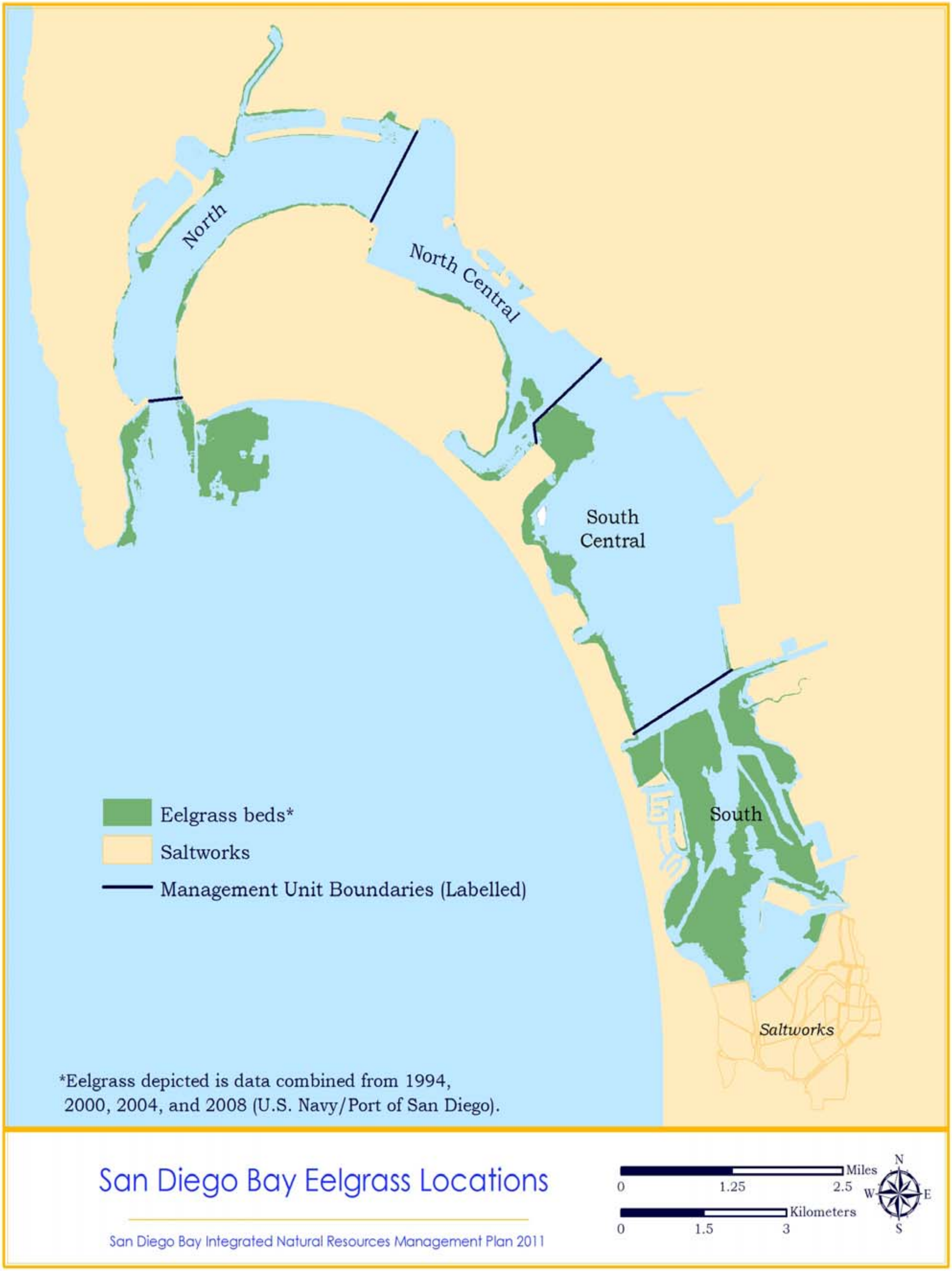


Figure 2-7. Eelgrass bed.

The plant density and biomass of eelgrass beds in San Diego Bay and elsewhere can vary widely from one season to another (Marsh 1973; Takahashi 1992a). The main factors responsible appear to be depth, sediment grain size distribution, nutrients, light levels, temperature, and salinity (Phillips and Lewis 1984). Distribution and abundance of eelgrass in San Diego Bay have changed significantly over time, declining and improving along with the water quality condition in the bay (Ford and Chambers 1974; Lockheed 1979; Hoffman 1986). Eelgrass is predominantly a subtidal resource and as a result it is difficult to monitor and track changes in its distribution. Recent advancements and application of sonar technology have significantly improved researches precision and accuracy to map eelgrass distribution. In 1993, the U.S. Navy applied this technology to San Diego Bay and provided the first comprehensive survey of eelgrass resources within the bay (U.S. Navy 1994). The Navy and the Port followed this effort with another baywide survey in 1999 using single-beam sonar methods (U.S. Navy 2000). In 2004 and 2008 complementary eelgrass surveys and bathymetric mapping updates of the entire bay were completed using side scan sonar, providing an important temporal time line of eelgrass distribution and potential habitat throughout the bay (Merkel 2004, 2008) (Map 2-12).

In addition to providing important habitat for fish, eelgrass is considered to be an important resource supporting migratory birds, particularly during migration. Black brant, a goose that uses eelgrass as its predominant food item, has been an indicator of eelgrass abundance in the bay since the 1880s. Reports of 50,000 to 100,000 brant in Spanish Bight alone (an inlet between Coronado and North Islands that was filled in 1941) suggest abundant eelgrass beds during that period. In 1941 there were reports of the complete loss of all eelgrass beds due to marine pollution, which peaked in the late 1950s and early 1960s. Reports of brant in 1942 totaled 1,100 individuals for the entire bay (USFWS 1995a). Since the elimination of sewage deposition into bay waters in 1963, eelgrass appears to grow naturally or as a result of revegetation throughout the bay wherever it can grow. Shallow subtidal areas that remain unvegetated may remain so due to turbidity or unknown reasons (R. Hoffman, *pers. comm.*).

In contrast, eelgrass habitat availability may be constraining the productivity of fishes (Pondella 2006). Using fish abundance to characterize the performance of a newly created eelgrass bed over a five-year study, Pondella speculated this could be the case based on the relatively constant fish utilization of the planted habitat (based upon the small error estimates), and colonization was rapid at the onset of the study. Pondella saw this as an indication that eelgrass habitat may be limiting in the north bay.



Map 2-12. San Diego Bay Eelgrass Locations.

Use of the Habitat

Eelgrass has an extremely rapid growth rate, high net productivity, and a very high level of biomass (McRoy and McMillan 1977). Its importance as habitat is evident both from the great diversity of its associated invertebrate and fish faunas (Phillips 1984; Hoffman 1986; Takahashi 1992a).

Because of their heterogeneous structure, eelgrass beds provide microhabitats for a wide variety of invertebrates and small fishes, primarily by increasing the available substrate surface and by providing effective refugia. Phillips (1984) and Takahashi (1992a) reported the following four functional groupings of animals living within the bed:

1. Epifauna living on the eelgrass blades and using them as a substrate for attachment.
2. Epifauna living on the surface of the sediment, sometimes also moving onto the eelgrass blades.
3. Infauna living in the sediment of the bed, with some of these moving onto the blades during the eelgrass growing season.
4. Invertebrates and fishes living in or above the eelgrass canopy. This last group involves animals that move easily in and out of the bed at different times of day or on a seasonal basis.

Photo 2-4. Kelp bass at edge of eelgrass bed at Shelter Island in north San Diego Bay. Photo courtesy of Merkel & Associates.

Pondella (2006) assessed the success of an eelgrass mitigation site completed in 1997 at North Island for fishes over a five-year period surveyed regularly from September 1997 to September 2002. The newly created eelgrass habitat quickly (in about one year) performed at the level of an existing, nearby eelgrass bed. The overall analysis found that the mitigation eelgrass habitat was not significantly different from the reference eelgrass habitat in terms of fishes. Over the course of this five-year study which compared fish abundances of at the north bay site among introduced reef enhancement structures, the eelgrass mitigation planting, an established eelgrass site, and Zuniga Jetty, several species of fish were found only in eelgrass beds after 44 visits and 1056 transects sampled. These were topsmelt, guitarfish (*Rhinobatos productus*), diamond turbot, bat ray, dwarf perch (*Micrometrus minimus*), arrow goby (*Clevelandia ios*), jack mackerel, pipefish (*Syngnathus* spp.), Pacific sardine, striped mullet (*Mugil cephalus*), and walleye surfperch (*Hyperprosopon argenteum*). This suggests that, baywide, eelgrass provides valuable habitat for several important species in San Diego Bay. Kelp bass (*Paralabrax clathratus*; Photo 2-4), giant kelpfish (*Heterostichus rostratus*), barred sand bass, and California halibut use eelgrass primarily as juveniles, while spotted sand bass and shiner surfperch (*Cymatogaster aggregata*) are present in eelgrass throughout their life cycles (Vantuna Research Group [VRG] 2006).

See Table 2-8 for fishes that utilize eelgrass habitat in San Diego Bay (Robbins 2006).

Function

Eelgrass beds are the most productive areas on the soft bottom.

Eelgrass beds are the most productive areas on the soft bottom. Roots and rhizomes help stabilize the unconsolidated substrate by forming an interlocking matrix that inhibits erosion. The plants themselves keep water clearer by trapping fine sediments and preventing their resuspension (Takahashi 1992a). Leaves cut down wave action and currents; the resulting decrease in turbulence causes more fine sediment to be deposited. Abundant algae and invertebrates that grow on the leaf blades provide primary and secondary productivity for consumption by larval and juvenile fish. Sediments within eelgrass beds are loaded with detrital leaves, rhizomes, and nutrients that fuel infaunal invertebrates. These provide food for fishes and sometimes birds including the federally endangered California least tern. When epibenthic invertebrate abundances are low, this indicates impaired food chain support functions (Rutherford 1989).

Table 2-8. Fish species found in eelgrass, as summarized in Robbins (2006).

Species	Common Name	Species	Common Name
Clevelandia ios	arrow goby	*Syngnathus californiensis*	kelp pipefish
Syngnathus exilis	barcheek pipefish	*Triakis semifasciatus*	leopard shark
Syngnathus auliscus	barred pipefish	*Engraulis mordax*	northern anchovy
Paralabrax nebulifer	barred sand bass	*Scomber japonicus*	Pacific mackerel
Myliobatis californica	bat ray	*Leptocottus armatus*	Pacific staghorn sculpin
Hypsoblennius gentilis	bay blenny	*Seriphus politus*	queenfish
Lepidogobius lepidus	bay goby	*Halichoeres semicinctus*	rock wrasse
Syngnathus leptorhynchus	bay pipefish	*Hypsoblennius gilberti*	rockpool blenny
Cheilotrema saturnum	black croaker	*Urobatis halleri*	round stingray
Embiotoca jacksoni	black surfperch	*Xenistius californiensis*	salema
Chromis punctipinnis	blacksmith	*Anisotremus davidsonii*	sargo
Menticirrhus undulatus	California corbina	*Quietula y-cauda*	shadow goby
Leuresthes tenuis	California grunion	*Cymatogaster aggregata*	shiner surfperch
Hyporhamphus rosae	California halfbeak	*Rhinobatos productus*	shovelnose guitarfish
Paralichthys californicus[1]	California halibut	*Anchoa delicatissima*	slough anchovy
Fundulus parvipinnis	California killifish	*Bryx arctus*	snubnose pipefish
Strongylura exilis	California needlefish	*Roncador stearnsii*	spotfin croaker
Ilypnus gilberti	cheekspot goby	*Paralabrax maculatofasciatus*	spotted sand bass
Anchoa compressa	deepbody anchovy	*Pleuronichthys ritteri*	spotted turbot
Pleuronichthys guttulata	diamond turbot	*Mugil cephalus*	striped mullet
Pleuronichthys vetulus[2]	English sole	*Atherinops afinis*	topsmelt
Heterostichus rostratus[3]	giant kelpfish	*Hyperprosopon argenteum*	walleye surfperch
Mustelus californicus	grey smoothound	*Genyonemus lineatus*	white croaker
Atherinopsis californiensis	jacksmelt	*Atractoscion nobilis*	white sea bass
Paralabrax clathratus	kelp bass	*Phaneroon furcatus*	white surfperch
Rimicola muscarum[4]	kelp clingfish	*Umbrina roncador*	yellowfin croaker
Brachyistius frenatus	kelp perch		

1. California halibut use San Diego Bay and its eelgrass as a nursery area (Allen 1999; Hoffman 1986; Kramer and Sunada 2001; SWRO NMFS 1992).
2. Juvenile and adult English sole forage in the intertidal over sand, mud and in eelgrass (NMFS 2004; Pearson and Owen 2001).
3. Young-of-year giant kelpfish recruit to the bay during the months of July and October (Allen 1999).
4. Kelp clingfish reside in among eelgrass (Eschemeyer et al. 1983).

Eelgrass beds are an important component of the San Diego Bay food web. Much of the eelgrass primary productivity enters the food web as detritus. Fish and invertebrates use eelgrass beds to escape from predators, as a food source, and as a nursery. Eelgrass plants provide surfaces for egg attachment and sheltered locations for juveniles to hide and feed. Fish produced from these beds are consumed by fish-eating birds, including the California least tern. Waterfowl, especially surf scoters, scaup, and brant are present in high numbers in late fall and winter. Black brant, in particular, rely heavily on eelgrass of central and south bay as they are one of the few birds that consume it directly. A small population of the federally endangered eastern Pacific green sea turtle (*Chelonia mydas*) feeds on eelgrass growing in several beds near the South Bay Power Plant in south bay (USFWS 1997).

2.5.4 Intertidal (+7.8 to -2.2 feet [+2.4 to -0.7 m] MLLW)

The intertidal habitat encompasses the area between high and low tides and is subject to varying degrees of tidal submergence. Losses in this zone have been the most severe of all bay habitats, with the greatest decrease in north and central bay (over 90%). Some of this occurred when the San Diego River was diverted and its tidal flats and salt marsh filled in. Intertidal areas currently constitute about 976 acres (395 ha), or 7% of the bay. Most historic intertidal areas have been filled in on their landward edge and constricted on their bay side due to dredging. Many sites are now mere slivers of their previous extent. Most of the remainder has been modified by structures for shoreline stabilization or access, with less than 15.8 miles (25.5 km) of soft shoreline left (26% of the total shoreline). "Hard" intertidal habitat (riprap and other structures) is plentiful but not natural to the bay.

Despite its relatively small size, the intertidal zone has the greatest variability of any area in the bay, and this variability can occur within centimeters. In part, this is due to the fact that the zone is exposed to air on a regular basis, and most physical factors show a wider range in air than in water (Nybakken 1997). Figure 2-8 describes the percent of time each tidal elevation is exposed above water in 1999 in the bay. Organisms must adapt to extremes of temperature and desiccation, as well as salinity stress, mechanical wash, and backwash of waves. These extremes are more pronounced on sandy shores, where there is less animal life than on muddy shores. The abundance and diversity of fauna of a typical sand flat can also vary by orders of magnitude within and among years (Nybakken 1997).

The intertidal zone has the greatest variability of any area in the bay, and this can occur within centimeters.

Photo 2-5. Sandy intertidal habitat. Photo courtesy of Rob Wolf.

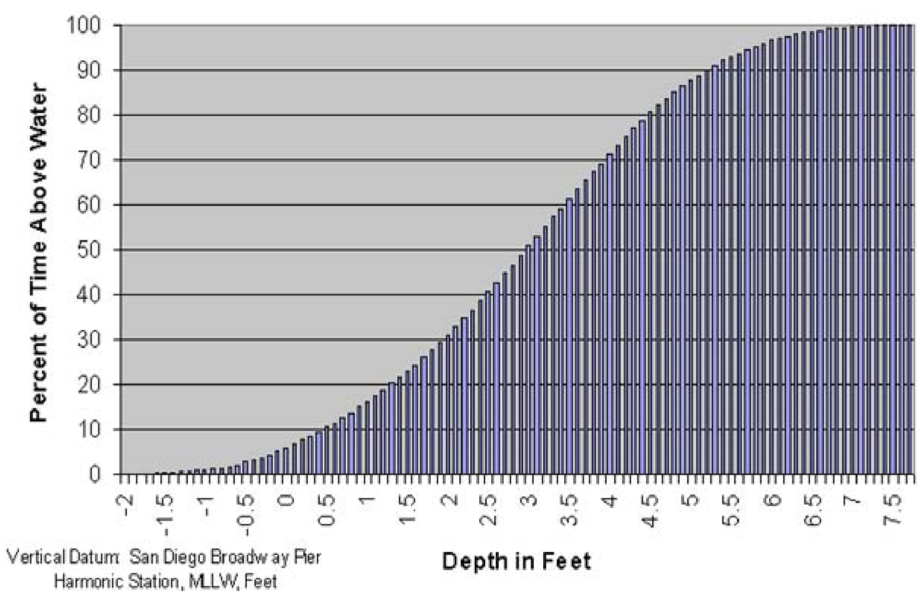


Figure 2-8. Intertidal area exposed annually in San Diego Bay (1999).

Shorebirds are the most visible species depending upon intertidal habitat for feeding, roosting and resting.

Shorebirds are the most visible species depending upon intertidal habitat for feeding, roosting, and resting. Both Boland (1981) and Kus and Ashfield (1989) observed shorebirds in the nearby Tijuana Estuary in a wide variety of habitats, and noted that nearly every species they studied made use of intertidal areas at some time. Boland (1981) consistently found the highest densities of nearly all shorebirds in intertidal flats and channels; likewise, Kus and Ashfield (1989) observed that the majority of large and small waders seen during low-tide surveys occurred in those habitats (citations from Zedler *et al.* 1992).

2.5.4.1 Intertidal Flats (+2.3 to 0 feet [+0.7 to 0 m] MLLW)

Habitat Description

Intertidal flats (Figure 2-9) of San Diego Bay include mudflats, sand flats, and salt flats (addressed under salt ponds, below). They occur between the highest high and lowest low tide zones, or otherwise between the lowest cordgrass (beginning of the salt marsh) and highest eelgrass, approximately 3 to 0 feet (1 to 0 m) MLLW in the bay. The zone normally lacks vegetation. The most extensive intertidal flats in the bay are along the northern shore of the salt ponds, north of the northernmost levee; along other shorelines of south bay; off the shore of North and South Delta beaches; and along the barrier edge of the power plant channel. Important, narrow intertidal flats also occur along the margins of tidal channels of the salt marshes of south bay, which may be used for foraging by the light-footed clapper rail and Belding's savannah sparrow (*Ammodramus sandwichensis beldingi*). Mudflats have been replaced by fill, concrete bulkheads, and a variety of other stabilization structures in the north bay and the eastern shoreline of the central bay to provide for recreational, commercial, industrial, and military uses.

Species composition and diversity of marine resources associated with soft substrates differ with sediment type, which often varies according to depth and energy gradients. This holds true for San Diego Bay. Generally, sediments are sandier near the shore and muddier with increasing depth offshore. Fewer species of invertebrates live in sandy sediments in the shallow energetic nearshore zone than in sandy to mixed sediments offshore, probably due to differences in sediment stability (Oliver *et al.* 1980; Thompson *et al.* 1997). Consequently, relative ecological values of sandy versus muddy habitats are influenced less by grain size than by disturbance gradients.

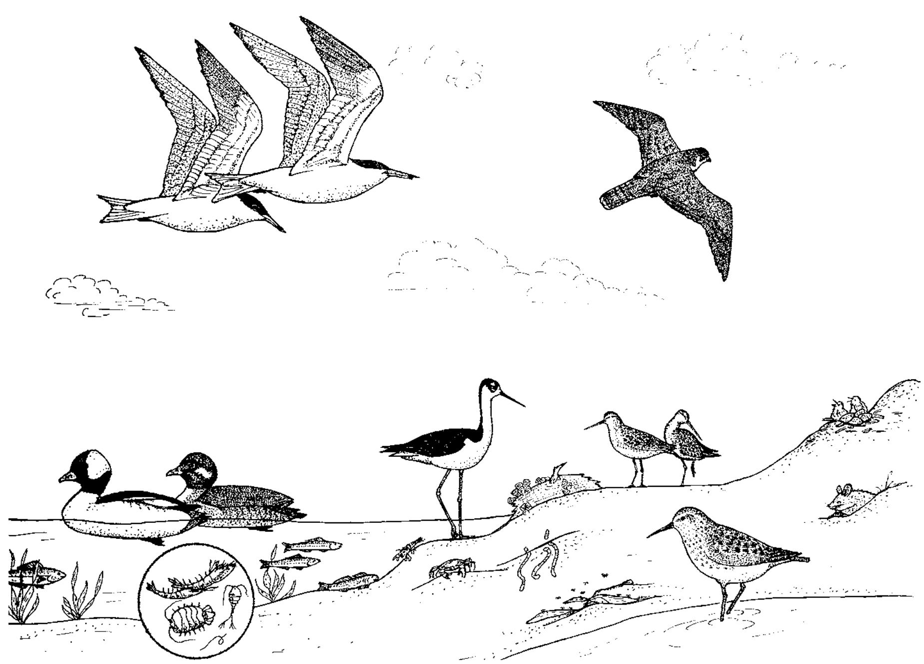


Figure 2-9. Intertidal flat community.

A well-developed mudflat is anaerobic within the sediment and stable due to a lack of significant wave action (Photo 2-6). Sand flats remain aerobic and typically experience more turbulence from waves, preventing development of permanent burrows. Sandy beaches are more strongly zoned than mudflats (Castro and Huber 1997) because they tend to have a steeper gradient topographically and because coarse grain sizes allow for more rapid and differential drying. The upper beach is drier than the lower beach. Because water drains away from the upper beach more rapidly, it is drier than the lower beach. Beach hoppers, sand fleas, and isopods may be expected there. On the lower beach, polychaetes, clams, and other animals predominate.

Photo 2-6. San Diego Bay mudflat. Photo courtesy of Eileen Maher.

Use of the Habitat

Mudflats contain abundant organic matter and microorganisms, but typically less so than eelgrass beds or salt marshes. Normally devoid of flowering plants, these areas may be covered with algae. Toward the uppermost elevations, green algae such as *Enteromorpha* sp., *Cladophora* sp., and *Ulva* spp. may form extensive mats (Mudie 1970). Burrows and siphon-holes of benthic invertebrates, tiny invertebrates that live among the grains of substrate (meiofauna), and algae and detritus fill the sediment with hidden activity, and are all necessary to support the food chain and mineral cycles of the bay. Snails, crabs and polychaete worms (deposit feeders) glean the surface for detrital bits and algae. Filter-feeders such as clams, mussels, and small crustacean isopods and amphipods collect plankton, algae, and detritus as they wash by when the tide is in. The deposit and filter feeders together are extremely efficient processors of the living and dead plankton.

Intertidal flats contain abundant algae and detritus, which along with tiny benthic invertebrates are necessary to the food chain and mineral cycles of the bay.

When the tide is rising and comes into the bay, numerous fishes, sharks, and rays move in to take advantage of the productivity of the flats. While most mudflat fishes are tidal visitors, and some remain at low tide in shallow drainage channels, a short list of species are full-time residents. These are commonly the ones that can live in the burrows of marine invertebrates (Moyle and Cech 1982). Other fishes are seasonal visitors during juvenile life stages: California halibut, California halfbeak (*Hyporhamphus rosae*), and striped mullet (Johnson 1999). Studies on tidal flats elsewhere have demonstrated that it is frequently only the juvenile decapod crustaceans such as shrimp, as well as demersal fish (Photo 2-7), that forage on tidal flats while the adults and pelagic larvae stay offshore. The tidal flats function as nurseries for the resident juveniles and the subadults, which migrate to the subtidal area to avoid low tide conditions on the flats. While relatively constant salinities and temperatures in offshore waters benefit larval development, these larvae eventually drift onto tidal flats so that the juvenile stages of these fish may take advantage of high temperatures, abundant food, and absence of large predators (Reise 1985).

Most mudflat fishes are tidal visitors, some remain at low tide in shallow drainage channels, and a short list of species are permanent residents.

Photo 2-7. Diamond turbot in north San Diego Bay. Photo courtesy of Merkel & Associates.

Shorebirds congregate sometimes by the thousands to consume invertebrate prey that becomes available when the tide recedes.

When the tide recedes, biodiversity in the mudflat becomes much more visible to even the casual observer. Shorebirds congregate sometimes by the thousands to consume invertebrate prey. See Table 2-9 for observations during the 2006-2007 avian survey. Each species specializes in a certain zone, evident by the length of its bill and feeding behaviors that help access the different lifestyles and niches of mud-dwelling species. In the flats that adjoin the salt ponds of south bay, the USFWS made 50,000 bird observations of 67 species, primarily sea birds and shorebirds, during year-long, weekly surveys in 1993–1994 (USFWS 1995a). The federally threatened western snowy plover and western sandpiper (*Calidris mauri*) forage on the mudflats during low tide. The federally endangered California least tern, other terns, and black skimmer forage in the waters over submerged mudflats during high tide.

Use of sandy versus muddy substrates has not been studied separately for the intertidal nor subtidal habitats of San Diego Bay. However, sand flats are expected to be used by invertebrates, fish, and birds similarly to mudflat areas, but at lower densities. These areas are more sheltered than the open ocean and may support hundreds of species, including a variety of invertebrates, fish, aquatic vegetation, fish-eating birds and waterfowl, and transient occurrence of marine mammals (e.g. Allen 1999; Marine Ecological Consultants [MEC] 2000; Thompson *et al.* 2000). Abundance patterns may vary across seasons associated with reproductive and inshore-offshore migratory patterns of some fauna. For example, invertebrates may exhibit higher abundance in spring-early fall than late fall-winter associated with greater wave activity and/or larval recruitment (Science Applications International Corporation [SAIC] 2008).

In 1973, CDFG reported as a specialized habitat the sand flats on the bay side of the Silver Strand: “The marine zone along the western edge of San Diego Bay contains extensive areas of sandy sediments which are relatively free of silts and clays, and which border beaches that are composed of nearly pure sand. These specialized ‘clean sand’ habitats apparently support several species of flora and fauna which cannot tolerate the clay and silt substrates or the muddy waters characteristic of other areas of the bay. Clean sand habitats are considered especially valuable because: 1) they are relatively uncommon in bays and estuaries along the California coast; and 2) they occasionally support a greater diversity of bottom organisms than found on silt and clay bottoms. Sampling at three clean sand stations along the west side of the bay yielded up to five species of plants and 23 species of invertebrates per station. By comparison, seven silt and clay bottom areas sampled in the central and southern portions of the bay were characterized by zero to four plant species and two to 14 species of invertebrates per station” (USACE 1972).

Table 2-9. Birds in cells adjacent to bay muddy shoreline habitat (Tierra Data Inc. 2009).*

Species	Number	Species	Number
western sandpiper	44,136	greater yellowlegs	144
marbled godwit	11,632	red-breasted merganser	291
willet	9,650	horned grebe	276
dowitcher sp.	8,236	barn swallow	258
black-bellied plover	5,709	Brandt's cormorant	243
brant	3,971	Belding's savannah sparrow	230
elegant tern	3,929	redhead	223
red knot	3,815	least tern	221
dunlin	3,469	sandpiper sp.	207
scaup sp.	3,020	western/Clark's grebe	197
American wigeon	2,883	ruddy turnstone	175
double-crested cormorant	2,206	shorebird sp.	120
surf scoter	2,174	Caspian tern	119
Forster's tern	2,075	gull sp.	118
semipalmated plover	1,931	great blue heron	115
western gull	1,632	cliff swallow	106
lesser scaup	1,489	white-crowned sparrow	99
least sandpiper	1,198	rock pigeon	90
brown pelican	1,187	mallard	90
red-necked phalarope	1,120	common tern	89
black-necked stilt	1,118	American white pelican	87
bufflehead	956	yellowlegs sp.	87
sanderling	919	osprey	79
black skimmer	854	gull-billed tern	76
snowy egret	769	killdeer	76
eared grebe	696	black turnstone	75
northern shoveler	684	Bonaparte's gull	66
northern pintail	668	herring gull	51
ring-billed gull	647	mourning dove	51
royal tern	622	whimbrel	44
Savannah sparrow	587	Heermann's gull	36
ruddy duck	583	American pipit	35
greater scaup	581	tern sp.	35
California gull	554	western meadowlark	33
short-billed dowitcher	490	house sparrow	33
American avocet	442	blue-winged teal	30
snowy plover	433	tree swallow	29
long-billed curlew	416	little blue heron	29
peep sp.	390	reddish egret	26
horned lark	361	European starling	25
great egret	352	Say's phoebe	24
western grebe	342	American coot	23
house finch	322	Heermann's gull or herring gull	22
pied-billed grebe	309	cinnamon teal	20
gadwall	295	Vaux's swift	20
long-billed dowitcher	159	common loon	20
		Grand Total	134,850

**Excludes 47 species for which the number observed was fewer than 20.*

Function

The specific effect of a severe reduction of intertidal flat habitat from historic proportions have not been characterized for the bay. It is possible that its own productivity may be limited by reduced sources of detritus they receive due to loss of eelgrass and salt marsh from the historic bay. It may also be that an impaired nutrient supply function of intertidal flats is affecting nearby habitats. Finally, there appear to be significant subsets of mudflat habitat that provide important functions, but these have not been described. For example, birds use narrow versus broad intertidal flats differently, as well as coarse-grained versus fine-grained. For some birds, this may limit their ability to use intertidal flats of the bay.

All types of intertidal flats serve as sheltered inlets that bring tidal exchange to coastal wetlands or as outlets for storm water runoff, nutrients, and sediment supply to the bay and nearshore coast. Invertebrates inhabit the sediments, anadronomous and marine fish may transit to reach spawning and foraging areas, and shorebirds and fish-eating birds forage here. Intertidal flats may experience sedimentation problems due to reduced tidal prisms and/or erosion and runoff from watersheds.

Recreational, commercial, or military uses are also served in these habitats, especially those dominated by sand.

2.5.4.2 Salt Marsh (+7.8 to +2.3 feet [+2.4 to 0.7 m] MLLW)

Southern California salt marshes differ from east and south coastal marshes in part because of contrasting rainfall and tidal regimes.

Salt marsh is the driest intertidal habitat, occurring in the upper intertidal zone above the mudflats (Figure 2-10). It is regularly wetted by tidal water and always exposed at least once every 24 hours. Since the climate is semiarid with little rainfall for much of the year, uninterrupted tidal circulation is the most important source for water, nutrients, and oxygen (Macdonald *et al.* 1990). This contrasts with marshes from the east and south coasts. Southern California salt marshes differ from eastern and southern coastal marshes in other ways. The rate of primary productivity for vascular plants is lower in southern California, while productivity for epibenthic algae underneath the open canopy is higher (Zedler 1992a). Annual productivity of dense algal mats beneath the marsh canopy could match or exceed that of vascular plants in local marshes. These differences between marshes of southern California and elsewhere suggest that what drives and regulates marsh function, and how the marsh relates to other habitats, may also differ here.

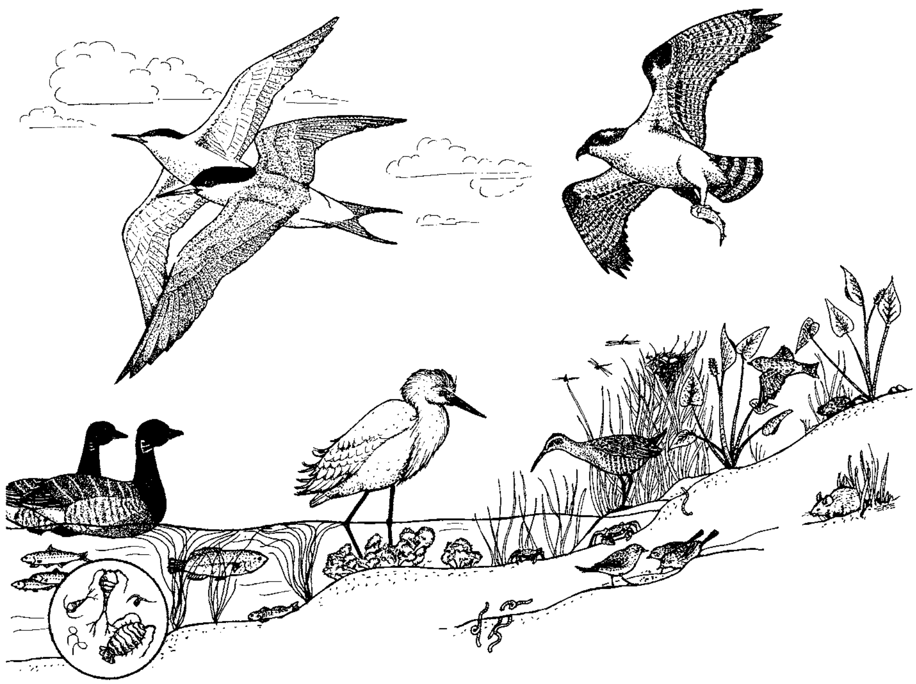


Figure 2-10. Intertidal Salt Marsh—Subtidal Interface.

The salt marsh parcels in the Sweetwater Marsh Unit of the NWR is considered regionally significant because they are permanently open to tidal flushing. As a result, they support a high diversity of salt marsh plant species, including a number of low marsh species, such as cordgrass, annual pickleweed (*Salicornia bigelovii*), and saltwort (*Batis maritima*), which are generally absent from nontidal wetland systems. Many salt marsh plant species cannot tolerate seasonal closure to tides, which over time have resulted in reduced native plant species diversity and lower habitat values (USFWS 2006).

Habitat Description

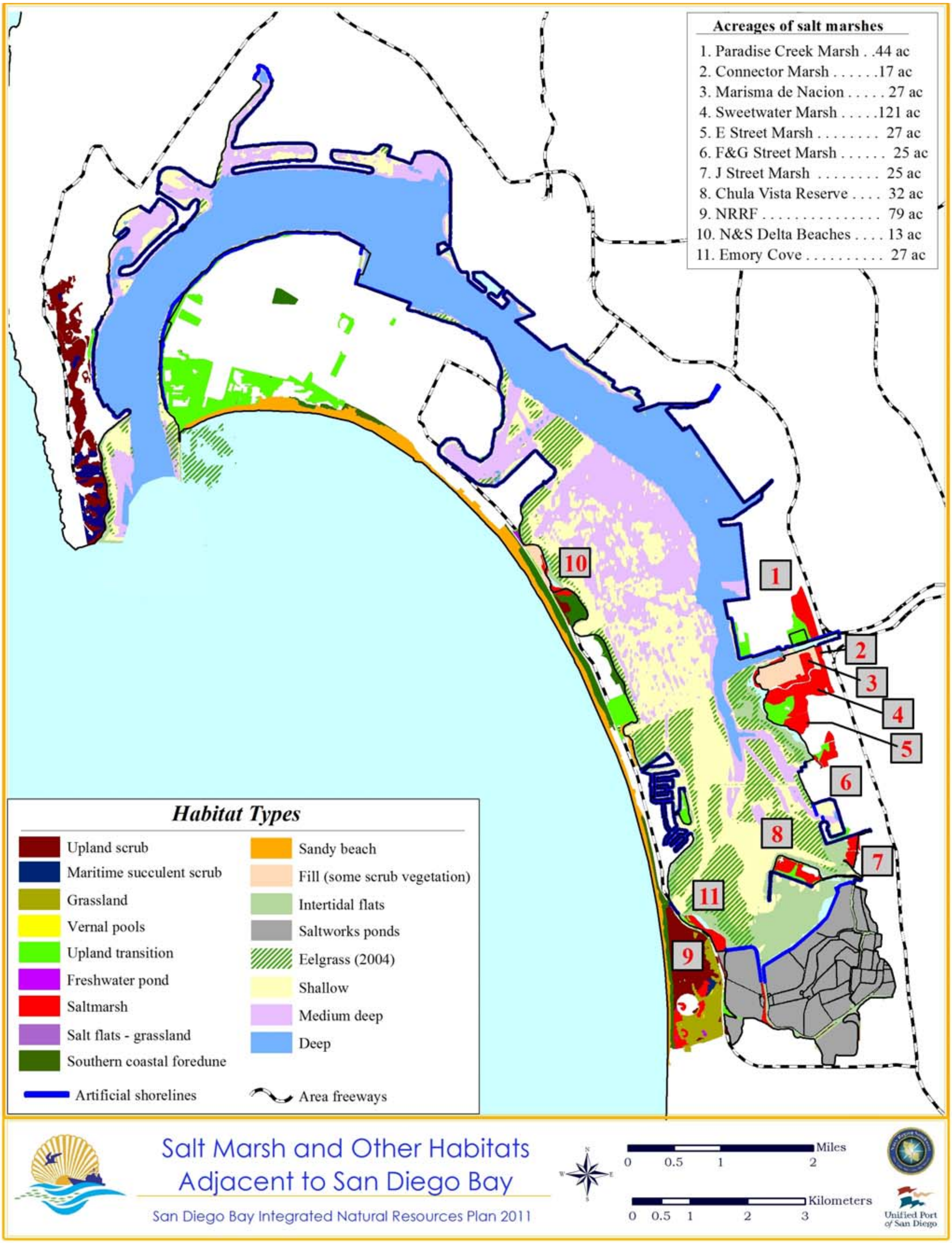
Salt marsh habitat has been severely reduced by urban development and only remains in south San Diego Bay. It previously existed at the mouths of seven drainages. In 1859, there were 642 acres (260 ha) of salt marsh in north San Diego Bay and 420 acres (170 ha) in central bay. South San Diego Bay had over 1,700 acres (688 ha). baywide, 88% of salt marsh habitat has been lost. The problem is not just loss of acreage, however, but fragmentation and isolation of the remaining parcels, which may cause them to lack long-term sustainability. This plant community is also considered to be scarce in southern California as a whole. Estimates of the amount of salt marsh habitats that have been destroyed in southern California range from 75 to 90% (Zedler 1996).

Important salt marsh fragments for some birds occur along dikes in the salt ponds and along portions of the Otay River. The primary marsh complex is at the SMNWR.

Today, the primary marsh complex is on the eastern shores of south bay at the Sweetwater Marsh National Wildlife Reserve (SMNWR) (Photo 2-8). The individual parcels are (Map 2-13) Sweetwater River (121 acres/49 ha), Paradise Creek (44 acres/18 ha), Marisma de Nacion (27 acres/11 ha, excavated from the D Street Fill in 1990), Connector (17 acres/7 ha constructed as a hydrologic link between Paradise Creek and the SMNWR), E St. (about 27 acres/11 ha), F and G Streets (25 acres/10 ha), and J Street (25 acres/10 ha) marshes. There is also the Chula Vista Wildlife Reserve (CVWR) (32 acres/13 ha of dredge fill constructed in 1987), the marsh at the south end of Emory Cove (about 27 acres/11 ha) and between North and South Delta Beaches (about 12 acres/5 ha). Portions of the marsh at the Naval Radio Receiving Facility (NRRF) no longer function as marsh land since they are no longer tidally influenced. Important salt marsh acreage for birds occurs in long, narrow strips along some of the dikes in the salt ponds and along the tidally influenced portions of the Otay River. Excavated borings in the vicinity of Pond 20A indicate that at least 40 acres of this area historically supported salt marsh habitat (Michael Brandman Associates 1989).

Photo 2-8. Sweetwater marsh. Photo courtesy of Rob Wolf.

Coastal salt marshes can be divided into more or less distinctive zones based upon vegetation patterns. These patterns are related to elevation and degree of inundation, and may be termed Lower, Middle, and Upper Marsh, and Upland Transition (Figure 2-11) (Zedler *et al.* 1992).



Map 2-13. Salt marsh and upland transition adjacent to San Diego Bay.

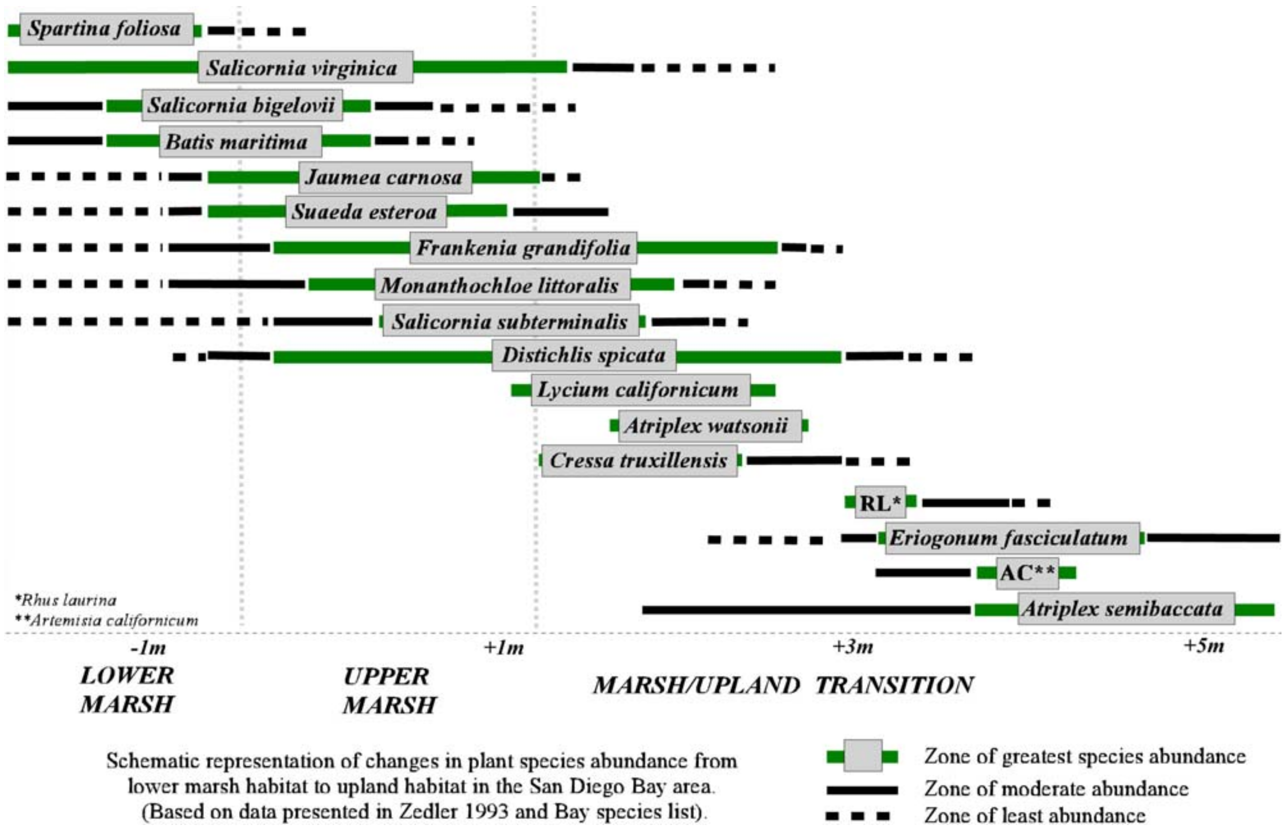


Figure 2-11. Vegetation patterns in salt marsh habitats.

The plant communities of each of these zones are described below.

Lower Marsh

The lower marsh is characterized by cordgrass, grading into pickleweed (*Salicornia virginica* and *S. bigelovii*). Cordgrass, which may be up to 3 feet (1 m) tall and half submerged, spreads through the habitat with buried rhizomes, and less commonly from seed. Pickleweed occurs in areas that are inundated by only the highest tides (Zedler *et al.* 1992; Schoenherr 1992; Boyer *et al.* 1996b).

Middle Marsh

The middle marsh habitat is typified by the presence of saltwort, pickleweed, sea blite (*Suaeda esteroa*), and arrow grass (*Triglochin concinna*) (not quantified by Zedler *et al.*, so not in Figure 2-11) (Zedler *et al.* 1992; Boyer *et al.* 1996b). Killifish and water boatmen typically inhabit pools of the middle marsh.

Upper Marsh

The upper marsh is characterized by golden bush (*Isocoma* spp.), prickly-pear (*Opuntia* spp.), glasswort (*Salicornia subterminalis*), sea blite, box thorn (*Lycium californicum*), salt grass (*Distichlis spicata*), and shore grass (*Monanthochloe littoralis*) (Zedler *et al.* 1992; Boyer *et al.* 1996a). Salt marsh bird's beak (*Cordylanthus maritimus* ssp. *maritimus*), a federal and state endangered species, occurs in the upper marsh zone. Within the Sweetwater Marsh Unit of the NWR, salt marsh bird's beak has been observed in Paradise Marsh and Sweetwater Marsh. A directed search within Paradise Marsh for nine sensitive plant species was conducted in 1998 for National City. Salt marsh bird's beak, which was the only listed plant encountered during the survey, was identified in nine locations within Paradise Marsh, occurring primarily within the southwestern end of the marsh (City of National City 1998). The subpopulation also occurs within Sweetwater Marsh proper. Additionally, revegetation funded by the Port was performed in 2006 at the CVWR and D Street Fill using local seed stock and cuttings. The results of the revegetation are currently unknown and will likely rely on adequate rainfall and growth conditions. Other populations are known from as far north as San Luis Obispo County and south into Baja California. Another population occurs at the Tijuana Estuary.

Upland Transition Marsh

The upland transition zone is not a distinct community in and of itself, but represents a gradient between the upper marsh and coastal scrub community (Zedler *et al.* 1992). The lower end of the transitional zone is characterized by *Salicornia*, *Distichlis*, *Monanthochloe*, *Frankenia*, and *Cressa* species, while the upper transition zone is characterized by *Atriplex*, *Eriogonum*, *Rhus*, *Salvia*, and *Artemisia* species (Zedler *et al.* 1992; Holland and Keil 1995). Palmer's frankenia (*Frankenia palmeri*) is a California Native Plant Society (CNPS) List 2 (plants rare, threatened, or endangered in California, but more common elsewhere) species. All of the plants constituting List 2 meet the definitions of §1901, Chapter 10 (Native Plant Protection Act) or §§2062 and 2067 (CESA) of the CDFG Code, and are eligible for state listing. It is mandatory that they be fully considered during preparation of environmental documents relating to the California Environmental Quality Act (CEQA) (CNPS 2009).

Use of the Habitat

A number of marine fish inhabit the bay's salt marshes. Topsmelt, arrow goby, California killifish, and longjaw mudsucker (*Gillichthys mirabilis*) are most abundant at SMNWR (Johnson 1999). Young round stingray and California halibut also occur. Two invasive fishes that are present and could become a nuisance include the yellowfin goby (*Acanthogobius flavimanus*) and sailfin molly (*Poecilia latipinna*). The former was probably introduced in ship bilge water, while the molly was likely introduced through the aquarium trade (Boyer *et al.* 1996a).

Function

A well-functioning salt marsh habitat provides nesting, feeding, and a high-water escape area for many species of birds, as well as food and cover for fish and invertebrates. Not all marshes in the bay have the salient features to attract birds, so those that depend on the marsh are concentrated on the parcels that retain such features. The Belding's savannah sparrow nests in patches of pickleweed or boxthorn in some areas of bay salt marshes, and forages in salt marsh and intertidal flats. Where it is found in the bay, the light-footed clapper rail depends entirely on salt marsh habitat for feeding, resting, and nesting. Cordgrass thickets, in particular, are an important component of the marsh for nesting by the rail. Cordgrass stabilizes low elevation salt marsh within a narrow range dependent on tidal flushing (Zedler 1992b). It also lines the edges of tidal channels. Since cordgrass is linked by tidal flows to the mudflats on a daily basis, mobile animals are able to move into the marsh at high tide to feed. Detritus and algae float out from the marsh into channel waters (Zedler 1992b). The plants and productive algal mats that occur within the marsh support detritus- and grazer-based food chains.

There is tremendous variability over time in the processes that determine the fate of carbon, detritus, and nitrogen in the system present in southern California.

There has been some difficulty characterizing the function of salt marshes of southern California because the systems are not stable long enough to quantify energy flow and nutrient cycling (Zedler *et al.* 1992). Investigators of southern California and east coast marshes have concluded that the traditional view that salt marshes are net exporters of productivity that subsidize waters nearby is not necessarily true. It may be different in each individual case. In southern California, there is tremendous variability over time in the processes that determine the fate of carbon, detritus, and nitrogen in the system. Rare events dominate the structure and function of the marsh (Zedler and Onuf 1984). Scientists have examined such patterns on nitrogen fluxes and productivity in the nearby Tijuana Estuary. Their results may not be transferable to San Diego Bay, however, because the Tijuana system experiences occasional sewage spills from Mexico and has experienced historical seasonal closures at the mouth that reduced tidal influence. The Tijuana Estuary no longer experiences seasonal closure—the last one was in 1983–1984. The mouth does become constricted from time to time, but the time of year is variable. Currently, the mouth is ready to be excavated immediately upon closure (B. Collins, USFWS, *pers. comm.*).

Some patterns in the mechanisms behind salt marsh structure and function have been teased out of the natural and human-related variability in work conducted both in San Diego Bay and in the Tijuana Estuary (summarized in Zedler *et al.* 1992). When soil salinities were measured six times in Sweetwater marshes in late 1995 through 1996, lowest salinities were found in the winter following rains (Boyer *et al.* 1996a). High marsh locations have higher peaks in soil salinity, with salinities at the lower elevation being moderated by frequent inundation (Boyer *et al.* 1996a). In tidal creeks of the Tijuana Estuary, algae in phytoplankton blooms peaked in areas with the lowest tidal circulation, with seasonal peaks in spring when weather was warm and tidal action minimal due to estuary closure. This suggests that phytoplankton accumulate when water currents are reduced and nutrients are plentiful (Fong 1986). Rudnicki (1986) found maximum volume of macroalgae where circulation was reduced and where prevailing winds moved the floating mats. Salinity affected the growth of both phytoplankton and macroalgae. Lower salinity delayed phytoplankton blooms, and the species composition became more dominated by blue-green types. In manipulative experiments at the Tijuana site, productivity rates in the marsh peaked in very open canopies during warm periods at sites that were frequently inundated, conditions where epibenthic algae could flourish (Rudnicki 1986; Fong 1986). Algae blooms (based on chlorophyll concentrations and cell counts) occur during nontidal periods (Fong 1986).

Productivity rates in the marsh peaked in very open canopies during warm periods at sites that were frequently inundated, conditions where algae on the marsh soil surface could flourish.

While salt marshes are considered productive habitats due to plant and algal photosynthesis and access to nutrients from nitrogen fixing bacteria and blue-green algae and from flood tides, there is some evidence that nitrogen may be limiting to bay marshes, at least in constructed marshes. The cordgrass marsh of the bay is nitrogen limited and receives this nutrient in pulses from freshwater systems or slowly by trapping inorganics from tidal water (Zedler 1992b). Low nitrogen pools reflect low tidal import and infrequent streamflow influxes (Langis *et al.* 1991). A one-year study at the SMNWR showed nitrogen fixation rates (as measured by acetylene reduction) to be very low (Zalejko 1989). Studies of marshes in the Sweetwater complex show peaks in water nutrient levels in January, presumably related to nutrient inputs from runoff during winter storms (Boyer *et al.* 1996a). Most organic matter and runoff is trapped behind reservoirs on the Sweetwater River, which only overflow during extreme storms, approximately once per decade.

There is some evidence that nitrogen may be limiting to constructed bay marshes. Studies of the Sweetwater complex show peaks in water nutrient levels in January.

There are several indicators that can reflect health of the salt marsh. One is loss of plant cover or density. Another is a change in plant composition towards species that tolerate brackish or fresh water. This can result from altered hydrology that decreases tidal influence, such as when fill is added to the marsh. The result is reduced flushing of the system so that sediment accumulates. This can also happen with increases in freshwater flow from urban runoff or imported water. Freshwater increases can cause conversion to cattail/bulrush vegetation and brackish water that may support different species. Most marine species have a low salinity tolerance range. If water becomes brackish, or if stagnant water becomes anoxic, such species are quickly killed (Zedler 1992a). A lack of marine fish and invertebrate species would indicate a lack of sufficient saline conditions for their survival. The presence of nonnative plants within the salt marsh could indicate reduced salinity levels, as could the presence of native upland plants.

Freshwater increases to the salt marsh system can cause conversion to brackish water, which quickly kills some species. Sufficient salinity conditions are necessary for the survival of marine fish and invertebrates.

Table 2-10 provides a list of fish species found in salt marsh habitat in San Diego Bay (Robbins 2006).

2.5.4.3 Artificial Shoreline Structures

Habitat Description

This section and Section 4.3.7: Artificial Structures discuss artificial structures as habitat (Figure 2-12), while Section 5.2.3 In-Water Construction addresses the building of these structures and the permitting process and use of materials associated with this construction.

Table 2-10. Fish species found in salt marsh habitat as summarized in Robbins (2006).

Species	Common Name	Species	Common Name
Clevelandia ios	arrow goby	*Gillichthys mirabilis*	longjaw mudsucker
Paralabrax nebulifer	barred sand bass	*Engraulis mordax*	northern anchovy
Myliobatis californica	bat ray	*Girella nigricans*	opaleye
Hypsoblennius gentilis	bay blenny	*Squatina californica*	Pacific angel shark
Lepidogobius lepidus	bay goby	*Sarda chiliensis*	Pacific bonito
Syngnathus leptorhynchus	bay pipefish	*Scomber japonicus*[5]	Pacific mackerel
Hippoglossina stomata	bigmouth sole	*Sardinops sagax*[6]	Pacific sardine
Cheilotrema saturnum	black croaker	*Leptocottus armatus*	Pacific staghorn sculpin
Chromis punctipinnis	blacksmith	*Seriphus politus*	queenfish
Embiotoca jacksoni[1]	black surfperch	*Paraclinus integripinnis*	reef finspot
Albula vulpes	bonefish	*Halichoeres semicinctus*	rock wrasse
Mustelus henlei	brown smoothound	*Hypsoblennius gilberti*	rockpool blenny
Pleuronichthys coenosus	CO turbot	*Urobatis halleri*	round stingray
Sphyraena argenta	California barracuda	*Xenistius californiensis*	salema
Menticirrhus undulatus	California corbina	*Anisotremus davidsonii*	sargo
Paralichthys californicus	California halibut	*Oxyjulis californica*	senorita
Fundulus parvipinnis	California killifish	*Cymatogaster aggregata*	shiner surfperch
Symphurus atricauda[2]	California tonguefish	*Quietula y-cauda*	shadow goby
Tridentiger trigonocephalus	chameleon goby	*Rhinobatos productus*	shovelnose guitarfish
Ilypnus gilberti	cheekspot goby	*Anchoa delicatissima*	slough anchovy
Anchoa compressa	deepbody anchovy	*Citharichthys stigmaeus*	speckled sand dab
Pleuronichthys guttulata	diamond turbot	*Roncador stearnsii*	spotfin croaker
Micrometrus minimus	dwarf perch	*Gibbonsia elegans*	spotted kelpfish
Pleuronichthys vetulus[3]	English sole	*Paralabrax maculatofasciatus*	spotted sand bass
Xysteurys lioleps	fantail sole	*Pleuronichthys ritteri*	spotted turbot
Heterostichus rostratus[4]	giant kelpfish	*Mugil cephalus*	striped mullet
Mustelus californicus	grey smoothound	*Atherinops affinis*	topsmelt
Medialuna californiensis	halfmoon	*Hyperprosopon argenteum*	walleye surfperch
Heterodontus francisi	horn shark	*Genyonemus lineatus*	white croaker
Pleuronichthys verticalis	hornyhead turbot	*Atractoscion nobilis*	white sea bass
Atherinopsis californiensis	jacksmelt	*Phanerodon furcatus*	white surfperch
Rimicola muscarum	kelp clingfish	*Umbrina roncador*	yellowfin croaker
Syngnathus californiensis	kelp pipefish	*Acanthogobius flavimanus*	yellowfin goby
Triakis semifasciatus	leopard shark	*Hermosilla azurea*	zebra perch

1. In San Diego Bay, black surfperch appear seasonally, usually during the month of April, when the young-of-year recruit to the bay after the females give birth (Allen 1999; SWRO NMFS 1991).

2. California tonguefish reside on soft-bottom (Allen 1985; Allen 1999). Their eggs are located on the benthos of bays (MBC Applied Environmental Sciences 1994).

3. English sole can be found in the northern portion of San Diego Bay (Allen 1999). Adults reside in estuaries with mud and sand bottoms (NMFS 2004). Juvenile and adult English sole forage is estuaries on bottoms of sand, mud, and eelgrass (NMFS NW Region 2004).

4. Young-of-year giant kelpfish recruit to the bay during the months of July and October (Allen 1999).

5. Juvenile Pacific mackerel reside along open cast sandy beaches, in kelp beds, and in bays and estuaries (Allen 1985; Konno and Wolf 2001).

6. The Pacific sardine is a small pelagic species that moves into San Diego Bay between July and October (Allen 1985; Allen 1999; Wolf and Smith 2001). Young-of-year occupy the midwater of the nearshore and channel of San Diego Bay (Allen 1999).

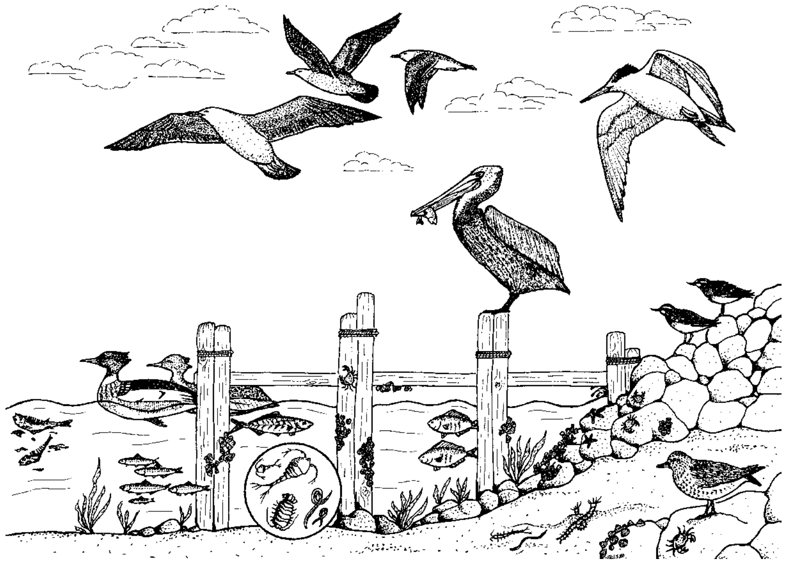
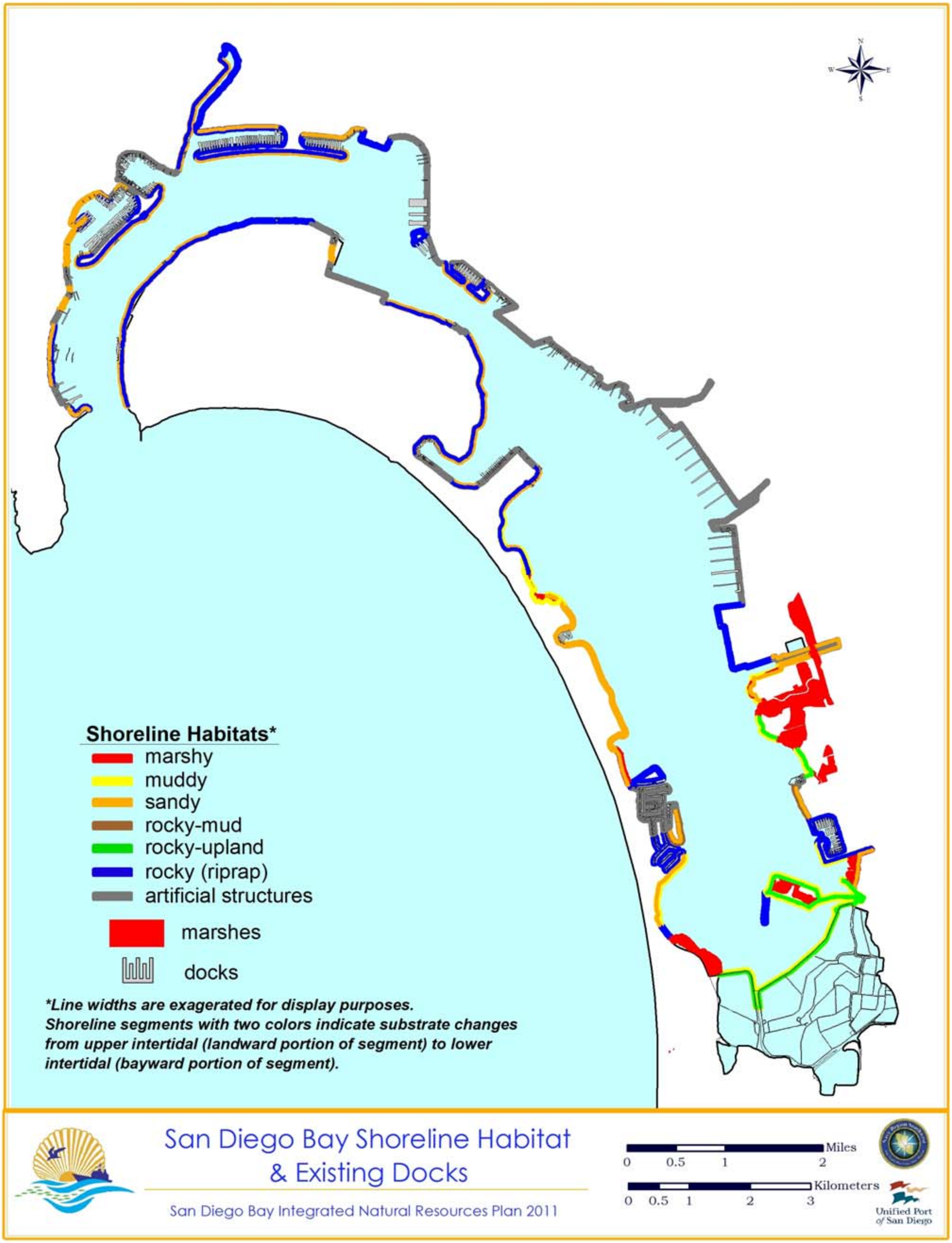


Figure 2-12. Artificial Shoreline environment.

Unprotected shoreline sites will erode when exposed to tidal fluctuation, storm waves, storm surges, and surface runoff. Hard structures are used to protect developed sites along the bay. Pier pilings, bulkheads, rock riprap, floating docks, sea walls, mooring systems, and derelict ships/ship parts form extensive artificial habitat in the northern and central portions of San Diego Bay and to a lesser extent in the southern bay. San Diego Bay presently has 45.4 miles (73.1 km) of armored shoreline out of 64.4 miles (103.6 km) of shoreline, or 74% affected (based on small boat survey in 1999 by Tierra Data). There are also 131 acres (53 ha) of surface structures shading bay waters, in both intertidal and subtidal habitats. These acreage figures are based on digitizing small and large surface structures directly on a 2003 orthocorrected aerial photo with one-foot resolution (Tierra Data 2006). See Map 2-14 to view the distribution of this habitat.

Riprap is the rocky rubble used to build jetties, breakwaters, and armored shorelines. Artificial structures such as riprap armoring likely represent one of the few marine habitats that is increasing in area. In addition, environmental changes caused by climate change, such as rising sea levels and increasing storm intensity, are expected to threaten coastal urban settlements (Dean *et al.* 1987; McCarthy *et al.* 2001). The proper design of riprap structures and other coastal modifications is a popular research area in civil engineering, and is of economic importance (Herbich 2000; Engineers 2002 cited in Pister 2007). There are little to no natural hard surfaces in San Diego Bay, and therefore, riprap and other artificial structures provide habitat that does not resemble any natural habitat in San Diego Bay (B. Pister, National Park Service, *pers. comm.* 2008). Certain artifacts of construction set riprap structures apart from natural shorelines. Among them is a change in scale of physical complexity. While appearing uniform from a distance, at small scales (meters) riprap is extremely heterogeneous. See Photo 2-9 for an example of a riprap slope.

Roughly 30% of the southern California shoreline (Pister 2007) is riprap, and it is a common shoreline element in San Diego Bay. A local example is the Zuniga Jetty, at the mouth of San Diego Bay. This jetty was constructed in 1890, and is roughly 7,500 feet long (Turhollow 1975). Pondella (2006) surveyed this jetty for use by fishes on 22 occasions over a five-year period between 1997-2002. The jetty was found to harbor high densities of fishes including senoritas (*Oxyjulus californica*) and garibaldi (*Hypsypops rubicundus*) not typical of the bay. The jetty also supports high densities of blacksmiths (*Chromis punctipinnis*), black perches (*Embiotoca jacksoni*), opaleye (*Girella nigricans*), kelp bass, and barred sand bass. The jetty is also a popular place for recreational lobster fishing.



Map 2-14. Shoreline habitats and existing structures of San Diego Bay as mapped in 1998.

Photo 2-9. Riprap slope in San Diego Bay. Photo courtesy of Rob Wolf.

Another artificial substrate is the subtidal artificial fish enhancement structures that have been placed as part of mitigation or enhancement projects at:

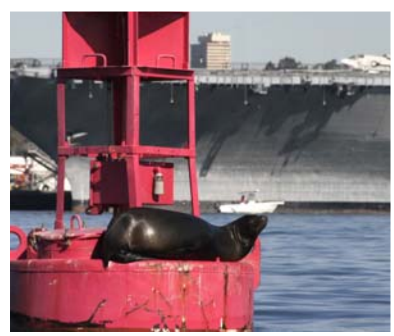
- South Embarcadero Fishing Pier
- Coronado Marriott near shore
- Borrow Pit, South Bay
- Shelter Island (design is concrete mooring block anchors with molded holes for fish/lobster refuge).
- Navy North Island enhancement site
- Navy Homeport Island enhancement site

Use of the Habitat

All of the man-made structures support a wealth of invertebrates and seaweeds, including some of the non-native species that have invaded the bay.

See Table 2-11 for fishes that utilize artificial hard-bottom in the rocky intertidal (Robbins 2006).

Man-made structures support invertebrates and seaweeds, including exotic species that have invaded the bay. Buoys and other floating structures are used by waterbirds and sea lions.



Sea lion in San Diego Bay

Table 2-11. Fishes that utilize artificial hard-bottom habitat in the rocky intertidal summarized by Robbins (2006).

Species	Common Name	Species	Common Name
Myliobatis californica	bat ray	*Girella nigricans*	opaleye
Embiotoca jacksoni[1]	black surfperch	*Paraclinus integripinnis*	reef finspot
Sphyraena argenta	California barracuda	*Hypsoblennius gilberti*	rockpool blenny
Scorpaena guttata[2]	California scorpionfish	*Cymatogaster aggregata*	shiner surfperch
Micrometrus minimus	dwarf perch	*Gibbonsia elegans*	spotted kelpfish
Heterostichus rostratus[3]	giant kelpfish	*Gibbonsia metzi*	striped kelpfish
Sebastes rastrelliger[4]	grass rockfish	*Atherinops affinis*	topsmelt
Atherinopsis californiensis	jacksmelt	*Hyperprosopon argenteum*	walleye surfperch
Brachyistius frenatus	kelp perch	*Phanerodon furcatus*	white surfperch
Triakis semifasciatus	leopard shark		

1. In San Diego Bay, black surfperch appear seasonally, usually during the month of April, when the young-of-year recruit to the bay after the females give birth (Allen 1999; SWRO NMFS 1992).
2. Adult California scorpionfish forage in the rocky intertidal and are in tidepools (Love 2001; NMFS NW Region 2004).
3. Giant kelp fish inhabit soft-bottom, rocky intertidal, shallow rocky reef and kelp (Allen 1985). Young-of-year recruit to the bay during the months of July and October (Allen 1999).
4. Grass rockfish occupy the rocky intertidal (Love 2002). Juveniles recruit to low growing algae and hard-bottom, and reside in tidepools (Love et al. 1991; McCain 2003).

Riprap

Riprap structures are known to attract and support a variety of fish and have been reported as good lobster diving and sport fishing sites (Chapman 1963; Davis *et al.* 1982; Kovach 1996). Native and non-native lobster, crabs, worms, mussels, barnacles, echinoderms (starfish, sea urchins), sponges, sea anemones, and tunicates (sea squirts) are all known to inhabit artificial structures. Some of the algae found attached to riprap are: *Corallina pinnatifolia, Gelidium coulteri, Gelidium robustum, Laurencia pacifica, Sargassum muticum, Polisiphonia* sp., and *Ulva* sp. Riprap also provides refuge and feeding areas for certain juvenile and predator fishes, such as perches, basses, dogfish, opaleye, and croaker. Artificial habitats were not part of the fish sampling design conducted by Allen (1997). A hardened shoreline typically produces a very steep shore profile that can provide elevated roosting sites for bay waterbirds to conserve energy and avoid harsh weather conditions (Ogden 1995).

Davis *et al.* (2002) looked at factors in San Diego Bay and nearby open coast sites affecting spatial and temporal variation of intertidal, hard-substrate biota (emergent species and fishes), with emphasis on the influence of exposure, distance from the open ocean, and similarity to open-coast, hard-substrate communities. They examined community composition at eight bay riprap sites (an exposed and a protected site at four bay locations) in June and November 2000 and two open-coast sites in August 2000. Community structure was more variable spatially than temporally on the scales studied, affected more by distance from the bay mouth and exposure to wave energy than by differences between June and November. Exposed sites near the bay mouth were more similar to natural open-coast sites, sharing about 45% of their species, than protected sites and sites farther from the mouth, which shared as few as 8%. Species richness was generally higher in exposed than protected bay sites. Species tended to occur higher in the intertidal zone at exposed than protected sites, and higher in November, when sea level was higher, than in June. Table 2-12 and Table 2-13 show the species found, listed in approximate order of occurrence from the mouth of the bay at Shelter Island to the back bay at Chula Vista.

The fishes associated with riprap also followed a similar trend from the mouth of the bay to the southern end at Chula Vista (Davis *et al.* 2002).

Wave exposure is known to be of profound influence in structuring rocky intertidal communities (Ricketts *et al.* 1985; Denny and Wethey 2001; Denny *et al.* 2004, as summarized in Pister 2007). Davis *et al.* (2002) compared intertidal and fish communities inhabiting pairs of sites on exposed and sheltered sides of riprap structures in San Diego Bay. Their sites ranged over a wave exposure gradient from the mouth to the south end of San Diego Bay. They found that as wave exposure decreased, and the disparity in wave exposure between the paired sites diminished, the communities became more similar. In addition, exposed communities at the south end of the bay, where wave exposure was low, differed greatly from those at the mouth where wave exposure was higher. Furthermore, they sampled natural rock outside the bay in more exposed conditions and found they were most similar to the most exposed sites inside the bay (i.e. at the mouth). In general, richness and cover of organisms was greater in more exposed conditions (Davis *et al.* 2002, as summarized in Pister 2007).

Organisms may experience greater wave energy on riprap sites than on nearby natural sites under similar conditions. This can lead to a difference in distribution of species, especially mobile ones between the more exposed and calmer sides of breakwaters. Several artifacts of construction enhance the forces generated by waves as they collide with breakwaters (Bucharth and Hughes 2006). For example, riprap structures are generally very steep, commonly with slopes of 30 degrees or more (Bottin 1988). This means a wave will impart much more energy onto a smaller area than it would on a shallower sloping shore. Pister (2007) found that most variation was found to exist between sites regardless of whether they were riprap or natural. On average, riprap and natural rocky habitats in wave-exposed environments in southern California did not differ from each other in diversity or community composition. The presence of invasive species was negligible on both substrates. These results are somewhat in contrast to studies from other regions which often find significant differences in diversity and community structure (Davis *et al.* 2002, as summarized by Pister 2007).

Table 2-12. Species reported by Davis et al. (2002) of emergent intertidal fauna at two open coast sites (August 2000) and eight San Diego Bay riprap sites (June and November 2000, locations at Shelter Island, Harbor Island, Embarcadero Park, and Chula Vista). Taxa are listed in approximate order of occurrence in the system, from open coast to the back of the bay. Following each scientific name is an identifying common name or code (B bivalve; BR bryozoan; C barnacle; G non-limpet gastropod; L limpet; S sponge; T tunicate).

Species/Common Name or Code
Fissurella volcano (G)
Collisella digitalis (L)
Littorina planaxis (G)
Serpulorbis squamiqerus (G)
Littorina scutulata (G)
Chthamalus fissus (C)
Collisella scabra (L)
Tetraclita rubescens (C)
Nuttilina fluxa (chiton)
Lottia gigantica (L)
Pachygrapsus crassipes (crab)
Collisella strigatella (L)
Anthopleura spp. (anemone)
Bulla gouldiana (G)
Collisella limatula (L)
Balanus glandula (C)
Ostrea lurida (B)
Mytilus spp. (B)
Pseudochama exogyra (B)
Styela spp. (T)
Aplysina fistularis (S)
Sponges-other
Crepidula onyx (G)
Serpulid worms
Watersipora spp. (BR)
Bryozoans-other
Leucetta spp. (S)
Botrylloides spp. (T)
Musculista senhousia (B)
Botryllus spp. (T)
Crucibulum spinosum (G)
Balanus amphitrite (C)
Ophiuroids (brittle stars)
Anemones-other

Table 2-13. High-tide fish abundance reported by Davis et al. (2002) in July 2000 at eight intertidal riprap sites at four locations in San Diego Bay (Shelter Island; Harbor Island; Embarcadero Park; Chula Vista), listed in order of increasing distance from the bay mouth). Fish species are listed in approximate order of those that occur near the mouth to those that occur in the back of the bay.

Species	Common Name
Hypsypops rubicundus	Garibaldi
Seriphus politus	queenfish
Clinocottus analis	woolly sculpin
Paralabrax clathratus	kelp bass
Cymatogaster aggregata	shiner surfperch
Hypsoblennius gilberti	rockpool blenny
Hypsoblennius gentilis	bay blenny
Scorpaena guttata	spotted scorpionfish
Hypsoblennius jenkinsi	mussel blenny
Gobiesox rhessodon	California clingfish
Gibbonsia elegans	spotted kelpfish
Girella nigricans	opaleye
Embiotosa jacksoni	black surfperch
Paralabrax nebulifer	barred sandbass
Heterostichus rostratus	giant kelpfish
Oxyjulis californica	senorita
Atherinops affinis	topsmelt
Atherinopsis affinis	jacksmelt
Urolophus halleri	round stingray
Micrometrus minimus	dwarf surfperch
Paralabrax maculatofasciatus	spotted sand bass
Phanerodon furcatus	white surfperch
Clevelandia ios	arrow goby
Fundulus parvipinnis	California killifish
Umbrina roncador	yellow croaker
Mugil cephalus	striped mullet

Function

Habitat value of the armored shoreline is expected to vary according to material, construction, relief, and maintenance activities. The surface roughness and complexity of a structure can affect its ability to provide refuge niches and allow retention of water at low tides. A structure's elevation in relation to the tidal prism can also be important, with higher structures affecting less intertidal habitat. Many examples exist around the bay of structures with clear differences in habitat value. For example, Shelter Island has better low tide habitat than Harbor Island where the structures and slope are too steep (R. Ford, SDSU, pers. comm.). Some riprap niches have been filled in with concrete, while others are filled with invertebrate fauna. Sea walls provide the poorest habitat for marine species, as their relatively smooth surfaces and vertical angles reduce suitable areas for attachment.

One aspect of riprap that seems to have never been investigated ecologically is the interstitial space (Pister 2007). When large boulders are piled on top of each other there is naturally a great volume of space in between. In fact, engineers have found this "pore" space to have a strong influence on the stability of the structure and its ability to absorb wave energy (Bucharth and Hughes 2006). It seems probable that pore space has a strong biological influence as well, since all of the space on boulders inside the riprap structures is potential habitat (Pister 2007). Most riprap structures are permeable to some extent and well colonized.

Limited research exists on what potential positive habitat structures like these would provide. A few innovative examples exist, such as experiments with docks (Russell *et al.* 1983; Hawkins *et al.* 1992) and littoral flat terraces that have been implanted in riprap-stabilized shorelines at the Port of Seattle (Simensted and Thom 1992).

Some studies suggest that anthropogenic structures favor invasive species over native ones (Wasson *et al*. 2005; Glasby *et al.* 2006; Tyrrell and Byers 2007), but this has not been studied directly for San Diego Bay. Bay riprap hosts a myriad of species, including native and exotic.

Fish Enhancement Structures Associated with North Bay Eelgrass Mitigation

Pondella (2006) assessed the success of a set of fish enhancement structures placed at a North Island mitigation site in 1997 for a five-year period surveyed regularly from September 1997 to September 2002. In addition to the establishment of a new eelgrass bed, four enhancement reefs made of either quarry rock or concrete rubble were created. Pondella (2006) also compared concrete materials and quarry rock reefs. Quarry rock has been the artificial reef building material of choice in California due to its environmental acceptability (Lewis and McKee 1989; Deysher *et al.* 2002). The CDFG in California has guidelines for the use of concrete materials in the marine environment due to environmental concerns. This was the first experiment in California that tests these two substrates against each other in a paired design.

Using the density of adult fishes Pondella *et al.* (2006) was able to describe the relationship between four reef, three bare sand, one eelgrass planting, one established eelgrass site, and Zuniga Jetty. These sites were also compared based on relief. Pondella *et al.* visited the study site 44 times during the five-year period and conducted 1056 transects. Fifty-nine species of fishes from 27 families were observed during the study period. The enhancement reefs (reefs 1–4 in Figure 2-13) were comprised of a typical southern Californian rocky-reef fauna. The most commonly encountered fishes were blacksmith, kelp bass, barred sand bass, opaleye, and black perch. The main difference in ranks of abundance between these reefs and Zuniga Jetty was for senoritas and garibaldi. These two species were more abundant at Zuniga Jetty, most likely due to the differences in reef relief and maturity. Species richness for the eelgrass enhancement and reference was 32 and 28, respectively, and was similar to what was observed on the reefs (24–29 for reefs 1–4 and 30 at Zuniga Jetty).

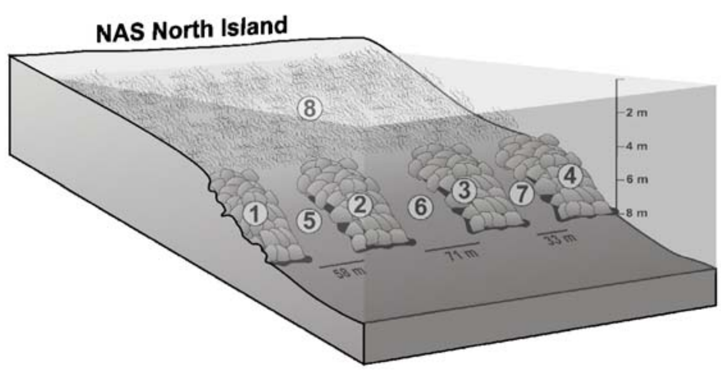


Figure 2-13. Schematic of transect locations used in a five-year study to evaluate four enhancement reefs (1–4), sand transects (5–7), and the eelgrass transplant area (8) in relation to Naval Air Station North Island. The reefs are on the slope of the channel. Diagram taken from Pondella et al. (2006).

With respect to site relief, eelgrass obviously offers greater vertical relief than sand, and the amount of vertical relief separated five rocky reefs with the exception of reef 4, which was situated close to reef 3. Reef 3 had the highest vertical relief of the four reefs and supported the highest density of adult fishes. No difference was found between rock versus concrete construction, nor between a horseshoe vs non-horseshoe design. Other than an unexpected effect of high relief, the reefs were indistinguishable.

Overall reef performance with respect to fishery production of three target species studied was also documented at various levels. Three fishery species were examined. First, spotted sand bass appeared to use the structures seasonally when alternative habitat sites are less available to them (i.e. in the winter) in San Diego Bay (Allen *et al.* 2002). Allen *et al.* (2002) found that the lowest abundances of fishes including spotted sand bass were in January (they sampled quarterly for five years). In addition, the absence of spotted bass from the artificial reef area during the spring and summer period is concomitant with their reproductive period. They have been reported to spawn from June through August (Allen *et al.* 1995). This analysis supports their hypothesis that spotted sand bass moves towards the mouth of the bay during the winter, which is consistent with the observed decreased density in the upper portions of the bay. These reefs appeared to be acting as a winter foraging area for spotted sand bass. In contrast, all age classes of kelp bass, *P. clathratus,* were abundant on these reefs at all times of the year during this study, indicating that these reefs were able to attract both adults and recruits. The seasonal use by young-of-year barred sand bass suggests that this species is developing on these reefs throughout their life history. It appears that these enhancement reefs were able to attract and produce barred sand bass throughout the study period.

Artificial Structures as Essential Fish Habitat

In a draft study to describe EFH (Merkel & Associates 2008), a number of artificial structures were examined qualitatively for relative abundance and diversity of fish communities by swimming 6-meter belt transects along each structure's length. Algae, benthic invertebrates, and encrusting organisms were also recorded. For natural habitats, paired sites of bare mud, bare sand, and eelgrass were visited. The categories of artificial habitats examined were:

- Launch ramp (Shelter Island, National City Wharf)
- Riprap (Embarcadero Marina Park)
- Bulkhead wall (10th Avenue Marine Terminal)
- Floating dock/pile system (Harbor Island, Coronado Cays)
- Wharf and pile (Navy Ammunition Pier/Pier Bravo and Navy Pier 13)
- Marina (Chula Vista Marina)
- Fish enhancement structure (North Island, borrow pit)

The study found that, for both fish and invertebrates, artificial reefs ranked as the habitat with the highest number of species observed. Sand and eelgrass habitats also ranked high in number of fish species. Total abundance and weight of infauna were also examined by habitat type as an average of the northern and southern locations. Infauna were most abundant at riprap sites, followed by artificial reefs and launch ramps. The highest biomass was observed at launch ramps, although this may be biased due to one sample with an unusually large amount of gastropod molluscs. Following launch ramps, eelgrass beds were high in infaunal biomass and were far higher than all other habitat types.

Comparing north and south bay regions, results of this study (Merkel & Associates 2008) showed that the diversity of fish species observed by divers was greatest around structures in the south bay. These structures are not native substrate, and may be attracting or allowing a more open coastal species guild to inhabit the south bay. It may also be that some fish species inhabiting native south bay environments, such as offshore and nearshore mud bottom and marshes are small and cryptic and not observed with survey methods used during the study. Although these species are not of direct importance to fishery management mandates or the recreational fishery, their value to the broader ecosystem should be considered. The number of fish species in the north bay was also greatest at the artificial reefs. Following artificial reefs were the natural sand and eelgrass habitats. Few fish were observed in marinas and on bare mud in both the north and south. These trends in the number of species may also be mirrored by fish abundance at these habitats, and a more focused and quantitative study of abundance between habitats of interest would be valuable.

Marinas

Merkel & Associates (2008) summarized their transect work for San Diego Bay marinas. Marinas are complex habitats typically consisting of bare bottom, riprap, pile, and floating dock substrates. They differ from pier and wharf habitats in that they have lower concentrations of piles, more light availability, and are generally located in more protected side basins of the bay. They also are areas of a high concentration of boats, which may have impacts on water quality.

The fouling or encrusting community of invertebrates and algae dominate this habitat, occurring on floating docks, piles, and boat hulls. Fish assemblages associated with marinas are not well studied partly because the use of seines and trawls is impractical. The fouling community attracts schooling fish, which feed on the attached invertebrates and algae. Fish common to marinas include silversides, perches, basses, opaleye, and croaker. The abundance of relatively well-lit floating docks is distinctive to marina habitats. Floating docks are not subject to tidal influence (are never exposed) and remain on the sea surface. This provides the dock substrate with constant light available for photosynthesis, and a distinct positioning relative to the currents. Surface versus other layers of the water column are subject to different currents, which may determine the species composition of larval settlers and levels of food resources. Connell (2001) performed a study comparing the epibiotic assemblages of floating structures, pilings, and natural reefs, and found that the abundance of most taxa was greatest on floating structures relative to pilings and reefs. In particular, mussels, tunicates, barnacles, bryozoans, and green algae were most abundant on floating structures. This may make marina habitats particularly good foraging resources for some fish species. Production from floating docks can be attributed directly from the biota attached to the dock, and also the material that falls from the dock, increasing production on the substrate below (Merkel & Associates 2008).

The fouling community on marina substrates has been studied in San Diego Bay relative to boat concentration in the marinas (Lenihan *et al.* 1990). High concentrations of boats are associated with concentrations of several pollutants including oil and gas, organochlorides, and metals. Mussels, sponges, and bryozoans (total and encrusting) had significantly greater cover in marinas with few boats, while only tunicates and branching bryozoans showed no patterns between marinas with few or many boats. This pattern was observed on all available substrates. Overall fewer species, less biomass, and lower cover of sessile groups was observed in marinas with many boats. Crustaceans and invertebrates, termed “nestling fauna” showed no significant pattern with the number of boats. Although not directly tested, the observed patterns were hypothesized to result from concentrations of tributylin, a toxic additive to paint. Bioaccumulation of toxic chemicals in invertebrates and fish in the bay is a concern. McCain *et al.* (1992) found high concentrations of PCBs in the liver of white croaker *(Genyonemus saturnum)* in San Diego Bay and signs of fin erosion were observed in barred sand bass (Merkel & Associates 2008).

Reefs

Reef assemblages on artificial habitat in San Diego Bay include a variety of encrusting organisms, algae, and fish. Information relevant to artificial reef invertebrates can be derived from one study of shoreline riprap (Davis *et al.* 2002) and one study of piling structures in the bay (Ford *et al.* 1975). Fish species associated with bay reefs include sand basses *(Paralabrax* spp.*),* surfperches (*Embiotocidae*), blacksmith, opaleye, sargo *(Anisotremus davidsonii),* and others. These reefs also provide cover for large invertebrates such as lobster *(Panulirus interruptus)* and octopus *(Octopus bimaculoides)* (Merkel & Associates 2008).

Davis *et al.* (2002) reported on species assemblages of artificial hard substrates in San Diego Bay. This study found that bare space increased and species richness decreased with increasing distance from the mouth. Although not demonstrated in a focused study, it can be anticipated that fish enhancement reefs in the southern portions of the bay are subject to higher rates of silt deposition and the encrusting community of filter and suspension feeders are negatively impacted (Merkel & Associates 2008). Therefore, south bay hard substrates may be less diverse at least in terms of open-coast fishes than those in north bay.

Artificial Structures as Shading (Wharves and Docks)

When comparing the composition of fishes in a Navy-commissioned study of large wharves (Merkel & Associates 1999), the effect of shading intertidal, shallow, and moderately deep water by a wharf was examined. The placement of wharves, docks, and piers has been historically viewed as relatively neutral with respect to impacts to fish and benthic communities. Such structures add three-dimensional substrate and cover that locally increases productivity of encrusting benthic organisms and also serves to locally increase richness and abundance of fish over the conditions observed in more open waters. However, there has been concern about diminishing returns with respect to larger structures and that negative impacts could outweigh these recognized benefits. To explore the conditions beneath a large wharf, surveys were conducted in the winter and summer of 1999 at Pier 13 at Naval Station and CVN Pier 700 at Naval Air Station North Island (NASNI). The distribution of species across a light gradient showed no pattern indicative of a light exposure effect. While some species were found that were expected to be restricted to the face of piers (such as giant kelpfish associated with algal growth on piles), there was also a propensity for some species to be better represented in the darker regions (such as black croaker). All in all, the surveys revealed a relatively sparse fish community along the transects, with abundance estimates heavily influenced by the presence of two small schools of topsmelt numbering over 400 individuals at the CVN wharf and about 100 individuals at Pier 13. If these schools are not considered or they are weighted as individuals, the fish abundance is more evenly distributed across the light exposure gradient. The overall density and biomass of benthic infauna was marginally higher in the shade region; however high variability among the samples collected precluded statistical analysis. Overall, it appeared that seasonal differences in fish communities were greater than differences associated with a light gradient.

While wharfs reduce the exposed surface area for foraging for fish-eating birds, such as the California least tern and brown pelican, there is no published evidence that foraging area is limiting productivity of these species. The foraging activity and foraging success of the California least tern in response to the presence or absence of piers was monitored in San Diego Bay at three stations in 2002 (a poor nesting year for terns). The stations were at the Point Loma Fuel Pier, NASNI wharf 700A, and Naval Station Pier 14. The results showed a greater difference among the stations for tern foraging activity than between open water and pier zones except at Pier 14. Pier 14 is in close proximity to two nesting sites, so more foraging activity is expected there. Still, no clear pattern of foraging activity between open water and pier habitats could be demonstrated. The location of foraging activity by terns is known to change over the course of a season, with peak activity following chick hatching. More open-water foraging (further from nest colonies) occurs during the courting and incubation period, while foraging closer to the nest and shore occurs after chicks hatch. Baird (1997) found that California least terns preferentially forage within different habitat types (mooring, channel, dock, shore) within San Diego Bay depending on the stage of breeding. Differences among the piers probably contributed to foraging behavior, including pier age, type, size, and associated boat traffic.

Artificial Structures Used for Roosting

Floating structures in shallow water, which are relatively undisturbed by human activity, are used for roosting and foraging by waterbirds such as brown pelicans, cormorants, and gulls (Ogden 1995). Buoys in the bay's deep water have long been used as haul out sites for sea lions.

2.5.5 Salt Ponds

Habitat Description

Marsh lands around the mouth of the Otay River in the shallow, south end of San Diego Bay were converted to salt evaporation ponds in the late 1800s. In 1871 the La Punta Salt Works, a small-scale solar salt evaporation facility, was constructed. Between 1911 and 1916, the area of solar salt production was expanded to include the entire end of the South bay. In 1916, a major flooding of the Otay River washed out the levees. Between 1920 and 1933, newly diked ponds were constructed, creating over 899 acres (364 ha) of new habitat. In 1933, the land now occupied by Ponds 11, 12, 14, and 15 was acquired for incorporation into the salt works. By 1942, Ponds 12, 14, and 15 had been constructed, followed later by the construction of Pond 11 (U.S. Coast and Geodetic Survey Chart 1942).

The salt ponds consist of shallow, open water cells of different salinity levels interspersed with mudflats, dry dikes, and salt marsh. The salt pond levees consist primarily of unvegetated uplands. The lack of vegetation on many of the levee tops is the result of ongoing maintenance activities associated with the salt operation, as well as the high salinities that exist in the vicinity of the levees (USFWS 2006). The nature of the salt extraction process has facilitated use of this artificial habitat by many shorebirds, sea birds, and waterfowl. It represents one of the few large feeding, roosting, and nesting areas remaining along the urbanized southern California coast.

The salt ponds consist of shallow, open water cells of different salinity levels interspersed with mudflats, dry dikes, and salt marsh, while the salt pond levees consist of unvegetated uplands. This area is frequently used by birds as a feeding, roosting and nesting ground.

Covering approximately 1,451 acres (587 ha), the salt ponds produce sodium chloride and magnesium chloride for industrial use. Primary ponds are approximately 3 feet (1 m) deep at their center, and are the least salty, representing the first stage of the extraction process. Secondary ponds are up to 5 feet (2 m) deep. These ponds are slightly more saline than sea water and are used for commercial brine shrimp production. Pickling ponds have the second-highest salinities. The final step in the extraction process occurs in crystallizer ponds, which support the highest salinity levels. The evaporation process takes 12 to 18 months, depending on rainfall, with each crystallization pond harvested once per year. Brine shrimp thrive in the secondary system; shrimp eggs hatch beginning in mid-May and mature shrimp are collected through mid-December. These are harvested commercially. Most birds use the southern side of these secondary ponds.

While observations of the upper primary and secondary salt ponds indicate the presence of brine shrimp, brine flies, and water boatmen beetles *(Trichocorixa reticulata),* a comprehensive survey to determine the diversity and abundance of these organisms within this system has not been conducted. Some sampling of species composition in the salt pond water column and pond sediments was conducted by Terp (1998) as part of her study of the role of salt evaporation ponds in South San Diego Bay in the habitat use patterns of wintering shorebirds. Sediment samples had virtually no specimens and where specimens were found, they were only present in samples taken from Pond 30. There, only four contained specimens, consisting of from two to 36 individuals of Ephydra larvae and pupae. Topsmelt larvae were present in the primary ponds at low densities.

The habitat restoration proposals within the CCP focus on supporting listed species such as the California least tern, western snowy plover, and light-footed clapper rail. The USFWS is proposing to restore portions of the salt ponds to the historic habitats of intertidal mudflat and coastal salt marsh, while retaining other ponds as managed water areas to support species that favor the brine invertebrates present in the current system. The plan would result in the restoration of up to 140 acres of intertidal salt marsh, freshwater wetland, and coastal sage scrub habitat within the Otay River floodplain. In addition, up to 410 acres of salt ponds would be restored to intertidal salt marsh habitat. The trade-off for these gains is a decreased potential habitat for shorebirds by reducing area of salt ponds by 145-440 acres. Nesting habitat for seabirds would be expanded by about 28 acres. The increase in tidal wetlands is up to about 800 acres.

Use of Salt Ponds

The dikes and ponds provide an escape area from rising tides, as well as feeding and resting areas for shorebirds and waterfowl. Different bird species preferentially select different areas of levees by the amount or proximity of vegetation or bare ground, or some other unknown factor about the substrate (USFWS 1998). Dikes are quite variable, but are often comprised of compacted or soft powdery silt, with typically sparse vegetative cover. Gulls, terns, black skimmers, and pelicans, including the California brown pelican, use the dikes for evening roosts. Dikes separating the ponds support significant nesting colonies of western snowy plover, Belding's savannah sparrow, black-necked stilt (*Himantopus mexicanus mexicanus*), black skimmer, and Caspian, Forster's, gull-billed, royal, and California least terns (*Sterna* sp.). One of only two nesting colonies of elegant terns (*Sterna elegans*) in the United States can be found at the salt ponds.

The San Diego Bay NWR CCP (USFWS 2006) summarized use of the Salt Works by sensitive birds. The levees provide relatively secluded nesting habitat for thousands of breeding terns and black skimmers, as well as black-necked stilts, American avocets, and western snowy plovers. Western snowy plovers were first documented nesting on the levees of the salt ponds in 1978, when 16 pairs were observed. The population of snowy plovers in South San Diego Bay has declined substantially since then. In 1993, an estimated seven breeding pairs were present at the salt works. Only one nest was located in 1994, five in 1997, and three in 1998 (Terp and Pavelka 1999). In 2005, four nests were identified at the salt works and it was estimated that three fledglings were produced (Patton 2006).

American avocets and blacked-necked stilts (Photo 2-10) also nest on the salt pond levees. In fact, the only recent nesting of these two species in San Diego Bay has been within the salt works (Patton 2004a). Nests tend to be abundant and distributed throughout the levees. In May 2002, at least 30 avocet nests and 24 stilt nests were recorded. Some of the other species observed nesting within the salt works in 2004 were killdeer *(Charadrius vociferous vociferous),* horned lark, gadwall, and mallard *(Anas platyrynchos).* Belding's savannah sparrows nest in the pickleweed salt marsh vegetation that occurs along the outer levees of the salt ponds, within the lower reach of the Otay River, and along the edges of the South Bay in remnant patches of salt marsh vegetation. The light-footed clapper rail has also been detected nesting within the Otay River channel, upstream of the ponds.

Photo 2-10. Black-necked stilt. Photo courtesy of Eileen Maher.

Double-crested cormorants *(Phalacrocorax auritus)* annually nest within the salt works on a dredging barge anchored in the salt ponds and in a few locations along the salt pond levees. This nesting activity has been noted since the late 1980s. Nesting begins in April and continues through late July. During the 1998 colonial seabird nesting study, 34 cormorant nests were observed on the barge, with over 70 adults and about 42 young were present at the time of observation (Terp and Pavelka 1999). A total of 77 cormorant nests were observed at the salt works during the 2005 nesting season (Patton 2006).

The salt works is one of three primary locations in California where black skimmers nest (USFWS 1993). In 1993, 62 California least tern nests were initiated along the salt pond dikes (USFWS 1993). Also in 1993, tern breeding pairs were recorded as 312 elegant terns, ten royal terns (*Sterna maximus*), 280 Caspian terns, and ten gull-billed terns. In 1994 these numbers were 80 elegant, no royal, 320 Caspian, and nine gull-billed terns. In 2007, 50-73 California least tern breeding pairs established 97nests (Marschalek 2008).

2.5.6 Upland Transitions

Terrestrial habitats along bay margins include riparian patches, fallowed agricultural lands, sandy beaches, foredunes, backdunes, coastal scrub, and eucalyptus groves. Historically, a natural ecotone existed between the upper edge of tidal habitats and upland vegetation. This area has been almost completely replaced by urban development. Where it is present, it is disturbed and nonnative plant species are present. The tidal influence in this transition zone is limited to salt spray. Map 2-13 depicts some of the upland transition and salt marsh habitats around the bay. Several wildlife and plant species of the upland transition areas are sensitive (See Section 2.7: Special Status Species and the MSCP for San Diego County which is directed towards protection of these species).

Uplands that border the bay are important as a buffer between the natural and constructed environment, and for the large number and diversity of avian species that use them as essential habitat for nesting, roosting, and refuge from high tides and adverse weather. Uplands may also be important for species that use a tidal habitat but do not live in it. For example, the bee pollinators of salt marsh bird's beak nest in upland areas. The western snowy plover prefers certain plants on southern foredunes or disturbed dunes outside its usual habitat affinity for sandy beaches. Yet, upland transition habitats are among the most threatened by development and management trends.

The portion of Gunpowder Point located to the west of the Nature Center supports disturbed coastal sage scrub, consisting primarily of broom baccharis (Baccharis sarothroides) and California sagebrush. A narrow band of disturbed coastal sage scrub, characterized by broom baccharis, coastal goldenbush, and flat top buckwheat, is also present along the western edge of Paradise Marsh. Numerous non-native grasses and annuals also occupy this area (City of National City 1998). Despite the extent of habitat disturbance that has occurred within the upland areas of the Sweetwater Marsh area, remnants of maritime succulent scrub and coastal sage scrub habitat persist. Two patches of maritime succulent scrub can be observed on Gunpowder Point, and along the southern edge of Sweetwater Marsh where it abuts the northern edge of the Mid-bayfront property. These areas are dominated by flat-top buckwheat, coast cholla (*Opuntia prolifera*), and California sagebrush. Coastal barrel cactus (*Ferocactus viridescens*) and snake cholla (*Opuntia parryi serpentina*) are also present. Another acre of disturbed maritime succulent shrub is located along a bluff at the northwestern end of Paradise Marsh. Ladies' fingers (*Dudleya edulis*), coast prickly pear, and coast cholla occur here (City of National City 1998).

Within the South San Diego Bay Unit of the Refuge, a band of disturbed maritime succulent scrub occurs in the vicinity of the railroad right-of-way between Ponds 22 and 20A. The habitat in this area is dominated by goldenbush and cholla. A variety of weedy species also are present including California everlasting (*Gnaphalium californicm*), stinging nettle (*Urticaholos ericea*), horehound (*Marrubium vulgare*), broom baccharis, and salt bush (*Atriplex lentiformis*) (Tierra Environmental Services 2001b).

Disturbed uplands at NBC NRRF are dominated by nonnative annual grass species such as foxtail chess (*Bromus madritensis rubens*), soft chess (*B. hordeaceus*), ripgut grass (*B. diandrus*), and slender wild oat (*Avena barbata*). Other common plants include the nonnative hottentot-fig, Australian saltbush (*Atriplex semibaccata*), white-stemmed filaree (*Erodium cicutarium*), and native coast locoweed (*Astragalus trichopodus lonchus*). Areas of increased soil salinity support alkali weed (*Cressa truxillensis*), saltgrass, and glasswort where this community intergrades into upper salt marsh vegetation.

2.5.6.1 Beaches and Dunes

The shoreline is a stressful environment, subject to wind and wave turbulence, salt spray, shifting sands, high temperatures, and desiccation. Before development overcame the southern California coastline, dunes acted as a buffer in the unstable zone between the tidal and upland environments. A number of plants and animals have become adapted to this instability and are found only on dunes or beaches (Figure 2-

14). However, many bay beaches are subject to heavy recreational use. Others are used intermittently for military training. For example, North and South Delta beaches are not used for training April through September due to the presence of nesting California least terns and the beach near the Fuel Supply Pier at Point Loma is never used. Because of use patterns and because most of the habitat in southern California has already been destroyed (Holland 1986), dependent species are particularly vulnerable to extinction on a local scale.

Habitat Description

Plants of the coastal strand habitats, such as along the beaches (Figure 2-14) and dunes of the bay's relatively undeveloped west shore, are typically well adapted to the sandy soils that occur there, with low water-holding capacity, low fertility, low humus content, and high concentrations of sea salts (Schoenherr 1992; Holland and Keil 1995). Many have deep taproots, enabling them to reach fresh water deeper in the soils. They are also commonly prostrate, and many are succulent. Plants typical of coastal strand communities include beach sagewort (*Artemisia pycnocephala*), dune buckwheat (*Eriogonum parviflorum*), beach ragweed (*Ambrosia chamissonis*), red sand verbena (*Abronia maritima*), and beach evening primrose (*Camissonia cheiranthifolia*) (Schoenherr 1992; Holland and Keil 1995). Over time, wind-blown sand will accumulate under and around coastal strand vegetation, gradually building up distinctive sand hummocks and dunes.

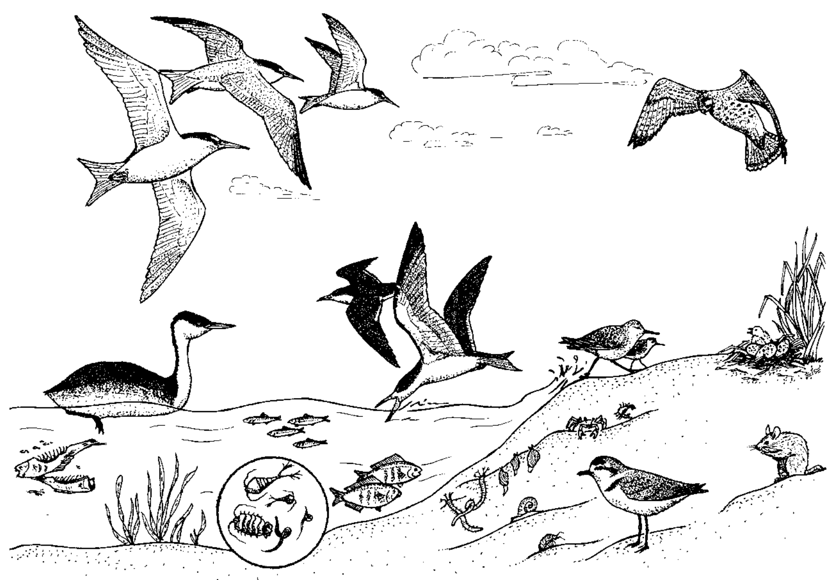


Figure 2-14. Beach environment.

Several plant species are better adapted to the foredune areas of the coast, which are subject to the greatest amount of salt stress. Primary foredune species are *Abronia maritima*, Watson salt bush (*Atriplex watsonii)*, *Atriplex leucophylla*, and *Cakile maritima*. Plant species diversity tends to increase with distance from the beach, with less salt tolerant species becoming more abundant, particularly species of *Artemisia*, *Baccharis*, *Ericameria*, *Eriogonum*, *Lotus*, *Lupinus*, and *Salvia* (Holland and Keil 1995).

Native plant cover is especially important to these habitats because it stabilizes the shifting substrate, which in turn protects the landward habitats from sea storms. Bayside portions of Silver Strand State Beach and dunes at NRRF contain examples of native dune plants such as beach evening primrose, sand verbena (*Abronia maritima* and *A. umbellata*), and beach-bur (*Ambrosia chamissonis*). Following human impacts, some native species declined, such as lemonade berry shrub (*Rhus integrifolia*), while several non-natives, such as hottentot-fig (*Carpobrotus edulis*), sea rocket (*Cakile maritima*), and Australian saltbush (*Atriplex semibaccata)* invaded.

The life stages of some invasive plants differ from those of native plants and this may also affect native insects. The sea rocket is eaten by dune beetles, but the plant does not live long enough to support insect growth to maturity (Snover 1992). Hottentot-fig, a kind of iceplant, is a very invasive species that is sometimes planted for erosion control and on freeways. It displaces native plants (Williams and Williams 1984), and the animals that depend upon them. It provides little food or habitat for native insects (C. Nagano, USFWS, *pers. comm.*, cited in Zedler 1992a; Snover 1992). Native dune beetles do not eat the hottentot-fig. In the field, dune beetles and other native insects are less abundant under invasive vegetation. Temperatures are cooler under the hottentot-fig than under the native vegetation, which may slow insect development (Snover 1992).

The hottentot-fig is a noxious weed. It invades dunes and displaces native plants, which in turn influences development of the endemic insect community.

Use of Beaches and Dunes

Hottentot-fig dominates much of Silver Strand State Beach, which consists of 86 acres (35 ha). Forty acres (16 ha) are leased from the NAB by California Department of Parks and Recreation (CDPR), and the balance is owned by CDPR. Only the leased portion is in this INRMP's Functional Planning Zone. The area supports the wandering skipper *(Panoquina errans)*, a federal Species of Concern. This butterfly is associated with southern California coastal dune ecosystems where its host plant, salt grass, is present (USFWS 1998). Nuttall's lotus (*Lotus nuttallianus*), a sensitive species (CNPS List 1B) is present in the dunes at NRRF. Other sensitive plant and animal species of limited distribution that inhabit dune and beach areas of the bay include coast woolly-heads (*Nemacaulis denudata denudata*, CNPS List 2), coast horned lizard, San Diego black-tailed jackrabbit (*Lepus californicus*), and coast horned lark (*Eremophila alpestris*). Dunes also provide habitat for the silvery legless lizard (*Anniella nigra argentea* [=*Anniella pulchra pulchra*]).

Surveys on NRRF in 2004 and 2005 (RECON 2005, 2006) detected common invertebrates such as various kelp flies (Families Coelopidae and Anthomyidae), dune silverfish (Family Lepismatidae), leaf beetles (Family Chrysomelidae), and snout beetles (Family Curculionidae). The spider fauna of the dunes was found to be diverse and includes at least one endemic species (RECON 2006). Funnel web weavers (Family Agelenidae), wolf spiders (Family Lycosidae), trapdoor spiders (Family Ctenizidae), and the endemic sand spiders of the genus Lutica (Family Zodariidae) were found. The nocturnal sand spiders are restricted to southern California coastal dunes and are adapted for burrowing in fine sand. Tarantula hawks (*Pepsis* sp.) can be seen flying around the dunes hunting for spiders. A few special status species have been recorded including the globose dune beetle (*Coelus globusus*), sandy beach tiger beetle *(Cicindella hirticollis gravida),* mudflat tiger beetle *(Cicindela trifasciata sigmoidea),* a third tiger beetle (*C. latesignata spp. latesignata),* and the wandering skipper. Invertebrates are the primary prey item for many types of wildlife and are important as pollinators for many plant species.

Dunes and adjacent beaches support invertebrate fauna, which are food for Belding's savanna sparrow, among other species.

The following fish species (Table 2-14) are found in sandy beach habitat (Robbins 2006).

Table 2-14. Fish found in sandy beach habitat as summarized by Robbins (2006).

Species	Common Name	Species	Common Name
Embiotoca jacksoni	black surfperch	*Triakis semifasciatus*[3]	leopard shark
Menticirrhus undulatus	California corbina	*Cymatogaster aggregata*	shiner surfperch
Leuresthes tenuis	California grunion	*Rhinobatos productus*	shovelnose guitarfish
Paralichthys californicus[1]	California halibut	*Atherinops affinis*	topsmelt
Ilypnus gilberti	cheekspot goby	*Hyperprosopon argenteum*	walleye surfperch
Micrometrus minimus	dwarf perch	*Phanerodon furcatus*	white surfperch
Pleuronichthys vetulus[2]	English sole		

1. California halibut use San Diego Bay and its eelgrass as a nursery area (Allen 1999; Hoffman 1986; Kramer and Sunada 2001; SWRO NMFS 1992). In April, young-of-year recruit to the intertidal portions of the bay (Allen 1999). California halibut move into the intertidal to feed during grunion runs (Martin 2003).
2. Juvenile and adult English sole forage in the intertidal over sand, mud and in eelgrass (NMFS 2004; Pearson and Owen 2001).
3. Leopard sharks move in and out with the tide to forage in the intertidal (Smith 2001). They reside in estuaries, bays, and kelp beds, over soft and hard bottoms, as well as along open coast sandy beaches (NMFS NW Region 2004; Smith 2001; Smith 2005).

Beaches serve as important habitat for nesting, roosting, and foraging bird species, including the endangered California least tern and threatened snowy plover. The plover also uses coastal dunes for roosting outside of nesting season. Belding's savannah sparrow feeds on dune and beach insects.

The following Table 2-15 depicts avian use of sandy beach habitats in 2006-2007 (TDI 2008 in draft). These results are from the shoreline survey only and include falling and peaking tide data.

Table 2-15. Number of observations of birds in cells adjacent to bay sandy shoreline 2006-2007 (Tierra Data Inc. 2008 in draft).*

Species	Number
surf scoter	1829
western sandpiper	1413
scaup sp.	1259
marbled godwit	1123
western gull	798
brown pelican	730
Brandt's cormorant	714
sanderling	564
western grebe	517
bufflehead	466
double-crested cormorant	460
Heermann's gull	410
willet	409
eared grebe	319
black-bellied plover	263
dowitcher sp.	252
house finch	201
ring-billed gull	177
elegant tern	172
horned lark	157
royal tern	146
great blue heron	110
semipalmated plover	108
brant	102
great egret	101
European starling	100
house sparrow	86
killdeer	86
least tern	82
rock pigeon	81
Forster's tern	77
lesser scaup	76
dunlin	69
snowy egret	63
mourning dove	57
ruddy turnstone	43
cormorant sp.	40
red knot	39
mallard	33
Audubon's warbler (yellow-rumped)	32
horned grebe	31
California gull	26
Savannah sparrow	24
cliff swallow	23
yellow warbler	22
black-crowned night heron	22
red-breasted merganser	22
Caspian tern	20
Grand Total	14310

**Excludes 56 species for which the number observed was fewer than 20.*

2.5.6.2 Coastal Created Lands and Disturbed Uplands

Habitat Description

Created lands are formed by deposition of dredged sediments from other locations in the bay. These areas may be devoid of vegetation, but may have wrack or debris washed up on the beach. Beach debris provides temporary shelter and sometimes food for shorebirds and small marine invertebrates such as crabs and amphipods. These lands are a mosaic of uplands and disturbed wetlands.

Coastal created lands and disturbed uplands provide important habitat for listed species, migrating shorebirds, and nesting sea birds.

The largest parcel of created land is found at the D Street Fill partially within the SMNWR. Created land is also found at the CVWR, where dredged material was used to develop new habitat for wildlife that depend on mudflats and salt marsh. Other sites include the portions of Silver Strand State Beach, North and South Delta beaches, and along the Otay River.

The D Street Fill was created in 1969 as part of a dredging project in which dredge spoils from the construction of the Sweetwater Channel and the National City Marina were deposited within an existing wetland on habitat similar to that found in Sweetwater Marsh. Today, the D Street Fill consists of vegetated and unvegetated dredge spoil with elevations ranging from 2 to 12 feet above mean sea level. During surveys conducted on the D Street Fill in 2000, Merkel & Associates describe the habitat on the northwestern half of the fill as disturbed coastal dune. This area, which was created using dredge materials from the bay, is regularly cleared of vegetation to prepare the area for annual California least tern nesting. In the eastern portion of this fill area, where maintenance is more sporadic, a number of species have colonized the site; including beachbur (*Ambrosia chamissonis*), Lindley's saltbush *(Atriplex lindleyi),* woolly lotus *(Lotus heermannii heermannii),* and beach evening primrose. Merkel (2000) also noted an abundance of woolly-heads in some areas. Merkel & Associates, Inc. (2000) also identified the vegetation at the eastern end of the D Street Fill as disturbed coastal sage scrub. The most conspicuous species in this area is broom baccharis. Other dominant species include coyote brush, fragrant everlasting *(Gnaphalium canescens beneolens),* and coastal goldenbush *(Isocoma menziesii).*

Use of the Habitat

These lands provide important habitat for listed species, migrating shorebirds, nesting sea birds, and foraging raptors. Annually, USFWS or the Port grades portions of the D Street Fill and the airport grades the CVWR to enhance nesting substrate for the California least tern and the western snowy plover. This area is designated as critical habitat for the western snowy plover with management goal of 25 breeding birds (USFWS 2007). The Navy grades areas of the Delta beaches used for nesting by California least terns. A large part of San Diego County's coastal burrowing owl population is located on uplands of the bay. The sensitive plant, coast woolly heads, occurs on D Street Fill as does Nuttall's lotus (B. Collins, *pers. comm.*).

The created lands at CVWR are used as feeding and resting areas by sea birds, migrating shorebirds, and wintering waterfowl. Vegetation is managed here and at other nesting sites to enhance their attractiveness for California least terns. The number of California least tern pairs nesting at the CVWR in 2004 to 2007 were 66, 57, 15, and 33 pairs, respectively. D Street Fill (SMNWR) held 77, 77, 88, and 100 pairs in those same years. Complete tern nesting information is provided in Section 2.7.1.2: California least tern—Sterna antilarium browni.

Table 2-16 lists mammals that have been documented in upland transition areas, but not necessarily disturbed uplands. Thirty terrestrial mammal species have been recorded on Point Loma. Commonly detected species include the desert cottontail rabbit (*Sylvilagus audubonii*), California ground squirrel (*Spermophilus beecheyi*), northwestern San Diego pocket mouse (*Chaetodipus fallax fallax*), deer mouse (*Peromyscus maniculatus*), California vole (*Microtus californicus*), and western harvest mouse (*Reithrodontomys megalotis*). Gray foxes (*Urocyon cinereoargenteus*) were recently observed during studies on Point Loma conducted by Fisher and Brown (2001). Gray foxes and coyotes were documented in a carnivore scat and tracking project (Soule and

Crooks 1996). Only four bats, the desert red bat (*Lasiurus blossevillii*), Mexican free-tailed bat (*Tadarida brasiliensis*), big brown bat (*Eptesicus fuscus*), and big freetailed bat (*Nyctinomops macrotis*) have been reported on the Point Loma peninsula within the past five years (Stokes *et al.* 2003). In 1997, a survey of bat species of Naval Base Point Loma (NBPL) identified western mastiff bats (*Eumops perotis californicus*), Mexican free-tailed bats, and myotis (*Myotis* spp.) foraging over the area (Brown and Berry 1997). Some species have been received by rehabilitators apparently from NBPL Fleet & Industrial Supply Center Fuel Farm November 2007 that were not detected in these surveys. They are the Mexican long-tongued bat (*Choeronycteris mexicana*) and pocketed free-tailed bat (*Nyctinomops femorosaccus*). During a 2002 survey, four species were detected: the western red bat, the big brown bat, the Mexican free-tailed bat, and the big free-tailed bat.

Table 2-16. Mammals observed on the San Diego Bay Integrated Natural Resources Management Plan Footprint (taken from the final CCP/EIS, RECON 2005, RECON 2006, Tierra Data 2007, Soule and Crooks 1996, Brown and Berry 1997, Stokes et al. 2003).

Common Name	Scientific Name	Where Observed
Western mastiff bats	*Eumops perotis californicus*	NBPL (NBPL)
Myotis	*Myotis* spp.	NBPL
Mexican long-tongued bat	*Choeronycteris mexicana*	NBPL
Pocketed free-tailed bat	*Nyctinomops femorosaccus*	NBPL
Desert red bat	*Lasiurus blossevillii*	NBPL
Mexican free-tailed bat	*Tadarida brasiliensis*	NBPL
Big brown bat	*Eptesicus fuscus*	NBPL
Big freetailed bat	*Nyctinomops macrotis*	NBPL
Virginia opossum	*Didelphis virginiana*	Sweetwater Marsh Unit, NBC properties
Brush rabbit	*Sylvilagus bachmani*	Sweetwater Marsh Unit
Desert cottontail	*Sylvilagus audubonii*	Both Refuge Units, NRRF, NBPL
San Diego black-tailed jackrabbit	*Lepus californicus bennettii* (federal species of concern and CDFG species of special concern)	Sweetwater Marsh Unit of NWR; Navy properties NASNI, NRRF, and NAB beaches and dunes. Locally common.
California ground squirrel	*Spermophilus beecheyi*	Both Refuge Units, NBC, NBPL
Botta's pocket gopher	*Thomomys bottae*	Sweetwater Marsh Unit
Northwestern San Diego pocket mouse	*Chaetodipus falax falax*	NBPL, Sweetwater Marsh Unit
Western harvest mouse	*Rhythrodontomys megalotis longicaudus*	NRRF
California pocket mouse	*Perognathus californicus*	Sweetwater Marsh Unit
California vole	*Microtus californicus*	NBPL
Pacific kangaroo rat	*Dipodomys agilis*	Sweetwater Marsh Unit
Deer mouse	*Peromyscus maniculatus*	Sweetwater Marsh Unit
Dusky-footed woodrat	*Neotoma fuscipes*	Sweetwater Marsh Unit
Black rat	*Rattus rattus*	All Navy properties, Sweetwater Marsh Unit
House mouse	*Mus musculus*	All Navy properties, Sweetwater Marsh Unit
Coyote	*Canus latrans*	Both Refuge Units, NBC properties, NBPL
Gray fox	*Urocyon cinereoargenteus*	Sweetwater Marsh Unit, NBC properties, NBPL
Domestic dog	*Canus familiarus*	All properties
Raccoon	*Procyon lotor*	Both Refuge Units, NRRF
Long-tailed weasel	*Mustela frenata*	Gunpowder Point, Sweetwater Marsh Unit, and South San Diego Bay Unit
Striped Skunk	*Mephitis mephitis*	Sweetwater Marsh Unit, NBC properties
Domestic Cat	*Felis domesticus*	All properties

2.5.6.3 Freshwater Wetlands and Riparian

Habitat Description

Freshwater wetlands and riparian areas are supported at the entry points of freshwater tributaries into San Diego Bay. They are nontidal. Freshwater marshes are generally contiguous with the upland side of the salt marshes and are occupied by cattails, rushes, and bulrushes. Freshwater riparian areas and wetlands adjacent to salt marshes have been severely impacted by development and reduced runoff from rivers and creeks.

Maps dating back as far as 1916 depict the Otay River in its present channelized configuration. A narrow corridor of salt marsh, freshwater marsh, and native riparian habitat are supported within the river channel, and remnant maritime succulent scrub habitat can still be found in the vicinity of the railroad right-of-way that extends between the south end of the salt works and the Otay River channel. The riparian habitat is degraded and many of the trees are nonnative eucalyptus and California pepper tree. However, the riparian functions of providing habitat structure, shading some of the river, and buffering disturbances from nearby development are intact (USFWS1998).

An area known as the Egger-Ghio parcel (formerly the MKEG/Fenton parcel) was purchased by the Coastal Conservancy and transferred to the Refuge in 2000. This property consists of former wetlands that were diked and drained decades ago and mostly converted to agricultural use, located between the southernmost salt ponds and Interstate 5.

San Diego Mesa vernal pools occur at NRRF, and some of these pools are considered jurisdictional waters of the U.S. due to their connection to intertidal salt marsh and other habitats that connect to San Diego Bay. Management of these pools is covered in the NBC INRMP. Also on this property are nontidal freshwater marshes that are usually contiguous with the upland boundaries of salt marsh habitat. In shallow standing water or on perennially saturated ground, the dominant plants of this community are southern cattails *(Typha domingensis),* mulefat *(Baccharis salicifolia),* prairie bulrush *(Scirpus robustus),* and spikerush *(Eleocharis* spp.*).* The spikerush series of freshwater marsh at NRRF is characterized by perennial, emergent monocots in permanently flooded areas. Pale spikerush *(Eleocharis macrostachya)* and curly dock (*Rumex crispus)* dominate.

Use of the Habitat

A portion of the vernal pools at NRRF are occupied by the federally listed San Diego fairy shrimp *(Branchinecta sandiegonensis).*

Riparian vegetation established on the berms along the Otay River in the Egger-Ghio area supports several migratory songbird species. Although agriculture was discontinued in 1986, most of the area is occasionally disked to control weeds. The fallow agricultural land includes soils classed as prime farm land. There are wetlands, disturbed fields, and shrubby areas that support modest numbers of wildlife. No surveys or censuses of wildlife for the Egger-Ghio parcel are available. The Egger-Ghio parcel possesses high potential for wetland restoration by virtue of its low elevation, past history as tidal wetlands, and relatively undeveloped nature. The site is also suitable for other less intensive types of habitat enhancement measures using existing surface water patterns (USFWS1998).

Function

Wildlife are attracted to riparian woodlands for the freshwater and the structural complexity that provides sites for shelter, refuge from predators, foraging, resting, and cooling. The riparian zone also serves as a natural corridor linking adjacent ecosystems and facilitating movement of animals between them. In these ways, the presence of riparian habitat significantly enriches regional biodiversity beyond what could otherwise be supported.

2.5.6.4 River Mouths

San Diego Bay is unusual among the world's river-dominated estuaries because it receives minimal freshwater input and has a high evaporation rate (J. Largier, Scripps Institute of Oceanography, *pers. comm.*). Seven intermittent stream systems and tidal influences created a shore lined with deltas, mudflats, and salt marshes before Europeans arrived to the embayment they later named San Diego. Waters of the San Diego River continued to flow over the delta to the bay until the Derby Dike was built in 1853–1854, permanently diverting the river to Mission bay. San Diego Bay was kept from further sedimentation while the character of the mudflat and salt marsh habitats around the former mouth of the river changed. Later, dams were built on the Sweetwater and Otay Rivers affecting pattern and quantity of freshwater inflow, as well as sedimentation. A flood in 1891 was followed by an eleven year drought (1895–1905). This periodic flooding and drought continues and has long been San Diego's pattern.

Historic maps from the mid 1800s illustrate the natural configuration of the river and creek deltas prior to human disturbance. For example, the Otay River mouth consisted of a series of three or four shifting channels that flowed generally to the northwest across a gentle sloping alluvial fan (Michael Brandman Associates 1989). The tidal marsh environment was regularly inundated. Near the bayward fringe of this historical salt marsh, smaller tidal-slough type channels existed that would have conveyed ebb and flood tides to and from the outer marsh plain (Philip Williams and Associates 2003). Since the early 1900s, the Otay River floodplain has experienced significant disturbance that has impaired the natural hydrologic, geomorphic, and ecologic functions of the river/marsh plan complex. The flood of 1916 deposited an undetermined amount of sediments within the marsh plain.

The tidal flows, characterized by diurnal (daily) and spring-neap (monthly) variations, inundate the lower reaches of the Otay River and Nestor Creek channels twice daily. In contrast to the tides, freshwater flows from the watershed to the Otay River and Nestor Creek are relatively sparse throughout the year (Philip Williams & Associates 2002). During extreme rainfall events, however, freshwater flows would be expected to dominate the system, typically exceeding channel capacity and flooding much of the Refuge's upland area, as well as many of the surrounding properties.

River mouths no longer have a natural role. They are controlled by dams or diversion.

Today, streams are channelized or confined to storm drains and sometimes completely missing. They include the mouths of Paleta Creek and Chollas Creek at Naval Station, the mouth of Switzer Creek at Tenth Avenue Marine Terminal, Sweetwater Channel and the mouth of the Otay at the Salt Works, Telegraph Canyon Creek between the Otay and Sweetwater, and small drainages in both north bay and south bay that drain directly into the bay (Map 1-3). Dabbling ducks are found primarily in shallow brackish water near the mouths of drainages. Brackish water is hard to obtain for those that require it in San Diego Bay.

Stormwater outfalls provide some flows and nutrients to the bay, but not with natural seasonality, timing, frequency, or content. Sedimentary organic matter is no longer provided to the system except what is available from below the dams on each stream system. How this has affected functioning of the bay ecosystem has not been examined.

2.6 Species Assemblages

From plankton to mammals, most marine organisms have patchy distributions, varying diurnally, tidally, seasonally, and with climate cycles. Physical variables include sediment, wave action and currents, temperature and salinity. Biological factors influencing species assemblages include predation and competition. While many surveys have been conducted of species in San Diego Bay, they have been similarly patchy in time and space, so few "status and trend" conclusions are certain. The sections that follow summarize what is known.

2.6.1 Plankton

While no recent studies are available, past work suggests that San Diego Bay supports plankton assemblages similar to those of other southern California bays and estuaries in that individuals are volumetrically quite abundant, but there are relatively few species (Ford 1968; McGowen 1977, 1981; San Diego Gas and Electric Company1980; Damon 1969; Krett 1979; Krett-Lane 1980; Lapota *et al.* 1993).

The nutritional base of any ecosystem is provided almost entirely by the “primary producer” organisms that use energy from sunlight to manufacture the biological chemicals needed for sustaining life. Other systems that obtain energy from sources other than sunlight are likely of minor consequence in the bay. There are three principal groups of producers: vascular plants, simpler nonvascular plants, and the extremely simple algal forms typified by phytoplankton.

Plankton are an extremely important component of bay and ocean ecosystems, both because they form a vital part of the food base for other species and they include the larval stages of many benthic species. These organisms drift in the water. Phytoplankton include tiny, single-celled plants or plants that are simple chains of cells, and other producers, such as diatoms and dinoflagellates, cyanobacteria (blue-green algae), protista (plant-like microalgae) and bacteria. Zooplankton includes tiny animals, such as protozoans, as well as the larvae of many invertebrates and fishes.

There have been few studies of the phytoplankton and zooplankton inhabiting San Diego Bay, with most focus only on the south bay. The three primary investigations by Ford (1968), McGowen (1977, 1981) and SDG&E (1980) were concerned with characterizing different plankton groups of the south bay and the possible effects on these organisms of heated water and entrainment caused by the South Bay Power Plant. Damon (1969), Krett (1979), and Krett-Lane (1980) have also described phytoplankton assemblages from central and north bay sites, while Lapota *et al.* (1993) studied phytoplankton processes in relation to physical and chemical conditions throughout the bay.

Despite some steps towards understanding plankton in San Diego Bay, there is scarcely any indication of long-term trends, nor understanding of what drives primary production. Also, plankton is well known to be patchy in both space and time; therefore, it is difficult to extrapolate from the sporadic studies that have been conducted. Finally, changes in the last 20 years may have altered plankton composition, not the least of which is climate change.

2.6.1.1 Phytoplankton

In shallow marine waters such as those of San Diego Bay, the benthic animals and zooplankton utilize many of the same food resources (of which phytoplankton is a major component) to a much greater degree than in deeper water. Both dead phytoplankton and zooplankton contribute significantly to the organic detritus in and on the sediment. This material, in turn, is utilized by a wide variety of invertebrates and bacteria.

Invertebrates and bacteria use organic detritus from dead phytoplankton and zooplankton in and on sediment.

Dominant species of phytoplankton that Ford (1968) sampled in south San Diego Bay were pennate (linear-shaped) and chain-forming diatoms. These serve as food for a variety of zooplankton, as well as for filter feeding bivalve molluscs and other benthic invertebrates. They include the genera *Rhizosolenia, Chaetoceros, Biddulphia, Grammatophora, Fragilaria, Navicula, Gyrosigma, Pleurosigma, Nitzschia,* and *Suriella. Lingulodinium* was the only genus of dinoflagellate encountered. Unidentified tintinnids (ciliate protozoan that secretes vase-like cases) were another important component of the phytoplankton in south San Diego Bay (Ford 1968). The genera and species of phytoplankton reported to occur in San Diego Bay are listed in Table 2-17.

Damon (1969) investigated the population dynamics of several of the above species and of *Coenobiodiscus* in relation to nutrient cycling in San Diego Bay. A year-round study was conducted by Krett (1979) and Krett-Lane (1980) in 1978–1979 to determine if natural phytoplankton assemblages were being affected by elevated concentrations of copper in San Diego Bay. Sample sites were located inside the Shelter Island Yacht Basin, at a control location near the Shelter Island Public Fishing Pier, and at Pier 6 of the 32nd Street Naval Station. The study examined the differences in species composition, diversity (Hurlbert's PIE Index), biomass, and productivity. Measurements of chlorophyll *a* were also made. Field studies were accompanied by laboratory experiments conducted on these same phytoplankton species assemblages to assess effects of different copper concentrations.

Table 2-17. Genera and species of phytoplankton reported in San Diego Bay.[a,b]

Dinoflagellates	Diatoms and Other Groups	
Ceratium	Achnanthes	Licomorpha
Dinophysis	Asterionella	Navicula
Lingulodinium	Biddulphia	Nitzschia
Gymnodinium oplendens	Ceratulina	Phaeodactylum tricornutum
Noctulica	Chaetoceros	Pleurosigma
Peridinium	Coenobiodiscus	Rhizosolenia
Prorocentrum	Coscinodiscus	Skeletonema
	Ditylum	Stephanophysix
	Dunaliella	Streptotheca
	Eucampia	Suriella
	Fragilaria	Thalassionema
	Grammatophora	Thalassiothrix
	Gyrosigma	other identified diatoms
	Leptocylindrus	unidentified tintinnids

a. This list is undoubtedly incomplete because of limited sampling.

b. By Ford (1968), Krett (1979), Krett-Lane (1980) and Salazar (1985).

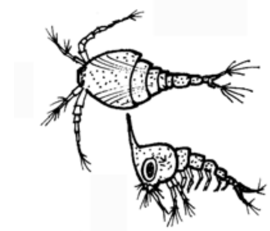
Krett (1979) and Krett-Lane (1980) found that the major diatom genera were *Chaetoceros, Asterionella, Leptocylindrus, Nitzschia, Skeletonema,* and an unidentified pennate, chain-forming species. The major genera of dinoflagellates that were sampled in the central and north bay were *Lingulodinium, Peridinium,* and *Prorocentrum.* Twenty-nine phytoplankton genera were at least moderately abundant members of the assemblages described. *Leptocylindricus* was frequently encountered during the fall, while *Chaetoceros* was the major genus encountered during the winter. Krett-Lane (1980) found that *Asterionella* was the numerically dominant form during February and March of 1979, when it represented more than 90% of the total phytoplankton cells present at the three sites. *Skeletonema* occurred throughout the entire year at these sites. *Nitzschia* was abundant during the spring.

Lapota *et al.* (1993) conducted six survey cruises throughout San Diego Bay from November 1992 through September 1993 to evaluate seasonal differences and interrelationships in the physical, chemical, and phytoplankton characteristics of the bay. These data were obtained using the Navy's survey vessel R/V ECOS and its associated sensor systems. The measurements included chlorophyll concentrations, water temperature, salinity, clarity, optical shifts in bay color, pH, dissolved oxygen, oil fluorescence, and standard nutrient chemical concentrations of silicate, phosphate, nitrate, nitrite, and ammonia. Seawater clarity was highest in the fall and lowest in winter and early spring. Surprisingly, mean chlorophyll levels for the bay as a whole did not show major changes seasonally. However, a relatively large increase in mean chlorophyll levels was measured in January, primarily in the south bay. The five nutrient chemicals measured had the highest concentrations throughout the bay in January, which were also attributable to the effects of stormwater runoff from the surrounding watershed. The highest mean dissolved oxygen levels baywide were measured in January, while the lowest levels were reported for night-time surveys in June and September.

Overall, Lapota *et al.* (1993) concluded that high chlorophyll concentrations in January, reflecting increased phytoplankton biomass, were probably the result of increased nutrient loading from freshwater runoff entering the bay through the watershed. Seawater transmission and clarity also decreased because runoff and effects of wind generated turbulence in January. In addition, the pH of seawater became more basic at this time because carbonic acid was being removed by the higher rates of photosynthesis. Increased photosynthesis by phytoplankton in the bay also caused greater oxygen production, leading to higher concentrations of dissolved oxygen in the seawater.

2.6.1.2 Zooplankton

Most of the limited research on zooplankton in San Diego Bay has been restricted to the south bay. The invertebrate zooplankton inhabiting San Diego Bay include a high proportion of meroplankton, which are the ephemeral planktonic larval forms of invertebrates that later settle to the bottom and become benthic juveniles and adults. These forms occur together with species called holoplankton, which spend their entire lives in the open water environment in planktonic form.



Zooplankton

Comparisons of zooplankton samples taken on the same dates in 1968 indicated that the numbers of species and the densities of many species were greater in north than south San Diego Bay locations (Ford 1968 and marine ecology class data, SDSU). These comparisons also indicated that zooplankton from the north bay consisted of a higher proportion of holoplankton and a somewhat lower proportion of meroplankton. Both of these differences are expected, given the closer proximity of the north bay to coastal ocean water, and the high density of invertebrates releasing meroplankton into the bay. The relative importance of these groups could vary with location, season, lunar cycle, or tidal phase.

Studies by Ford (1968) and SDG&E (1980) indicate that the major zooplankton of south San Diego Bay include species of calanoid copepods (a type of crustacean), of which *Acartia* spp. are the dominant forms. Also relatively dominant are the calanoid genera *Oithona, Paracalanus,* and *Pseudodiaptomus*. A large variety of harpacticoid copepods are also present in lower abundance. Most of the copepods feed on phytoplankton, while others rely to varying degrees on suspended detritus. Other presumed detrital feeders, the hypoplanktonic mysid crustaceans *Mysidopsis californica, Metamysidopsis elongata,* and *Acanthomysis macropsis*, are common at many south bay locations (Ford 1968; SDG&E 1980). Other dominant crustacean zooplankton are cladocerans of the genus *Podon* and unidentified ostracods (bean clams). Meroplankton represent the most diverse and abundant zooplankton component of the south bay. This is due in large part to the high density of adult benthic invertebrates releasing their meroplanktonic larvae into the bay. In the samples analyzed by Ford (1968) and SDG&E (1980), these were primarily larval and post-larval stages of benthic polychaetes, molluscs, and crustaceans, which in adult stages inhabit the bay floor. In addition, some of the meroplankton may be forms that are brought into the bay by tidal action but do not successfully settle there.

2.6.1.3 Ichthyoplankton

Because of their importance and distinctive mode of life, planktonic larvae of fishes are considered as a separate category of plankton called ichthyoplankton. Ichthyoplankton have been studied extensively on a seasonal basis only in south San Diego Bay (McGowen 1977, 1981; SDG&E 1980). The California Cooperative Oceanic Fisheries Investigations (CalCOFI) unit has conducted standardized ichthyoplankton surveys, primarily offshore of California and Baja California, since 1951. Survey methods and results are described by Moser *et al.* (1993). Geographic Information System (GIS) maps of egg and larval distributions of managed species have been developed from data collected during these surveys.

It appears that ichthyoplankton species composition and abundance may differ substantially from juvenile/adult fish composition and abundance in south San Diego Bay. This means the value of south bay for juvenile and adult fishes is different from its value for fish eggs and larvae, when plankton sampling data from Allen (1998) and VRG (2006) (see Section 2.6.4: Fishes) are compared in south bay. Distribution of ichthyoplankton is dependent on a multitude of physical and biological factors that are both seasonal and species dependent. Few studies directed at evaluating ichthyoplankton of specific fish species known to spawn in the bay are available, thus limiting researchers ability to develop relationships between abundances of ichthyoplankton and adult fish species.

McGowen (1977, 1981) conducted a detailed seasonal study in which conical net tows were taken at eight south San Diego Bay stations every two to four weeks over a one-year period in 1972–1973. The primary purposes of this research were to describe and evaluate the species composition and seasonal dynamics of larval fishes in the area and to assess possible general effects on them from the South bay Power Plant. McGowen identified the eggs and larvae of 18 species of fishes from the study area. He found that the eggs of two species, the deepbody anchovy and the diamond turbot, accounted for over 97% of the planktonic eggs collected. These species are not dominant in juvenile and adult fish catches (Allen 1998a; VRG 2006). One taxon, consisting of the larvae of arrow, cheekspot and shadow gobies, accounted for over 87% of the fish larvae sampled during the one-year period. Atherinid larvae, consisting of the topsmelt and the jacksmelt (*Atherinopsis californiensis),* accounted for 8.5%, while the remaining 4.5% included representatives of ten other species or higher taxa. Several of these exhibited seasonal patterns of occurrence in the plankton. It was concluded that the ichthyoplankton assemblage of south San Diego Bay contained fewer species than occur in coastal waters at other locations studied along the Pacific Coast of the United States.

SDG&E (1980) conducted a one-year study that involved extensive net sampling at four south bay stations designed to assess possible effects of the South Bay Power Plant on ichthyoplankton. The sampling design and methods were the same as those described in the previous section on zooplankton. This study was restricted primarily to consider selected important or "featured taxa" rather than all ichthyoplankton species. Based on several lines of evidence, the results of the study indicated that operation of the South Bay Power Plant had no significant adverse ecological effects on the ichthyoplankton of south San Diego Bay (SDG&E 1980).

2.6.2 Algae

It is estimated that there are over 50 species of macroalgae present in the bay (R. Ford *pers. comm.*). They are the principal producers in the ecosystem and provide an important food source. Seasonal variability in productivity and dominance of algae is high.

With the exception of the algal forms living under the open canopy of salt marsh vegetation, the discussion on bacteria, cyanobacteria (blue-green algae), and protista (plant-like microalgae) is found under Section 2.6.1.1: Phytoplankton.

2.6.2.1 Macroalgae

In the nearshore marine environments and in enclosed waters such as San Diego Bay, the contribution of the macroalgae (seaweeds) to overall productivity may be substantial. These larger algal species are described in this section.

Phylogenetic Description

In San Diego Bay, macroalgae belong to three different phyla, or divisions: the Chlorophyta (green algae), the Phaeophyta (brown algae), and the Rhodophyta (red algae). The differences among the algal phyla primarily relate to photosynthetic pigments, certain physiological processes, and reproductive/life history characteristics.

Macroalgae differ primarily by photosynthetic pigments, physiological processes, and reproductive/life history characteristics.

Chlorophyta: Of the close to 50 native macroalgal species present in the bay (see Appendix C), nine belong to the Chlorophyta. Most local green algal species are quite small.

Phaeophyta: There are 12 native species of brown algae that are consistently found in the bay (see Appendix C).

Rhodophyta: The largest group of algae, represented by 25 species, is the red algae. Many species of red algae are quite small and may be present only cryptically attached to a variety of structures or as epiphytes, living atop another plant or algal form.

Morphologic Variability

Algal species may change their morphology or form with environmental conditions. Changes in water quality, including turbidity, dissolved gases, and chemical constituents, can trigger this morphological response. Such changes, which can result in cryptic forms, produce an apparent seasonal variation in species composition that is usually due to change in light or temperature. Other changes are related to a life cycle characteristic known as "alternation of generations," which confers extensive variability and often causes taxonomic confusion. For example, the greens that occupy the intertidal and upper subtidal zones will often "die out" during the summer. What has actually taken place is that the next "generation" of individuals has simply germinated in a more favorable nearby habitat, and often in a cryptic form on a plant or algal form, or attached to some fixed object. When conditions change, the following generation will reoccupy old habitat and assume the appropriate morphology. Though typical of the chlorophytes, this habit is not restricted to them as some browns and many red algae undergo the same sort of changes.

Ecological Roles of Algae

The contribution made by algae begins with being principal producers in the ecosystem. Substantive structure is also imparted to the habitat by larger algal species and eelgrass. Additionally, many algal species reproduce with swimming gametes and zoospores not only to enhance dispersal, but to provide an important food resource for zooplankton and filter-feeders.

Algal mats respond to nutrient loading, such as from stormwater outflow.

Seasonal variability in productivity and dominance of algae is high, as is evident in algal mats that become more predominant with warm summer temperatures. These mats also respond to nutrient loading, such as from stormwater. In the salt marsh, seasonal variability has been looked at only in terms of phytoplankton and in the salt marshes near San Diego Bay (Mission Bay and Tijuana Estuary). Epibenthic algal mats underneath the open canopy of salt marsh vegetation have been shown to match or exceed the productivity of vascular plants. Epibenthic algae predominated only in winter, whereas mats with blue-green algae and diatoms dominated in summer. High light and high temperatures favored blue-green algae and phytoplankton, whereas low light and low temperature stimulated the green macroalgae. Lower salinity delayed phytoplankton blooms, and the species composition changed to more blue-green types (Lapota *et al.* 1993, discussed in Section 2.6.1.1: Phytoplankton).

Algae-Habitat Relationships in San Diego Bay

Algal species are found in association with a wide range of habitats. In some cases, these associations are strongly tied to physical substrate. Some algae are found only on sandy substrate, and many that grow subtidally on rocky substrate are also found on hard intertidal surfaces. In other cases, the relationship seems to be opportunistic—any or all are commonly found in a given habitat. Algae are categorized here in "ecological" groups. No specific studies on algal distribution for the bay have been conducted, so these conclusions are made based on studies elsewhere in San Diego Bay and the SCB: Ford (1968), Murray and Bray (1993), and Stewart (1991). A species-by-species summary of habitat associations is presented in Appendix D.

Ecological Groups of Algae and Plants

A. **Turf algae of sandy substrate, variable depths.** *Tiffaniella snyderae, Polysiphonia pacifica,* and *Hypnea valentiae* (all Rhodophyta) and *Chaetomorpha linum* (Chlorophyta). These algae are found mainly over sandy bottoms in deep subtidal, shallow subtidal, and intertidal habitats.

B. **Microalgae of variable depths.** *Aglaothamnion cordatum, Griffithsia pacifica, Ceramium eatonianum, Dasya sinicola* var. *abyssicola* and *Dasya sinicola* var. *californica* (all Rhodophyta), and *Cladophora* sp. (Chlorophyta). These tiny algae, often occurring as epiphytes on plants or other algae, are found in both the deep subtidal and shallow subtidal zones.

C. **Shallow subtidal, "attached" algae.** *Antithamnion* sp. and *Polysiphonia pacifica* (both Rhodophyta). Found attached to fixed objects, other algae, or plants, these algae occur in shallow waters.

D. **Subtidal/intertidal epiphytes.** *Cladophora* sp. (Chlorophyta) and *Ceramium eatonianum* (Rhodophyta). This pair is usually found as epiphytes on other algae or plants, in shallow waters on *Chaetomorpha* algal mats, and on intertidal hard substrate.

E. **Subtidal/intertidal, muddy-rocky group.** *Chaetomorpha linum* and *Ulva expansa* (both Chlorophyta), *Dictyota flabellata* (Phaeophyta), and *Aglaothamnion cordatum* (Rhodophyta). This group is found in shallow rocky and muddy habitats, and on hard substrate in the intertidal zone.

F. **Shallow subtidal/intertidal rocky group.** *Cladophora* sp. (Chlorophyta) and *Colpomenia sinuosa* (Phaeophyta). These algae are found on hard substrate in both the shallow subtidal and intertidal zones.

G. **Desiccation/hypersaline-tolerant group.** *Ulva* sp. (Chlorophyta) found in the intertidal zone in both muddy and salt panne habitats.

2.6.3 Invertebrates

Invertebrates comprise a significant portion of the organisms present in the San Diego Bay. They serve as important components of bay habitats and essential food sources for marine life. Assessments of benthic community data are difficult because biological communities are complex. Dozens of species and hundreds of organisms are often found in a single sample, with numbers and species of organisms varying from habitat to habitat. To improve environmental assessments, SCCWRP funded an Evaluation of Benthic Assessment Methodology in Southern California Bays and San Francisco Bay in April 2004. This study funded scientists in developing biological indices that reduce complex data to single values useful for evaluating community health using thresholds of concern and for tracking trends in benthic conditions (SCCWRP 2004).

Differing substrate types within the bay's region shape the associated invertebrate community and the fish assemblages preying upon them.

Infaunal benthic invertebrates dominate the majority of invertebrates living on or in the soft bottom sediment of the bay and include polychaete worms, crustaceans, mollusks, and unidentified species of oligochaete and nematode worms (Kinnetic Laboratories Inc. 1990). The type and abundance of invertebrates present within various regions of the bay vary in relative numbers but remain dominated by infaunal invertebrates inhabiting soft bottoms sediments. The availability of differing substrate types within each bay region shapes the associated invertebrate community and in turn the fish assemblages preying upon them. Important regional data on benthic invertebrates has been collected continuously since 1951 (CalCOFI) and provides a baseline of documented species. Previous bay specific surveys have been limited to defined studies investigating development projects or mitigation studies and lack a comprehensive evaluation of all substrate types and values. The bay primarily consists of soft bottom; however, hard substrate both natural and introduced provides important structure for additional important assemblages that are comprised of encrusting and motile invertebrates. As human development increases around the bay, man-made habitats such as rock riprap, pier pilings, and marina floats have become habitats for invertebrates and other marine life.

Taxonomists have estimated that at least 97% of all animal species on earth are invertebrates, forms that lack skeletal vertebrae. In fact, there are more species of invertebrate animals than all other kinds of aquatic and terrestrial animals and plants combined. This is also the case in the major intertidal and subtidal habitats of San Diego Bay, which together support more than 650 species of marine, estuarine, and salt marsh invertebrates (see Appendix C). These include marine representatives of all the major invertebrate phyla, as well as insects and spiders important as components of the salt marsh community. In addition to the large number of invertebrate species and their great taxonomic and functional diversity, many invertebrate populations are very abundant in San Diego Bay. All of these characteristics make them important ecological components of bay habitats and essential food sources for marine fishes, birds, and other invertebrate animals in those habitats.

One of the mobile macroinvertebrates legally harvested in San Diego Bay is the California spiny lobster *(Panulirus inerruptus).* It is an ecologically and economically important species throughout southern California coastal waters, providing a local fishery for over 100 years. Lobsters are a major predator of benthic invertebrates, and they are believed to act as a keystone species in nearshore coastal areas as well as they bay by preying upon competitively dominant mussels on rocky shorelines and on sea urchins that consume kelp, thereby promoting the existence of diverse shoreline communities (Hovel and Lowe 2007). Hovel and Lowe (2007) used benthic SCUBA (for shelter searches) and sonic-based tagging to monitor nocturnal movements of lobsters to assess 12 benthic landscapes in the Point Loma kelp forest and nearby surfgrass beds. Bare sediment was avoided by lobsters (sand and mud bottoms clear of large rocks and algae). This is probably because open areas contain predators or because there is less food in open areas.

2.6.3.1 Invertebrates of Soft Bottom, Unconsolidated Sediment

The subtidal bottom of San Diego Bay consists primarily of unconsolidated sediments. These include various grain size mixtures of sand, silt, and clay, depending on the degree of water movement and other environmental factors. The silt and clay fractions together are also classified in a more general way as the mud fraction. Around the shoreline of south bay, and also along the western shoreline of central bay, there are fairly extensive intertidal areas of unconsolidated sediment forming mudflats and sand flats. With some notable exceptions, these relatively natural intertidal flats are absent from the remainder of the bay, where they have been replaced by concrete bulkheads and a wide variety of other man-made structures.

It is important to note that intertidal and shallow subtidal habitats of unconsolidated sediment (0 to 13 feet [0 to 4 m] below MLLW) that do not support eelgrass are of great importance to invertebrates and to the ecological functioning of the bay. Together with eelgrass beds, these unvegetated, shallow areas of soft bottom represent the two primary subtidal habitats and their associated fauna that were present in San Diego Bay prior to its development for human use.

Factors Affecting Invertebrates in Soft Bottom Habitats

Unconsolidated sediment or soft bottom habitats in intertidal and subtidal areas are dynamic in nature. They can be disturbed easily by human activity, wind, waves, tidal currents, and feeding by bottom fishes and shorebirds. Because they lack solid places for attachment, a large majority of the invertebrates in soft bottom intertidal and subtidal habitats of San Diego Bay are part of the infauna, animals that burrow into the substrate for food, for protection from predators, and to avoid being carried away by water movement. Relatively few species form part of the epifauna, invertebrates such as sponges, gastropod molluscs, and some larger crustaceans and tunicates that spend all or most of their time on the sediment surface. Very few marine plants have adapted to this condition in San Diego Bay. One notable exception is eelgrass, the rooted flowering plant which forms thick beds and its own distinct subtidal benthic habitat, as discussed in Section 2.6.3.2: Invertebrates of Eelgrass Beds.

In the intertidal and subtidal soft bottom habitats of San Diego Bay, few marine plants have solid and stable attachment sites. To avoid being carried away, infauna burrow into the substrate, as well as use the substrate for food and protection from predators.

Invertebrates living in soft bottom habitats have also developed a variety of methods to burrow through the sediment and to anchor themselves. For example, most free-living worms, such as the San Diego Bay species of *Nereis* and *Nephtys*, alternately flare their anterior body segments and then anchor them to aid in moving forward and pulling their bodies through the sediment. Many species of clams, such as the bent-nosed clam (*Macoma nasuta)*, make their muscular foot thin and penetrate the sediment with it. The end of the foot is then expanded into a thick anchor shape to hold position while the rest of the body is pulled down into the sediment. The foot is also expanded as an anchor to hold the clam in position once it is established at the proper depth below the sediment surface. Many crustaceans, such as amphipods and the red ghost shrimp (*Callianassa californiensis),* use their jointed appendages to dig through the sediment and to hold position.

Tiny invertebrates live and move around in spaces between sediment grains or attach to the grain. Thus far, no special sampling has been conducted for these interstitial fauna (they pass through standard sampling sieves).

Some soft bottom invertebrates are so small that they live and move around in the spaces between the sediment grains or attach to the grains. These are called the interstitial fauna. They include protozoans, nematodes, hydroids, polychaete and oligochaete worms, flatworms, and copepods, gastrotrichs, kinorhynchs, rotifers, archiannelids, and gnathostomulids. It should be noted that most of these interstitial species do not appear in the species list for San Diego Bay (Appendix C), or are represented in that list only by notations such as “unidentified oligochaete spp. or nematode spp.;” most pass through the 0.02 inches (0.5 mm) sieves normally used to process standard infauna samples. No special sampling has been conducted for the interstitial fauna or for other meiofauna in San Diego Bay thus far. As a result, our knowledge is incomplete as to the species composition of these animals or their distribution and abundance.

Feeding Relationships of Invertebrates in Soft Bottom Habitats

Most infaunal and some epifaunal species of intertidal and subtidal soft bottom communities in San Diego Bay and other estuaries feed on the abundant detritus suspended in the water and deposited in the sediments (See Figure 2-30 for an example of a simplified food web). This detritus consists of both dead organic matter and the bacteria and other decomposer organisms that live on it. Both these dead and living components of detritus are important in the diet of invertebrate detritus feeders. These detritus feeders include deposit feeders, which are animals that ingest detritus and associated bacteria accumulating on and within the sediment; and suspension feeders, which are animals that capture particles suspended in the overlying water, either by filter feeding or by other means. Examples of such deposit feeders in San Diego Bay include the bent-nosed clam, the mud snails *Nassarius* spp., and the California horn shell (*Cerithidea californica)*, as well as amphipods and some decapod crustaceans. Filter feeders include many clam species, while suspension feeders using other feeding mechanisms, such as tentacles and mucus, include many species of tube-forming polychaete worms. Invertebrate carnivores are also important members of the infauna and epifauna in all soft bottom communities of San Diego Bay. They include polychaete worms, such as *Neanthes* spp. and *Glycera* spp., the tectibranch or sea slug (*Navanax inermis*), and the swimming crab (*Portunus xantusi*).

Deposit feeders predominate in soft bottom areas with large amounts of mud. These species prefer mud because it contains more bacteria, which is their food. In contrast, suspension feeders are more common in soft bottom areas where sandy sediments predominate, such as in some areas of central and north San Diego Bay.

Bacteria associated with the detritus and sediment are believed to be a primary food source of deposit feeders. These deposit feeding invertebrates tend to consume muddy sediments in preference to sandy ones because the surface area to volume ratio is greater in mud, allowing more bacterial colonization of the grain surfaces. As a result, deposit feeding species tend to predominate in soft bottom areas with large amounts of silt and clay, the primary sediment type throughout most of San Diego Bay. Another reason for this relationship is that more detritus accumulates in the interstitial spaces between fine sediment particles than between those of larger grain size. In contrast, suspension feeders are more common in soft bottom areas where sandy sediments predominate, such as in some areas of central and north San Diego Bay.

Detritus is also considered to be the most important food source for the interstitial fauna, as it is for larger infauna and invertebrates. However, many interstitial species are predators or scavengers. Others are grazing herbivores that feed on diatoms living in the upper few millimeters of the sediment.

Soft Bottom Invertebrate Fauna of South San Diego Bay

During Bight '98 (Bay *et al.* 2000), a total of 1,172 megabenthic invertebrates, representing 43 taxa, were collected in San Diego Bay. The nonindigenous bivalve *Musculista senhousia* was present in more than 70% of the samples, making it the most widely distributed trawl caught invertebrate in the bay. Other common invertebrates that were present in at least one third of the samples included two undescribed species of sponge, *Porifera* sp. SD4 and *Porifera* sp SD5, the ascidian *Microcosmus squamiger,* the bivalve *Argopecten ventricosus,* and the gastropod *Crepidula onyx. Musculista senhousia* together with another nonindigenous species *Microcosmus squamiger,* accounted for over 50% of the total catch.

The invertebrate fauna of south San Diego Bay has historically been studied far more extensively than other parts of the bay. However, all of these studies were conducted after the mid-1960s, during the recovery and stabilization periods following serious effects of habitat disturbance and of sewage and industrial pollution. Therefore, it is important to consider the degree to which the present invertebrate assemblages differ from those that existed in San Diego Bay prior to its extensive modifications by human activity.

Lockheed (1981) discussed the results of comparisons of the dominant infaunal species reported in the literature for south San Diego Bay with those reported for San Quentin Bay in Baja California, and Newport Bay and Alamitos Bay, California (Reish and Winter 1954; Barnard and Reish 1959; Reish 1968; Barnard 1970). The results of these comparisons revealed that there were no substantial differences in species composition among these four sites. The results of the comparison with San Quentin Bay, a nearly natural estuary similar in other characteristics to San Diego Bay, are particularly significant. They suggest that the infaunal species assemblages of south San Diego Bay probably are relatively natural ones similar to those that existed there prior to disturbances caused by humans.

The infaunal species assemblages of south San Diego Bay are very similar to those of San Quentin Bay in Baja California, a nearly natural estuary similar in other characteristics to San Diego Bay.

As in soft bottom sediments of most locales, and as described by Ford (1968), Ford and Chambers (1973), Ford *et al.* (1975), Lockheed (1981), Macdonald *et al.* (1990), and others, the invertebrate fauna living on and in the soft bottom sediment of south San Diego Bay is dominated in terms of numbers of species, abundance, and biomass by polychaete worms, crustaceans, and molluscs (Table 2-18).

Polychaete worms, crustaceans, and molluscs are the dominant invertebrate fauna living on and in the soft bottom sediment of south San Diego Bay. This is true for most soft bottom habitats everywhere.

Table 2-18. South bay invertebrate sampling 1976-1989.

Dominant South Bay Invertebrate Sampling 1976–1989, by Number of Species and %[a].		
Polychaetes	118	40.0%
Crustaceans	85	29.0%
amphipods	32	11.0%
decapods	15	5.0%
ostracods	10	3.0%
others	28	10.0%
Molluscs	53	18.0%
bivalve	25	8.5%
gastropod	28	9.5%
Other invertebrate species	36	13.0%
Total No. Species	292	

a. Data tabulated by Macdonald et al. (1990).

Data on the infauna of south San Diego Bay (Kinnetic Laboratories Inc. 1990) indicate that the numerically dominant species include:

- Polychaetes (*Capitella capitata, Cirriformia* spp., *Exogone* sp., *Fabricia limicola, Leitoscoloplos elongatus, Lumbrineris* spp., *Mediomastus* spp., *Megalomma pigmentum, Neanthes acuminata, Streblospio benedicti, Typosyllis* spp.), and the phoronid *Phoronid* spp.

- Crustaceans (*Acuminodeutopus heteruropus, Caprella mendax, and Caprella* spp., *Euphilomedes carcharadonta, Parasterope barnesi, Rudilemboides stenopropodus,* and *Synchelidium* spp.)
- Molluscs (bivalves *Lyonsia californica, Musculista senhousia* [an invasive species], *Tagelus californianus,* and the gastropods *Barleeia californica* and *Cylichnella inculta).*
- Unidentified species of oligochaete and nematode worms.

As expected, many of the species that occur in intertidal habitats of south bay also occur subtidally (Ford and Chambers 1973). The subtidal areas are nearly all quite shallow and sediment characteristics at a given location are much the same both intertidally and subtidally. However, the number of intertidal species present generally appears to be much smaller (Ford and Chambers 1973; Ford *et al.* 1975; Macdonald *et al.* 1990). This may be partly because some subtidal species may not tolerate the desiccation that occurs in the intertidal zone.

Some species of molluscs are used as human food. South San Diego Bay has long been considered good for clam digging.

Some species of common intertidal and subtidal bivalve molluscs inhabiting south San Diego Bay are used as human food, and the area has long been considered good for clam digging. These include the banded, smooth, and wavy cockle clams (*Chione californiensis, C. fluctifraga,* and *C. undatella*), the littleneck clam (*Protothaca staminea*), the bent-nosed clam, and others (Ford and Chambers 1973). However, the size of most individuals of these species appears to be small compared with those in nearby clamming areas, such as the San Diego River mouth. The jackknife clam (*Tagelus californianus* and *T. subteres*), rosy razor clam (*Solen rosaceus*), and other small bivalves are commonly used as bait for fishing. The ghost shrimp is also used as bait. While the other invertebrates present are not of direct value to man, they are extremely important to the ecological functioning of south bay. The feeding of nematode and polychaete worms, gastropod molluscs, brittlestars, crabs, isopods, and a wide variety of smaller crustaceans serves to transform detritus, bacteria, and small invertebrates into usable food for larger invertebrates and fishes. The latter, in turn, are eaten by other large fishes and aquatic birds, many of which are of sport fishing value or aesthetic value to man. Bivalve molluscs and other suspension feeders serve a similar function in transforming plankton and suspended detrital material into food for fishes and birds (Ford 1968; Ford and Chambers 1973).

An unusual colonial ectoproct or bryozoan animal, *Zoobotryon verticillatum*, is present on the bottom sediment throughout much of south San Diego Bay, where it forms large, flexible, tree-like masses during the warmer months of the year. Some clumps are attached to shell material embedded in the sediment or to algae, while much of it simply moves around freely on the bottom. Like the benthic plants discussed above, it serves as food for a variety of invertebrates and as refuge or cover for both motile invertebrates and small fishes. It is a suspension feeder.

Another unusual epifaunal species is a large purple and green basket sponge. These sponges are so large and abundant in some areas of south San Diego Bay that they give the bottom the appearance of an underwater "cabbage patch." This sponge has been identified in previous studies of San Diego Bay as *Tetilla mutabilis*, originally described from inner Newport Bay. However, recent examination by specialists indicates that it may be an undescribed species.

Invertebrate Fauna in Soft Bottom Habitats of Central and North Bay

There has been only one multiseason study of soft bottom communities in north San Diego Bay, that conducted by Ford *et al.* (1975) in the downtown area adjacent to and offshore from the Broadway and Navy piers. All of the sampling stations employed were in relatively deep subtidal areas. In addition, the 1996 (and 1998 addendum) study by Fairey *et al.* (in Tables 7 through 11) provided important information about infaunal invertebrate assemblages at a large number of sites throughout central and north San Diego Bay. Other environmental impact studies of limited scope have also provided useful information about the invertebrate fauna of soft bottom habitats in other areas of the central and north bay.

Of the 218 invertebrate species in soft bottom habitats sampled during four seasons in 1972–1978 near and offshore of the Broadway and Navy piers, 81 (37%) were polychaete worms, 47 (22%) were crustaceans, and 24 (11%) were bivalve and gastropod molluscs (Ford *et al.* 1975, partial list cited). While the number of species in each category was smaller at the north bay location, the percentages were very similar to those reported for south San Diego Bay. This indicates, as expected, that polychaetes, crustaceans, and molluscs are the dominant invertebrates in both areas. Data on abundance and biomass also confirm the dominance of these three invertebrate groups at the north bay location. This ranking is typical of soft bottom habitats elsewhere.

Because of their limited coverage, the data now available are insufficient to characterize the numerically dominant species of these major taxonomic groups in central and north San Diego Bay. The most complete, recent species list for infauna of these areas of the bay is that reported in Table 7 of the study by Fairey *et al.* (1996). However, comparison of the data for infaunal invertebrates reported from north and central San Diego Bay by Ford *et al.* (1975) and Fairey *et al.* (1996) with those for the south bay (Macdonald *et al.* 1990) indicates that there is considerable overlap, with many of the same species occurring in all three areas.

2.6.3.2 Invertebrates of Eelgrass Beds

On the basis of a seasonal study of eelgrass beds in central San Diego Bay, Takahashi (1992b) and Takahashi and Ford (1992) reported 117 different species or higher taxa of invertebrates associated with this habitat. Polychaete worms were the dominant group during all seasons and at all sampling sites. Of these, the two dominant infaunal species were *Lumbrineris zonata* and *Exogone lourei*, both considered to be deposit feeders. Most of the abundant polychaete species found in eelgrass beds are deposit feeders.

Takahashi (1992b) found that the other dominant invertebrate groups in San Diego Bay eelgrass beds were crustaceans and molluscs. Among crustaceans, the dominant forms were either tube forming or infaunal amphipods. Tanaid crustaceans were more abundant than amphipods only in the January samples. The high densities of amphipods in *Zostera* beds may occur because of the protection afforded by the eelgrass blades. The introduced Asian mussel (*Musculista senhousia*) was the dominant bivalve mollusc at all sites throughout the study. Gastropod mollusc species were also dominant forms.

Takahashi (1992b) found that densities of infaunal species, as well as the number of these species, were considerably higher in the San Diego Bay eelgrass beds sampled than those values reported for adjacent, unvegetated areas of unconsolidated sediment. In addition, the infaunal species composition of these two habitats differed very markedly, with consistently greater numbers of polychaete, amphipod, and mollusc species present in the eelgrass bed habitat and with relatively few species common to both habitats. It is important to note, however, that both eelgrass habitats and unvegetated shallow subtidal habitats of unconsolidated sediment are equally important to San Diego Bay invertebrates, to many fish predators, and to the ecological functioning of the bay ecosystem.

Both eelgrass habitats and unvegetated shallows of unconsolidated sediment are equally important to San Diego Bay invertebrates, to many fish predators, and to the ecological functioning of the bay ecosystem.

2.6.3.3 Invertebrates of Man-Made Habitats

Since the 1800s San Diego Bay has been developed to support a wide variety of human activities. The resulting man-made features, including concrete bulkheads, rock riprap, pier pilings, marina floats, and a wide range of other dock structures are now and will continue to be intertidal and subtidal habitats for marine algae, invertebrates and fishes. The fact that they are not natural bay habitats is of little consequence, because these diverse structures will not be removed and will continue to support a wide variety of marine life.

On average, riprap and natural rocky habitats in wave-exposed environments in southern California did not differ from each other in diversity or community composition (Davis et al. 2002).

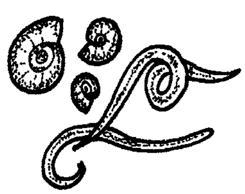
Davis *et al.* (2002) studied the communities on the riprap lining San Diego Bay to illustrate the role of wave exposure in structuring the intertidal communities. On average, riprap and natural rocky habitats in wave-exposed environments in southern California did not differ from each other in diversity or community composition. Sessile species made up the majority of species recorded, and no differences were found in diversity or community structure when they were part of the analyses. Mobile species, when considered on their own were more diverse on natural shores, largely driven by a handful of molluscan species that were relatively uncommon (Pister 2007).

A multiseason study was conducted on the concrete and wooden piling structures of the B Street, Broadway, and Navy piers during 1972–1973 (Ford *et al.* 1975). These pilings were sampled at a series of intertidal and subtidal depths to obtain quantitative data on species composition, abundance and distribution of marine algae, invertebrates, and fishes.

Sponges, cnidarians (sea anemones, hydroids and others), bryozoans, polychaete worms, crustaceans, molluscs, and tunicates dominated the rich sessile (attached to the bottom or a surface) and free living invertebrate fauna associated with concrete and wooden pier pilings in this study area in terms of numbers of species, abundance, surface coverage, and biomass (Ford *et al.* 1975). These same animal groups also appear to be the dominant forms on similar structures elsewhere in north San Diego Bay. Of the invertebrate species encountered on pier pilings in the study area during the period September 1972–August 1973, five (2%) were sponges, 24 (8%) were cnidarians, seven (2.5%) were bryozoans, 89 (30%) were polychaetes, 75 (27%) were crustaceans, 65 (23%) were molluscs, and seven (2.5%) were tunicates (Ford *et al.* 1975). With the exception of the purple hinge rock scallop (*Hinnites multirugosus)*, none of these species is of commercial or sportfishing importance.

The results of this study also showed that these epifaunal invertebrates and associated algae living on the pilings changed fairly markedly in species composition and abundance from one season to the next. This is typical of species assemblages on artificial structures elsewhere and underscores the need to conduct such studies on a multiseason basis.

2.6.3.4 Assessment of Invertebrates as Indicators of Pollution or Habitat Disturbance



Benthic micro-invertebrates

Infaunal invertebrates have many characteristics that make them good subjects and good ecological indicators for studies concerning the effects of pollution, residual toxicity in marine sediments, and habitat disturbance. The invertebrate infauna tend to remain in the same area and are, therefore, consistently exposed to existing conditions in the sediment and in the water passing over them. A majority of these species have planktonic larval stages and enter their benthic habitats through metamorphosis settling into sediments with suitable characteristics. The settlement process involves responses of the larvae or post larvae to a variety of species-specific physical and chemical cues, including those produced by pollution and habitat disturbance. Of particular importance is the fact that many infaunal species have relatively short life spans, with population turnover occurring as often as two to ten times per year. These species seem to show a corresponding rapid response to changing environmental conditions, which makes many of them good short-term indicators of environmental quality.

While the short life spans and rapid turnover rates of infaunal species make them good indicators of the effects caused by environmental degradation, those same characteristics also can make it very difficult to interpret the biological data obtained from "snapshot" samples, such as those taken only every few months at a limited number of stations. These opportunists are also more tolerant of habitat degradation. Short life spans and rapid population turnover also produce wide and often unpredictable fluctuations in species composition, biomass, and abundance of infaunal species. Under these conditions, it is particularly difficult to interpret infrequent biological "snapshots" and relate them to either conditions of environmental degradation or to natural environmental changes. Ecological data from more frequent sampling and those data from sampling over a long series of years usually allow a more meaningful interpretation, as shown for the studies concerning ecological effects of thermal effluent in south San Diego Bay. (See, for example, Lockheed 1981; Kinnetic Laboratories Inc. 1990.)

Studies in San Diego Bay, such as those of Ford and Chambers (1973), Ford *et al.* (1975), Lockheed (1981), and Fairey *et al.* (1996), illustrate the value of using quantitative data for the invertebrate infauna to assess the effects of pollution and sediment toxicity. In the toxicity study by Fairey *et al.* (1996), analyses were made of infaunal community structure and degree of community degradation, using a variety of methods, based on sampling at 75 benthic stations in north and central San Diego Bay. This information was then employed in conjunction with data from different measures of chemical toxicity in the sediments to develop rankings that identified and prioritized sediment toxicity problems at each station site.

Lenihan *et al.* (1990) conducted field studies of invertebrates and algae inhabiting floats, pilings, and other man-made structures in a representative series of boat mooring harbors or embayments at different locations at San Diego Bay. The study found that the inner “back harbor” sections of areas which contained a large number of boats were characterized by depauperate hard-bottom communities with lower biomass, lower percent cover, and fewer species than for similar “back harbor” areas with few boats. The fauna and flora of “back harbor” sites with large numbers of boats consisted of a simpler species assemblage dominated by the solitary tunicate *Ciona intestinalis* (an invasive species), serpulid polychaete worms, and filamentous algae. These species appear to tolerate the environmental stresses associated with large numbers of boats. In similar “back harbor” sites with few boats, a much richer fauna was present, in which the dominant forms were species of mussels, sponges, ectoprocts (bryozoans), and tunicates.

The associated motile invertebrate species, primarily polychaetes and crustaceans, that nestle or live among these sessile invertebrates and algae were found to be strongly associated with microhabitats (e.g. dense algal or serpulid worm aggregations) rather than with conditions related to the number of boats moored at a given location. However, Lenihan *et al.* (1990) found that there were more species of these nestling invertebrates present at inner harbor locations where smaller numbers of boats were moored. In comparing these boat harbors with large and small numbers of boats, sampling was confined to inner or “back harbor” locations. Hard-bottom communities found in the outer or front portions of these boat harbors were generally similar to one another and also most closely resembled those of inner or “back harbor” locations with few boats.

Evaluation of differences in hydrographic conditions among boat harbors with large and small numbers of boats could not explain the consistent community patterns Lenihan *et al.* (1990) observed. The concentrations of TBT, then used extensively as a toxic additive to antifouling paint for boats, were found to be higher in the mooring harbor areas where large numbers of boats were present. This may have been at least a partial cause of the differences in hard-bottom communities observed. Similar effects on hard-bottom epifaunal species attributed to TBT (Valkirs and Davidson 1987; Salazar and Salazar 1991) and copper in possible combination with other toxic chemicals (Johnston 1989, 1990; VanderWeele 1996) have been evaluated in Shelter Island Yacht Harbor and elsewhere in San Diego Bay.

The concentrations of TBT, then used extensively as a toxic additive to antifouling paint for boats, were found to be higher in the mooring harbor areas where large numbers of boats were present. This may have been at least a partial cause of the differences in hard-bottom communities observed.

2.6.4 Fishes

San Diego Bay provides extensive and diverse habitats for fishes including deep channels, shallow areas with eelgrass, and salt marshes. Bays and estuaries are known to be important nursery and refuge areas for marine fishes (Cronin and Mansueti 1971; Haedrich and Hall 1976). The warm temperatures during the spring and summer months, as well as their high productivity, enable them to support large numbers of juvenile fishes. Although bays and estuaries in southern California are relatively small and scarce, they do function as nursery and refuge areas for some species. At

The warm water temperatures present in bays and estuaries during the spring and summer months, as well as their high productivity, enable them to support large numbers of juvenile fishes.

least one commercially and recreationally important species, the California halibut, is known to rely on southern California bays and estuaries as nursery areas (Allen 1988; Kramer 1990). Other fisheries species, including the kelp bass, appear to use these bays as alternative habitat refuges for a portion of their life histories. Juveniles of other fish species can be extremely abundant and usually dominate the fish species assemblages of bays and estuaries in the SCB (Allen 1982). Many of these abundant species (e.g. gobies, anchovies, and silversides) are important forage fishes for fish species of commercial or sport fishing value (Horn 1980) and for sea birds. Another important, but often overlooked, characteristic of the fishes inhabiting southern California bays and estuaries is that they form distinct species assemblages found nowhere else (Horn 1980; Horn and Allen 1981; Allen 1985, 1997; Macdonald *et al.* 1990). In terms of the movement of species, the fish assemblage found in the bay may be classified as resident, seasonal, or visitor (Merkel & Associates 2008).

Fish monitoring studies began in the late 1960s, primarily concentrated in south San Diego Bay (Ford 1968, 1985; Ford *et al.* 1971a; Lockhead 1979; Macdonald *et al.* 1980; SDG&E 1980; Lockhead 1983). Work by McGowen (1977, 1981). SDG&E (1980) was concerned with larval fishes (ichthyoplankton) of the south bay and their entrainment in the cooling water system of the South Bay Power Plant (since closed), as described in Section 2.6.1: Plankton. Information about fish populations and their species assemblages of the central and north bay regions had been more limited, based on larger-scale studies in the central bay by Lockheed (1983), baywide studies by Peeling (1975) and Lockheed (1979), and site-specific work by Ford and Macdonald (1986) and Macdonald *et al.* 1990.

The first comprehensive study on fish populations in San Diego Bay was completed by Allen (1999).

In July 1994, Dr. Larry G. Allen began conducting surveys in San Diego Bay to: identify, quantify, and determine the season utilization of the fishery populations in San Diego Bay; identify key habitats that support juvenile fish species; and determine geographic and/or habitat areas of San Diego Bay that support significant populations of fish species utilized as forage by endangered avian species (Allen 1999). The overall goal of these surveys was to provide the first definitive assessment of the fish populations inhabiting San Diego Bay. Sampling initially occurred on a quarterly basis, beginning in July 1994 and ending in April 1999 and included a total of 20 sampling dates. Sampling dates have since been replicated in April and July 2005, 2008, and 2012. These surveys have continued to add important data about fish populations in the bay (VRG 2006, 2009, 2012). The following sections are a synopsis of data from these surveys.

2.6.4.1 Composition and Abundance

Allen (1999) and VRG (2006, 2009, 2012) recorded the number of species caught during surveys, biomass, and abundance (Table 2-19). Allen (1999) reported the highest number of species caught (78 species); however, this included 20 sampling dates while VRG (2006, 2009, and 2012) each included only two sampling dates (Table 2-19).

Table 2-19. Numerical Catch and Biomass of Fishes Collected during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

Survey Dates	Number of Species Caught	Weight (kilograms)	Abundance (number of fishes)
July 1994-April 1999 (20 sampling dates)	78	2,775	497,344
April and July 2005	57	910	24,457
April and July 2008	48	183	15,692
April and July 2012	52	348	17,263

In 1999, northern anchovy was the most abundant fish species (Table 2-20) despite its virtual absence in 1997-1998 due to the El Niño event. During this time, the greatest, detectable impact on fish assemblages in San Diego Bay was the generally low abundance of schooling, planktivorous species, including northern anchovy, topsmelt, slough anchovy, sardine, and shiner surfperch (Allen 1999). Of the most abundant schooling fishes, topsmelt and slough anchovy seemed to be the least affected by the El Niño event. Overall, the abundance of these planktivorous species was significantly and negatively correlated with summer-fall (July-October) surface water temperature over the entire 1994-1999 sampling period. Over the last two sampling events (2008 and 2012), northern anchovy has not been included in the most abundant fish species caught. However, throughout this study topsmelt, slough anchovy, and shiner surfperch have continued to be one of the most abundant fish species caught (Table 2-20).

Table 2-20. Most Abundant Fish Species during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

July 1994-April 1999 (20 sampling dates)	April and July 2005	April and July 2008	April and July 2012
northern anchovy	topsmelt	slough anchovy	topsmelt
topsmelt	deepbody anchovy	topsmelt	arrow goby
slough anchovy	slough anchovy	shiner surfperch	shiner surfperch
Pacific sardine	northern anchovy	salema	giant kelpfish
shiner surfperch	shiner surfperch	arrow goby	slough anchovy

Round stingray has continued to dominate in weight over the length of the study (Table 2-21). Spotted sand bass has also consistently been included in the list of highest biomass of fish species caught.

Table 2-21. Fish Species with the Highest Biomass during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

July 1994-April 1999 (20 sampling dates)	April and July 2005	April and July 2008	April and July 2012
round stingray	round stingray	round stingray	round stingray
spotted sand bass	bat ray	spotted sand bass	spotted sand bass
northern anchovy	spotted sand bass	topsmelt	bat ray
bat ray	deepbody anchovy	slough anchovy	California butterfly ray
topsmelt	topsmelt	California butterfly ray	shiner surfperch

In 1999, the greatest number of individuals was taken at Station 1 followed by Station 2 (Table 2-22). The high count at Station 1 and 2 compared to other stations was due to the large numbers of juvenile northern anchovy, Pacific sardine, and topsmelt taken at these stations in most years (Allen 1999).

The abundance at the North-Central Ecoregion in 2005 (Table 2-22) was elevated in part because of the presence of schools of deepbody anchovy and juvenile topsmelt that comprised over 81% of all fishes (VRG 2009). Alternatively, deepbody anchovy were relatively rare at the South-Central Ecoregion where total abundance was dramatically lower.

Table 2-22. Number of Individuals Collected from Sampling Stations during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

	July 1994-April 1999 (20 sampling dates)	April and July 2005	April and July 2008	April and July 2012
Station 1 (North Ecoregion)	198,141	4,237	7,233	4,244
Station 2 (North-Central Ecoregion)	188,147	12,357	3,355	5,645
Station 3 (South-Central Ecoregion)	57,892	2,346	2,666	3,422
Station 4 (South Ecoregion)	53,164	5,336	2,438	9,952

The Pacific sardine that was common in the 1994-1999 surveys was virtually absent in 2008 (VRG 2009). Topsmelt, northern anchovy, and deepbody anchovy were most abundant in the northern portion of the bay while the slough anchovy was most abundant in the southern Ecoregions (Table 2-23).

In 2008, catch of shiner surfperch increased to the south with a high in the South-Central Ecoregion (Table 2-22). The slough anchovy and topsmelt decreased from the North to South Ecoregion with their lowest catch at the South-Central Ecoregion. Arrow gobies were caught in greater numbers in the North and South Ecoregions while salema were only caught in the North Ecoregion (VRG 2009).

In 2012, catch of topsmelt was higher in the North and North-Central Ecoregions and decreased towards the south (Table 2-22). Arrow gobies increased in abundance from the north to south, as did slough anchovy, with few arrow gobies and no slough anchovy being caught in the North Ecoregion. shiner surfperch were caught in the greatest number in the South-Central Ecoregion, and giant kelpfish were caught in the greatest number in the North-Central Ecoregion.

Table 2-23. Most Abundant Fish Collected by Ecoregion during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

Ecoregion	July 1994-April 1999 (20 sampling dates)	April and July 2005	April and July 2008	April and July 2012
North Ecoregion	northern anchovy	topsmelt	slough anchovy	topsmelt
	topsmelt	northern anchovy	topsmelt	giant kelpfish
	Pacific sardine	California grunion	salema	dwarf surfperch
	slough anchovy	giant kelpfish	arrow goby	round stingray
	California grunion	dwarf perch	giant kelpfish	bay pipefish
North-Central Ecoregion	northern anchovy	deepbody anchovy	slough anchovy	topsmelt
	topsmelt	topsmelt	topsmelt	giant kelpfish
	slough anchovy	shiner surfperch	giant kelpfish	shiner surfperch
	jacksmelt	slough anchovy	bay pipefish	slough anchovy
	shiner surfperch	giant kelpfish	shiner surfperch	arrow goby
South-Central Ecoregion	slough anchovy	slough anchovy	shiner surfperch	shiner surfperch
	topsmelt	topsmelt	slough anchovy	arrow goby
	northern anchovy	deepbody anchovy	bay pipefish	topsmelt
	shiner surfperch	bay pipefish	spotted sand bass	slough anchovy
	bay pipefish	shiner surfperch	topsmelt	bay pipefish
South Ecoregion	slough anchovy	slough anchovy	slough anchovy	arrow goby
	topsmelt	topsmelt	shiner surfperch	slough anchovy
	arrow goby	round stingray	topsmelt	shiner surfperch
	round stingray	northern anchovy	arrow goby	topsmelt
	shiner surfperch	shiner surfperch	round stingray	round stingray

Table 2-24 lists the fish species with the highest biomass caught during this study separated by ecoregion.

In 1999, large catches of round stingray and spotted sand bass were taken across all stations (Table 2-24). Large catches of northern anchovy occurred at Station 1 and 2, in addition to those of stingrays and spotted sand bass yielded much higher biomass in the northern part of the bay (Allen 1999).

Round stingrays were dominate in terms of biomass at all ecoregions throughout the bay in 2005 (Table 2-24). Spotted sand bass were also found in large numbers throughout the bay.

Table 2-25 through Table 2-28 list the number of species, abundance, and biomass of fishes collected in each Ecoregion of the bay.

Table 2-24. Fish Species with the Highest Biomass by Ecoregion during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

Ecoregion	July 1994-April 1999 (20 sampling dates)	April and July 2005	April and July 2008	April and July 2012
North Ecoregion	round stingray	round stingray	salema	round stingray
	bat ray	topsmelt	slough anchovy	spotted sand bass
	northern anchovy	Pacific angel shark	topsmelt	topsmelt
	topsmelt	diamond turbot	round stingray	California halibut
	spotted sand bass	California halibut	spotted sand bass	giant kelpfish
North-Central Ecoregion	round stingray	round stingray	spotted sand bass	round stingray
	spotted sand bass	bat ray	shortfin corvina	spotted sand bass
	northern anchovy	spotted sand bass	topsmelt	shiner surfperch
	topsmelt	deepbody anchovy	giant kelpfish	diamond stingray
	slough anchovy	shiner surfperch	slough anchovy	diamond turbot
South-Central Ecoregion	round stingray	round stingray	spotted sand bass	bat ray
	spotted sand bass	spotted sand bass	California corbina	spotted sand bass
	slough anchovy	Pacific bonito	shiner surfperch	round stingray
	topsmelt	topsmelt	California halibut	spotfin croaker
	California halibut	barred sand bass	barred sand bass	shiner surfperch
South Ecoregion	round stingray	round stingray	spotted sand bass	round stingray
	spotted sand bass	bat ray	California butterfly ray	California butterfly ray
	bat ray	spotted sand bass	shiner surfperch	spotted sand bass
	barred sand bass	shovelnose guitarfish	slough anchovy	yellowfin croaker
	slough anchovy	slough anchovy	topsmelt	gray smoothhound

Table 2-25. Numerical Catch and Biomass of Fishes Collected in the North Ecoregion during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

Survey Dates	Number of Species Caught	Weight (kilograms)	Abundance (number of fishes)
July 1994-April 1999 (20 sampling dates)	68	985.5	198,141
April and July 2005	38	59	4,237
April and July 2008	33	36.2	7,233
April and July 2012	30	119.7	4,244

Table 2-26. Numerical Catch and Biomass of Fishes Collected in the North-Central Ecoregion during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

Survey Dates	Number of Species Caught	Weight (kilograms)	Abundance (number of fishes)
July 1994-April 1999 (20 sampling dates)	55	759.2	188,147
April and July 2005	38	121	12,537
April and July 2008	27	55	3,355
April and July 2012	37	83	5,645

Table 2-27. Numerical Catch and Biomass of Fishes Collected in the South-Central Ecoregion during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

Survey Dates	Number of Species Caught	Weight (kilograms)	Abundance (number of fishes)
July 1994-April 1999 (20 sampling dates)	49	440.2	57,892
April and July 2005	25	34	2,346
April and July 2008	23	43	2,666
April and July 2012	32	70.7	3,422

Table 2-28. Numerical Catch and Biomass of Fishes Collected in the South Ecoregion during Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

Survey Dates	Number of Species Caught	Weight (kilograms)	Abundance (number of fishes)
July 1994-April 1999 (20 sampling dates)	51	590.4	53,164
April and July 2005	23	95	5,336
April and July 2008	25	49	2,438
April and July 2012	30	74.8	3,952

2.6.4.2 Seasonal Changes in Abundance and Biomass

Due to small sample size, VRG (2006, 2009, 2012) did not make seasonal correlations of changes in fish abundance and biomass. However, Allen (1999) found substantial changes in the number of individuals and total biomass over the course of the 20 sampling dates. Abundance was highest in the spring (April 1995, 1996, 1997, 1998, and 1999) and summer (July 1995, 1996, and 1998) months, based on pooling the data for all species and stations (Figure 2-15). Heavy recruitment of juvenile surfperches and topsmelt in April of 1995 and 1996 appear to be largely responsible for spring abundance peaks. Large numbers of topsmelt, slough anchovy, shiner surfperch, and California grunion contributed to high abundance in April 1997 while April 1998 surveys were dominated by slough anchovy. Extremely large catches of juvenile northern anchovy and Pacific sardine caused the pronounced peaks in July 1995 and 1996. The virtual absence of northern anchovy during the July 1997 surveys caused low abundance during this time. The July 1998 catch was dominated by slough anchovy, northern anchovy and topsmelt (Allen 1999).

Lowest abundances were encountered in January 1995, 1996, 1997, and 1999 when water temperatures were lowest. In January 1998, fish abundance tripled from previous January samples due to high recruitment of jacksmelt. This abundance pattern was consistent among Stations 1, 2, and 3. However, fishes at the southernmost location (Station 4) exhibited peak abundance in October 1994, 1996, and April 1998 (Allen 1999).

Biomass varied greatly from season to season (Figure 2-17 on page 100). This appeared to be related primarily to the abundances of northern anchovy, round stingrays, bat rays, and spotted sand bass. Biomass values of the fish samples consistently were highest in the spring (April 1995, 1996,1997, and 1998) and the summer (July 1995 and 1996). Significant catches of bat rays in October 1998 at Station 1 and January 1999 at Station 4 greatly disrupted the pattern of the first four years.

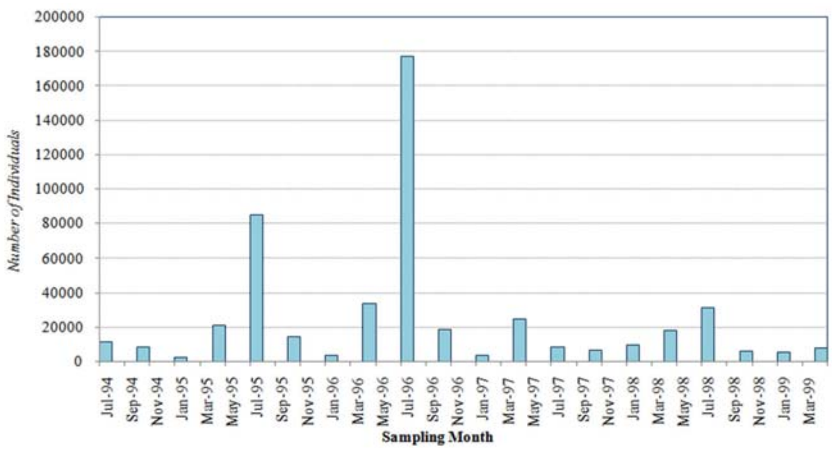


Figure 2-15. Abundance of fishes in San Diego Bay by sampling period (Allen 1999).

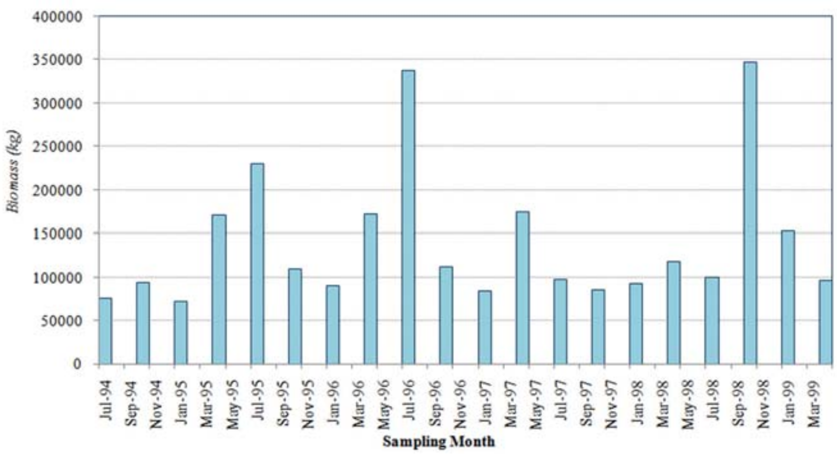


Figure 2-16. Biomass of fishes in San Diego Bay by sampling period (Allen 1999).

2.6.4.3 Ecological Importance of Fish Species

Ecologically important species within the bay were quantified in Allen (1999) and VRG (2006, 2009, 2012) with the use of the important ecological variables (% Number, % Weight, % Frequency) for each species collected for the study to determine an ecological index value (Table 2-29). This index is indicative of the importance of each species to the energy flow within the fish component of the San Diego Bay ecosystem.

Table 2-29. Top Ecologically Important Fish Species in San Diego Bay based on the Ecological Index for Surveys from 1994-2012 (Allen 1999; VRG 2006, 2009, 2012).

July 1994-April 1999 (20 sampling dates)	April and July 2005	April and July 2008	April and July 2012
topsmelt	round stingray	slough anchovy	round stingray
round stingray	topsmelt	round stingray	topsmelt
northern anchovy	slough anchovy	spotted sand bass	spotted sand bass
slough anchovy	deepbody anchovy	topsmelt	shiner surfperch
spotted sand bass	spotted sand bass	shiner surfperch	arrow goby
barred sand bass	shiner surfperch	arrow goby	giant kelpfish
California halibut	northern anchovy	giant kelpfish	bat ray
shiner surfperch	bat ray	bay pipefish	slough anchovy
Pacific sardine	California halibut	California halibut	California halibut
giant kelpfish	barred sand bass	barred sand bass	bay pipefish

Round stingray have consistently ranked high, indicating that this species remains one of the most important resident species in San Diego Bay (Table 2-29). Topsmelt also ranked high in all study periods. Topsmelt are an important resident schooling species in the bay that are also prey items for birds and predatory fish (VRG 2006). Spotted sand bass was the most important predatory species in San Diego Bay (VRG 2006).

2.6.4.4 Patterns of Biodiversity and Species Assemblages

There is considerable overlap in the composition of numerically dominant or important fish species within different areas of the bay (Allen 1999). Northern anchovy was the most abundant species in both the north and north-central areas of the bay, while the slough anchovy was the most abundant form in the south-central and south bay regions. Topsmelt, shiner surfperch, and the round stingray were relatively common in all four regions.

However, surveys also concluded that fish assemblages sampled in the north, north-central, south-central, and south bay regions showed subtle differences from one another, in both species composition and the relative abundances of the fish species found. Allen (1999) illustrated these subtle differences qualitatively in a series of figures which we have adapted for this INRMP (Figures 2-17 through 2-20).

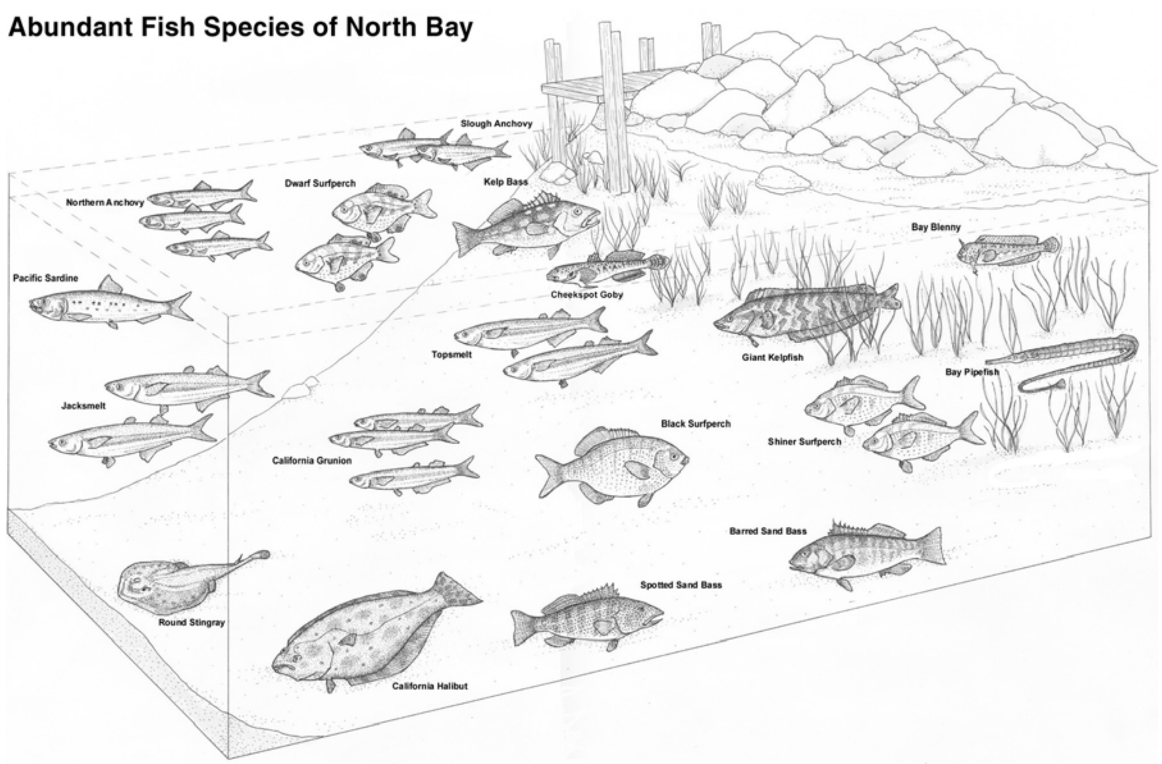


Figure 2-17. Abundant fish species of North Bay, based on Allen 1999.

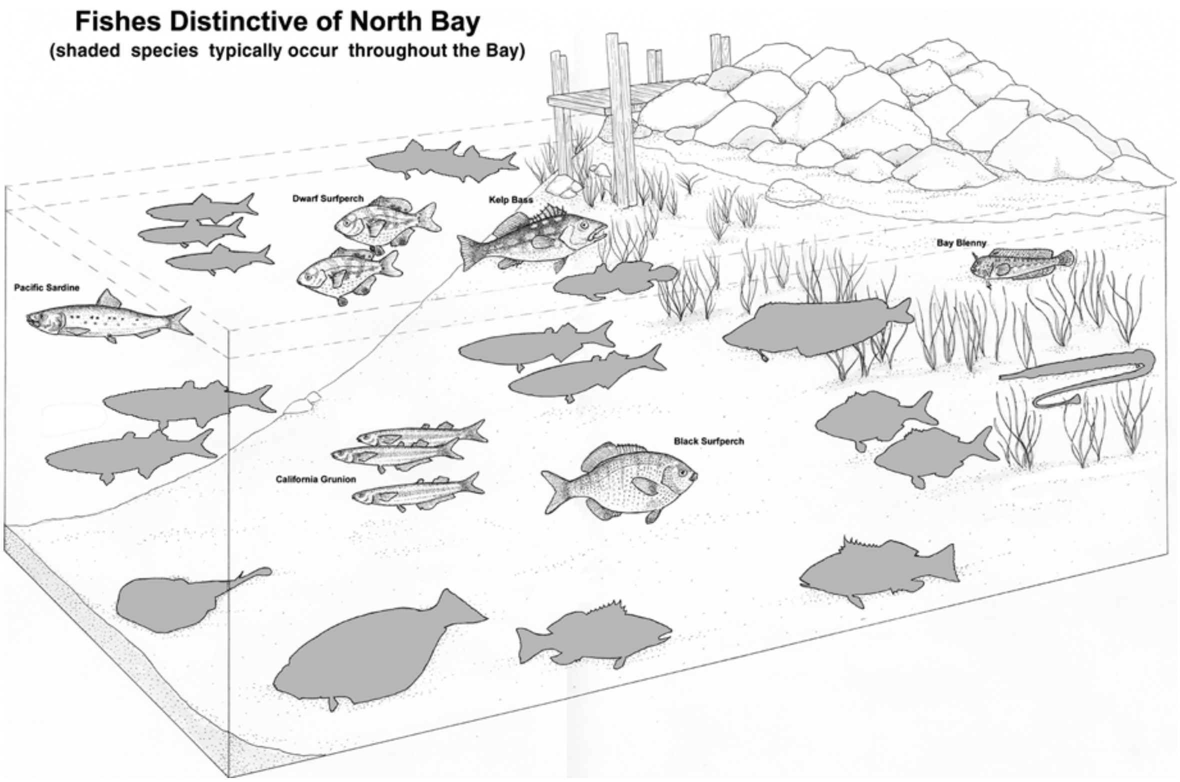


Figure 2-18. Fishes distinctive of North Bay, and not typically found in South Bay, based on Allen 1999.

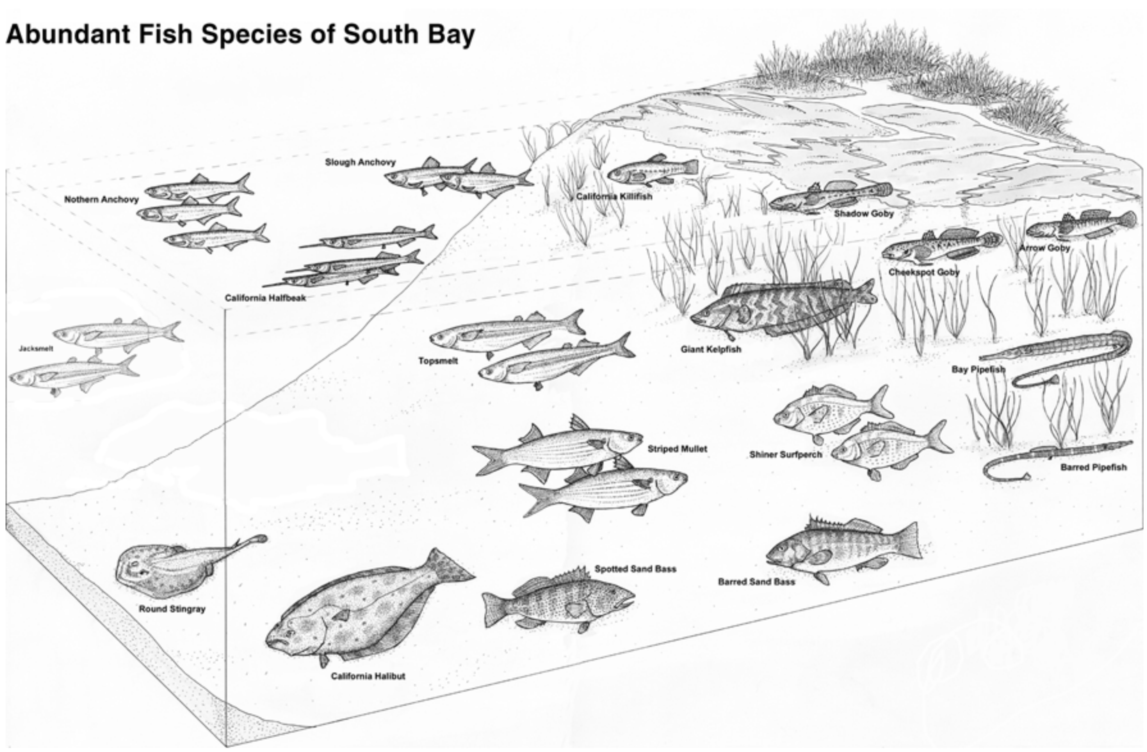


Figure 2-19. Abundant fish species of South Bay, based on Allen 1999.

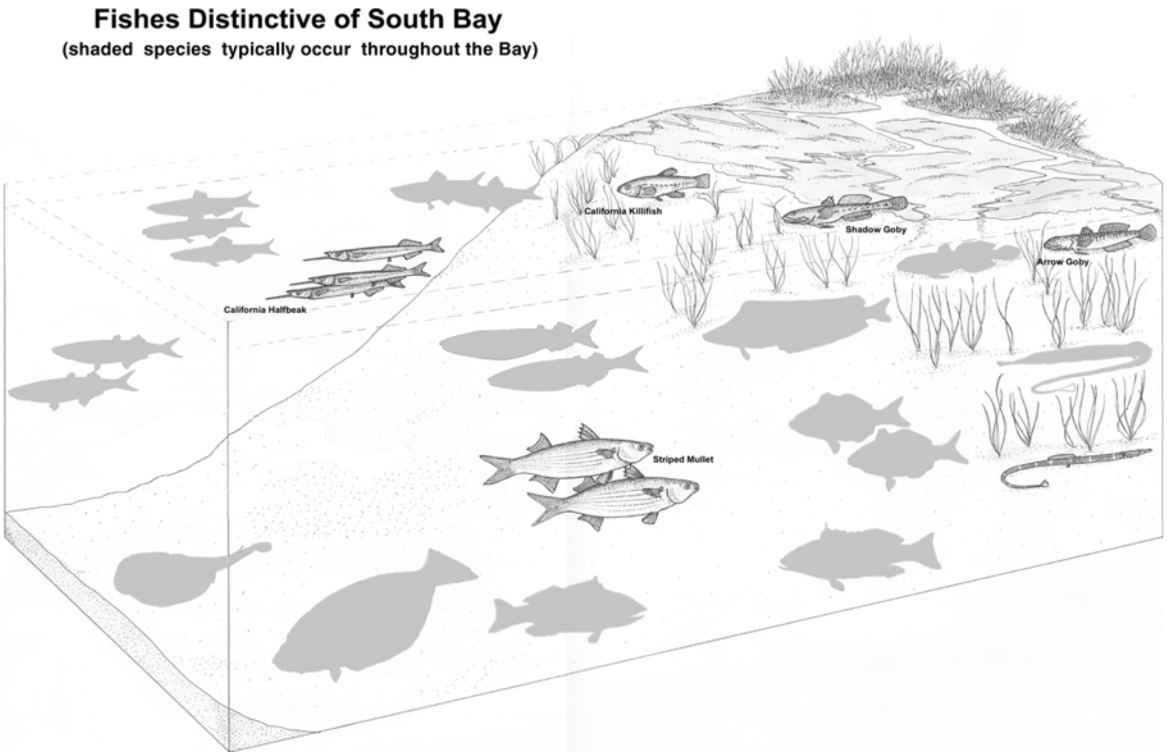


Figure 2-20. Fishes distinctive of South Bay, and not typically found in North Bay, based on Allen 1999.

2.6.4.5 Density and Standing Stock

San Diego Bay remains one of the most productive fish habitats known in California based on estimates of density and standing stock (VRG 2006; Table 2-30). In 1999, most of the individuals included northern anchovy, followed by the slough anchovy, topsmelt, Pacific sardine, arrow goby, and shiner surfperch. Among the most common, higher-level carnivores are round stingrays, spotted sand bass, barred sand bass, and California halibut (Allen 1999).

In 2005, many of the individuals were comprised of deepbody anchovy, slough anchovy, and northern anchovy. Eelgrass associated fishes were also very abundant including bay pipefish, giant kelpfish, shiner surfperch. Large predatory fishes including round stingray, spotted sand bass, and California halibut were also abundant and distributed throughout the bay. Juvenile kelp bass and barred sand bass also inhabited the bay in large numbers and appear to use the bay as a nursery area. The standing stock was highest in the South Ecoregion followed by North-Central, South-Central, and North. The best estimate of biomass density and stock are lower than Allen (1999); however, this could be as a result of year-round sampling was not being completed and the shorter sampling duration (VRG 2006).

Table 2-30. Best Estimates of Density and Standing Stock for San Diego Bay (Allen 1999; VRG 2006, 2009, 2012).

	July 1994-April 1999 (20 sampling dates)	April and July 2005	April and July 2008	April and July 2012
Total Stock Size (fishes)	85,000,000	56,000,000	24,776,133	16,153,537
Fish Density (individual/m^2)	1.75	1.16	0.51	0.33
Biomass (kg)	305,000	249,000	190,892	459,754
Overall Estimate (g/m^2)	7.05	5.14	3.93	9.46

In 2008, nearly half of the estimated stock was slough anchovy. Salema, arrow goby, shiner surfperch, topsmelt, bay pipefish, and giant kelpfish also dominated the stock estimate. The standing stock was highest in the South Ecoregion and followed closely by the South-Central Ecoregion. The North Ecoregion and North-Central Ecoregion were much lower (VRG 2009).

In 2012, the highest estimated fish species was giant kelpfish, followed by topsmelt, arrow goby, shiner surfperch, and slough anchovy. The stock estimate in 2012 was far lower than in any other survey (Table 2-30), though the biomass standing stock was the highest of any other survey. This is due to the comparatively low number of small schooling fishes and higher number of large predators, such as round stingray, spotted sand bass, and bat ray (VRG 2012).

2.6.4.6 Functional Groups of Fishes

Using cluster analyses of fish data for 1994–1997, Allen (*pers. comm.*) identified distinct species groups of San Diego Bay. The clustering strategy was based on fish abundances by station, month of capture, and sampling gear type. The clustering method employed Pearson's correlation coefficient among all possible combinations of 36 species with complete linkage (L. Allen, California State University Northridge, *pers. comm.*).

Species Associated with Eelgrass and Subtidal Unvegetated Habitat

The results of these cluster analyses identified eleven species of fishes closely associated with eelgrass habitat in San Diego Bay. These are listed in Table 2-31.

Table 2-31. San Diego Bay fish species closely associated with subtidal eelgrass habitat.

Scientific Name	Common Name		Scientific Name	Common Name
Cymatogaster aggregata	shiner surfperch		*Micrometrus minimum*	dwarf surfperch
Embiotoca jacksoni	black surfperch		*Paralabrax clathratus*	kelp bass
Gibbonsia elegans	spotted kelpfish		*Paraclinus integripinis*	reef finspot
Heterostichus rostratus	giant kelpfish		*Syngnathus auliscus*	barred pipefish
Hypocampus ingens	Pacific seahorse		*Syngnathus leptorhynchus*	bay pipefish
Hypsoblennius gentilis	bay blenny			

A complete list of all fish species taken in eelgrass habitats is given in Table 2-32. A comparable list of all species of fishes taken in subtidal unvegetated habitat of unconsolidated sediment is shown in Table 2-33. Both of these species lists are based on samples taken in all four Ecoregions during the period 1994–1997 by Allen (1997). They were not produced by cluster analysis.

Allen (1999) found that very similar total numbers of fish were taken in intertidal and subtidal vegetated (239,607) and unvegetated (224,983) habitats over the period of July 1994 to April 1999. However, Allen (1999) concluded that the only meaningful way to evaluate both numerical and biomass densities among different habitats was to limit comparisons to data taken by the same gear-type. These comparisons are shown in Figure 2-21 and Figure 2-22.

Purse seine samples yielded total fish densities that were similar at vegetated and unvegetated sites (Figure 2-21), with slightly higher values at the unvegetated sites. However, purse seine catches were highly variable, and this small difference was not statistically significant (Allen 1999). For the large seine, fish densities were again slightly higher in unvegetated samples, but the difference was not significant. As shown in Figure 2-21, all other sampling methods yielded significantly higher catches in vegetated areas than in unvegetated areas.

Table 2-32. San Diego Bay fish species taken in subtidal eelgrass bed habitat.[a]

Scientific Name	Common Name	Scientific Name	Common Name
Urolophus halleri	round stingray	*Heterostichus rostratus*	giant kelpfish
Albula vulpes	bonefish	*Acanthogobius flavimanus*	yellowfin goby
Sardinops sagax caeruleux	pacific sardine	*Clevelandia ios*	arrow goby
Engraulis mordax	northern anchovy	*Gillichthys mirabilis*	longjaw mudsucker
Anchoa compressa	deepbody anchovy	*Ilypnus gilberti*	cheekspot goby
Anchoa delicatissima	slough anchovy	*Quietula y-cauda*	shadow goby
Hyporhamphus rosae	California halfbeak	*Tridentiger trigonocephalus*	chameleon goby
Strongylura exilis	California needlefish	*Xenistius californiensis*	salema
Fundulus parvipinnis	California killifish	*Umbrina roncador*	yellowfin croaker
Atherinopsis californiensis	jacksmelt	*Medialuna californiensis*	halfmoon
Atherinops affinis	topsmelt	*Cymatogaster aggregata*	shiner surfperch
Bryx arctos	snubnose pipefish	*Embiotoca jacksoni*	black surfperch
Syngnathus californiensis	kelp pipefish	*Micrometrus minimus*	dwarf surfperch
Syngnathus leptorhynchus	bay pipefish	*Mugil cephalus*	striped mullet
Syngnathus auliscus	barred pipefish	*Sphyraena argentea*	California barracuda
Syngnathus exilis	barcheek pipefish	*Hypsoblennius gentilis*	bay blenny
Leptocottus armatus	staghorn sculpin	*Hypsopsetta guttulata*	diamond turbot
Paralabrax nebulifer	barred sand bass	*Paralichthys californicus*	California halibut
Gibbonsia montereyensis	crevice kelpfish		

a. Based on Data for 1994–1997 (Allen 1997).

Table 2-33. San Diego Bay fish species taken in subtidal unvegetated, unconsolidated sediment habitat.[a]

Scientific Name	Common Name	Scientific Name	Common Name
Mustelus californicus	gray smoothhound	*Ilypnus gilberti*	cheekspot goby
Mustelus henlei	brown smoothhound	*Quietula y-cauda*	shadow goby
Myliobatis californica	bat ray	*Paralabrax clathratus*	kelp bass
Urolophus halleri	round stingray	*Paralabrax maculatofasciatus*	spotted sand bass
Sardinops sagax caeruleus	pacific sardine	*Paralabrax nebulifer*	barred sand bass
Engraulis mordax	northern anchovy	*Trachurus symmetricus*	jack mackerel
Anchoa compressa	deepbody anchovy	*Anisotremus davidsoni*	sargo
Anchoa delicatissima	slough anchovy	*Xenistius californiensis*	salema
Porichthys myriaster	specklefin midshipman	*Seriphus politus*	queenfish
Hyporhamphus rosae	California halfbeak	*Atractoscion nobilis*	white sea bass
Strongylura exilis	California needlefish	*Cheilotrema saturnum*	black croaker
Leuresthes tenuis	California grunion	*Cynoscion parvipinnis*	shortfin corvina
Atherinopsis californiensis	jacksmelt	*Umbrina roncador*	yellowfin croaker
Atherinops affinis	topsmelt	*Cymatogaster aggregata*	shiner surfperch
Bryx arctos	snubnose pipefish	*Embiotoca jacksoni*	black surfperch
Syngnathus californiensis	kelp pipefish	*Micrometrus minimus*	dwarf surfperch
Hippocampus ingens	pacific seahorse	*Phanerodon furcatus*	white surfperch
Syngnathus leptorhynchus	bay pipefish	*Mugil cephalus*	striped mullet
Syngnathus auliscus	barred pipefish	*Sphyraena argentea*	California barracuda
Scorpaena guttata	spotted scorpionfish	*Oxyjulis californica*	senorita
Gibbonsia elegans	spotted kelpfish	*Halichoeres semicinctus*	rock wrasse
Gibbonsia montereyensis	crevice kelpfish	*Hypsoblennius gentilis*	bay blenny
Gibbonsia metzi	striped kelpfish	*Scomber japonicus*	Pacific mackerel
Heterostichus rostratus	giant kelpfish	*Citharichthys stigmaeus*	speckled sand dab
Acanthogobius flavimanus	yellowfin goby	*Hypsopsetta guttulata*	diamond turbot
Clevelandia ios	arrow goby	*Paralichthys californicus*	California halibut
Gillichthys mirabilis	longjaw mudsucker	*Pleuronichthys ritteri*	spotted turbot

a. Based on Data for 1994–1997 (Allen 1997).

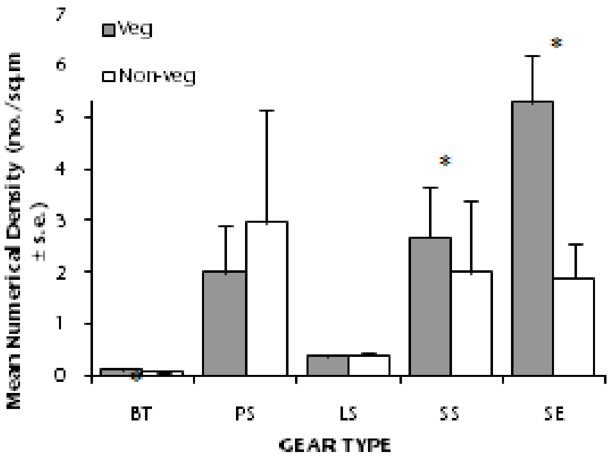


*Figure 2-21. Comparison of fish numerical density in vegetated and unvegetated samples. Gear type: BT=Beam Trawl, PS=Purse Seine, LS=Large Seine, SS=Small Seine, SE=Square Seine. *Statistically significant differences.*

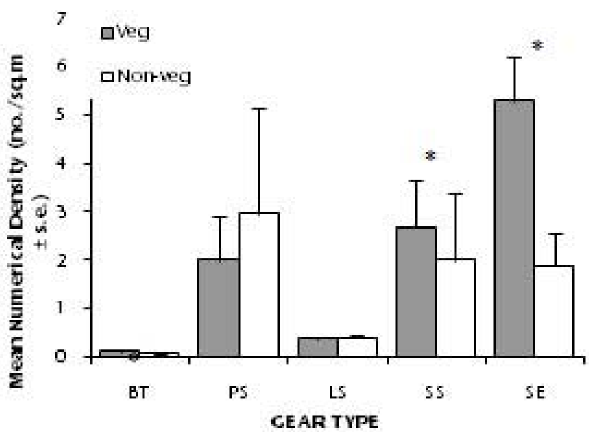


*Figure 2-22. Comparison of fish biomass density in vegetated and unvegetated sites. Gear type: BT=Beam Trawl, PS=Purse Seine, LS=Large Seine, SS=Small Seine, SE=Square Seine. *Statistically significant differences.*

All three seining methods captured comparable biomass densities in unvegetated and vegetated areas (Figure 2-22). While densities in unvegetated areas were slightly higher than in vegetated areas, the differences were not significant for any of the seining methods. The biomass values measured by using the beam trawl and square enclosure were significantly greater in the vegetated than the unvegetated areas (Allen 1999).

VRG (2006) used data collected in 2005 to compare vegetated versus non-vegetated areas of the bay. However, during the 1994-1999 survey periods, the distribution of eelgrass started changing, diffusing the effect of the comparison design. Thus, it was not surprising that a similar number of fishes were taken from vegetated and non-vegetated areas (224,983 for non-vegetated; 239,607 for vegetated; Allen 1999). VRG (2006) duplicated the original sampling design but used a map of the eelgrass from 2004 to determine post hoc which stations were surveyed in vegetated areas vs. non-vegetated areas. From the eelgrass map it was clear that the amount of eelgrass coverage in San Diego Bay had greatly increased. Density was higher in eelgrass samples for five of six species examined; only kelp bass were slightly more abundant in non-vegetated areas. However, significant differences were only detected with shiner surfperch (Mann-Whitney, U = 14.4, P = 0.001) and spotted sand bass (Mann-Whitney, U = 153.0, P = 0.012). Even though there is a clear pattern across all taxa, with the exception of kelp bass, the reason the differences were not significant in some cases was due to the low sample size and associated high variances around the mean values (VRG 2006).

The data suggest that eelgrass provides valuable habitat for several important species in San Diego Bay. Kelp bass, giant kelp fish, barred sand bass and California halibut utilize the eelgrass primarily as juveniles while spotted sand bass and shiner surf-perch are present in this habitat throughout their lives. Eelgrass increases complexity in habitat and provides a source of food and refuge for juvenile fishes that may lead to increased survivorship and increased adult populations. Continued sampling may allow for a greater understanding of the species that benefit from this habitat including estimations of growth, survivorship and movement patterns of juvenile fishes in the eelgrass. It is important to fully understand these dynamics to document the importance of this habitat for juvenile, estuarine and nearshore fishes that utilize this habitat (VRG 2006).

Conclusions of significantly higher catches in vegetated sites in Allen (1999) and VRG (2006) are consistent with the results of Hoffman (1986), who concluded that catches were generally twice as large over eelgrass compared to unvegetated sites. Allen (1999) concluded that the data from the small seine, large seine, and purse seine sampling should be interpreted with caution, both because of variability in catches and because the unvegetated sites sampled had varying degrees of eelgrass coverage. He also noted that when making the original selection of station sites, it was difficult to locate truly unvegetated sites. As a result, it was difficult to make clear comparisons. Additionally, seasonal growth and die-off of eelgrass most likely added to the variance in fish catches (Allen 1999).

Fishes Associated with Deep Subtidal Habitats

The group of fish species taken in deep subtidal habitats (>20 feet [6 m] below MLLW) is listed in Table 2-34. This species list, which was not produced by cluster analysis, is based on all samples taken during the period 1994–1997 (Allen 1997).

Table 2-34. San Diego Bay fish species taken in deep subtidal habitats.[a]

Scientific Name	Common Name	Scientific Name	Common Name
Heterodontus francisi	California horn shark	*Xenistius californiensis*	salema
Mustelus californicus	gray smoothhound	*Seriphus politus*	queenfish
Rhinobatus productus	shovelnose guitarfish	*Atractoscion nobilis*	white sea bass
Myliobatis californica	bat ray	*Cheilotrema saturnum*	black croaker
Urolophus halleri	round stingray	*Genyonemus lineatus*	white croaker
Sardinops sagax caeruleux	pacific sardine	*Roncador stearnsii*	spotfin croaker
Engraulis mordax	northern anchovy	*Umbrina roncador*	yellowfin croaker
Anchoa compressa	deepbody anchovy	*Cymatogaster aggregata*	shiner surfperch
Anchoa delicatissima	slough anchovy	*Embiotoca jacksoni*	black surfperch
Synodus lucioceps	California lizardfish	*Phanerodon furcatus*	white surfperch
Porichthys myriaster	specklefin midshipman	*Mugil cephalus*	striped mullet
Porichthys notatus	plainfin midshipman	*Oxyjulis californica*	senorita
Hyporhamphus rosae	California halfbeak	*Halichoeres semicinctus*	rock wrasse
Strongylura exilis	California needlefish	*Hypsoblennius gentilis*	bay blenny
Atherinopsis californiensis	jacksmelt	*Heterostichus rostratus*	giant kelpfish
Atherinops affinis	topsmelt	*Scomber japonicus*	Pacific mackerel
Syngnathus californiensis	kelp pipefish	*Citharichthys stigmaeus*	speckled sand dab
Hippocampus ingens	Pacific seahorse	*Xysteurys liolepis*	fantail sole
Syngnathus leptorhynchus	bay pipefish	*Symphurus atricauda*	California tonguefish
Syngnathus auliscus	barred pipefish	*Hypsopsetta guttulata*	diamond turbot
Scorpaena guttata	spotted scorpionfish	*Paralichthys californicus*	California halibut
Leptocottus armatus	staghorn sculpin	*Pleuronectes vetulus*	English sole
Paralabrax clathratus	kelp bass	*Pleuronichthys coenosus*	CO turbot
Paralabrax maculatofasciatus	spotted sand bass	*Pleuronichthys ritteri*	spotted turbot
Paralabrax nebulifer	barred sand bass	*Pleuronichthys verticalis*	hornyhead turbot

a. Based on Data for 1994–1997 (Allen 1997).

Fishes Associated with Artificial, Man-made Habitats

Fishes associated with artificial or man-made habitats have not been studied extensively in San Diego. The species list shown in Table 2-35 was compiled by reviewing data from a large series of ecological studies conducted to develop environmental impact statements for projects throughout the bay (Ford and Macdonald 1986; Michael Brandman and Associates 1989).

The species listed in Table 2-35 also occur in other natural bay habitats. However, apparently they are adaptable enough to occupy areas that have been disturbed or modified by the presence of rock riprap, concrete bulkheads, piers, marina floats, and a wide variety of other artificial habitats.

Table 2-35. San Diego Bay fish species associated with artificial, man-made habitats.

Scientific Name	Common Name	Scientific Name	Common Name
Platyrhinoidis triseriata	thornback	*Medialuna californiensis*	halfmoon
Rhinobatus productus	shovelnose guitarfish	*Cymatogaster aggregata*	shiner surfperch
Urolophus halleri	round stingray	*Damalichthys vacca*	pile surfperch
Sardinops sagax caeruleux	Pacific sardine	*Embiotoca jacksoni*	black surfperch
Engraulis mordax	northern anchovy	*Hyperprosopon argenteum*	walleye surfperch
Anchoa compressa	deepbody anchovy	*Phanerodon furcatus*	white surfperch
Anchoa delicatissima	slough anchovy	*Rhacochilus toxotes*	rubberlip surfperch
Porichthys myriaster	specklefin midshipman	*Hypsoblennius gentilis*	bay blenny
Atherinops affinis	topsmelt	*Hypsoblennius jenkensi*	mussel blenny
Syngnathus leptorhynchus	bay pipefish	*Paraclinus integripinnis*	reef finspot
Scorpaena guttata	spotted scorpionfish	*Gibbonsia elegans*	spotted kelpfish
Leptocottus armatus	staghorn sculpin	*Gibbonsia montereyensis*	crevice kelpfish
Paralabrax clathratus	kelp bass	*Heterostichus rostratus*	giant kelpfish
Paralabrax maculatofasc	spotted sand bass	*Clevelandia ios*	arrow goby
Paralabrax nebulifer	barred sand bass	*Ilypnus gilberti*	cheekspot goby
Anisotremus davidsoni	sargo	*Lepidogobius lepidus*	bay goby
Seriphus politus	queenfish	*Quietula y-cauda*	shadow goby
Cheilotrema saturnum	black croaker	*Scomber japonicus*	Pacific mackerel
Genyonemus lineatus	white croaker	*Hypsopsetta guttulata*	diamond turbot
Umbrina roncador	yellowfin croaker	*Paralichthys californicus*	California halibut
Girella nigricans	opaleye		

Indigenous Bay-Estuarine Species Group

As shown in Table 2-36, the results of cluster analyses identified twelve species that form an indigenous bay-estuarine species group. These are species occur primarily in the shallow, estuarine habitats of south and central San Diego Bay. With the exception of the striped mullet, these species are restricted to bays and estuaries.

Table 2-36. Indigenous bay-estuarine species.

Scientific Name	Common Name
Anchoa compressa	deepbody anchovy
Anchoa delicatissima	slough anchovy
Fundulus parvipinnis	California killifish
Clevelandia ios	arrow goby
Gillichthys mirabilis	longjaw mudsucker
Syngnathus leptorhynchus	bay pipefish
Syngnathus auliscus	barred pipefish
Ilypnus gilberti	cheekspot goby
Mugil cephalus	striped mullet
Paralabrax maculatofasciatus	spotted sand bass
Hypsoblennius gentilis	bay blenny
Quietula y-cauda	shadow goby

2.6.4.7 Species Caught by Commercial or Recreational Fishing

Although commercial fishing is no longer permitted inside San Diego Bay, many commercial fish species utilize the bay, primarily during the juvenile life stage. Seven species inhabiting San Diego Bay support commercial fisheries in southern California waters. The most important of these fishery populations is the California halibut and, to a lesser extent, the white sea bass. The northern anchovy is taken commercially primarily for use as live bait. In addition, the Pacific sardine is taken as part of this catch. Fish caught for this purpose are held in bait receivers located in north San Diego Bay, where they are sold to commercial and recreational fishermen.

San Diego Bay is utilized extensively by recreational fishermen, including fishermen that fish primarily to obtain food. As shown in Table 2-37, at least 58 species are involved in recreational catch, although most of these are probably taken shiner surfperch only in very small numbers. During the most recent study (VRG 2012), 12 species were captured which have importance in either the recreational or commercial fisheries in California. Including all Ecoregions, standing stock estimates of fisheries species totaled 139 (mt). Estimates were greatest at the South-Central Ecoregion (58 mt), followed by the South (44 mt), North-Central 21 (mt), and North Ecoregions (15 mt).

Table 2-37. Recreational and Commercial fish species that utilize San Diego Bay. [a]

Scientific Name	Common Name	Scientific Name	Common Name
Osteichthyes	Bony Fish	*Pleuronichthys ritteri*	spotted turbot
Atherinops affinis	topsmelt	*Pleuronichthys verticalis*	hornyhead turbot
Atherinopsis californiensis	jacksmelt	*Cheilotrema saturnum*	black croaker
Leuresthes tenuis	California grunion	*Atractoscion nobilis**	white sea bass
Hippoglossina stomata	bigmouth sole	*Genyonemus lineatus*	white croaker
Xysteurys liolepis	fantail sole	*Menticurrhus undulatus*	California corbina
Caranx caballus	green jack	*Roncador stearnsii*	spotted croaker
Caranx hippos	crevalle jack	*Seriphus politus*	queenfish
Trachurus symmetricus	jack mackerel	*Umbrina roncador*	yellowfin croaker
Chanos chanos	milkfish	*Sarda chiliensis*	Pacific bonito
Clupea harengus pallasii	Pacific herring	*Scomber japonicus*	Pacific mackerel
*Sardinops sagax caeruleus**	Pacific sardine	*Scomberomorus sierra*	sierra
Scorpaena guttata	sculpin	*Medialuna californiensis*	halfmoon
Scorpaenichthys marmoratus	cabezon	*Morone saxatilis*	striped bass
Amphistichus argenteus	barred surfperch	*Paralabrax clathratus**	kelp bass
Cymatogaster aggregata	shiner surfperch	*Paralabrax maculatofasciatus*	spotted sand bass
Damalichthys vacca	pile surfperch	*Paralabrax nebulifer*	barred sand bass
Embiotoca jacksoni	black surfperch	*Sphyraena argentea*	California barracuda
Hyperprosopon argenteum	walleye surfperch	*Albula vulpes*	bonefish
Micrometrus minimus	dwarf surfperch	*Cynoscion parvipinnis*	shortfin corvina
Phanerodon furcatus	white surfperch	*Chondrichthyes*	Sharks and Rays
Rhacochilus toxotes	rubberlip surfperch	*Carcharhinus remotus*	narrowtooth shark
*Engraulis mordax**	northern anchovy	*Galeorhinus zyopterus*	soupfin shark
Girella nigricans	opaleye	*Mustelus californicus*	gray smoothhound
*Mugil cephalus**	striped mullet	*Mustelus henlei*	brown smoothhound
Hypsopsetta guttulata	diamond turbot	*Mustelus lunulatus*	sicklefin smoothhound
*Paralichthys californicus**	California halibut	*Prionace glauca*	blue shark
Platichthys stellatus	starry flounder	*Triakis semifasciata*	leopard shark
*Parophrys vetulus**	English sole	*Sphyma zygaena*	smooth hammerhead shark
Pleuronichthys coenosus	CO turbot	*Squalus acanthias*	spiny dogfish

*a. * Indicates species of commercial importance in southern California waters.*

2.6.4.8 Forage Species in San Diego Bay

Forage species are defined as those which are accessible to diving avian predators, particularly terns (Allen 1999). Forage species are typically silvery-sided, schooling fishes that spend a lot of their time near the surface of the water in all habitats. Over the course of the study (Allen 1999; VRG 2006, 2009, 2012) thirteen important species were captured including deepbody anchovy, slough anchovy, northern anchovy, California grunion, California halfbeak, topsmelt, jacksmelt, shiner surfperch, Pacific sardine, Pacific mackerel, striped mullet, giant kelpfish, and arrow goby. These species were primarily found at small (juvenile) size classes appropriate for nesting birds to feed their young in the area. They typical timing for the recruitment of fishes to San Diego Bay begins in the spring and continues through the summer (VRG 2012).

2.6.4.9 Southern Species in San Diego Bay

San Diego Bay is known for being the northern edge of the range for a number of southern fishes that are not normally distributed in the SCB (VRG 2012). San Diego Bay serves as a warm water refuge for tropical or warm-temperate species of fishes that normally occur farther south. This effect is most pronounced during and following strong El Niño conditions. A prime example is the Pacific seahorse (*Hippocampus ingens*), as described by Jones *et al.* (1988). This species became established in San Diego Bay during the 1980s El Niño events and has continued to take advantage of warm water conditions in the south bay.

Other unusual open water species were recently reported from San Diego Bay during the large El Niño event of 1997–1998 (LaRue 1998). Mike Irey, formerly involved in the fishery for striped mullet in south San Diego Bay, reported to LaRue (1998) that he has caught bigeye trevally (*Caranx sexfasciatus*), Pacific triple tail (*Lobotes pacificus*), and the Mexican lookdown (*Selene brevoortii*) in gill net gear. All three of these tropical species are normally found primarily in warmer Mexican waters to the south. During the strong El Niño conditions of 1997–1998, they are thought to have entered San Diego Bay and taken up residence in the warmer waters of the south bay. Water temperature effects produced by the South Bay Power Plant (not longer running) may possibly have contributed to their survival there, but this has not been established.

VRG (2006) identified the list of species shown in Table 2-38 as non-indigenous warm-water types that can be found, or have been found, in San Diego Bay.

2.6.4.10 Correlation of Fish Abundance With Environmental Factors

Allen (1999) employed univariate correlation analysis on log-transformed data for fish abundance and biomass from each station, in relation to water temperature, salinity, and pH. For these data summarized by month, water temperature was found to show significant positive correlations with the number of individuals of all fish species combined, as well as with the abundance of the slough anchovy, northern anchovy, deepbody anchovy, California halfbeak, black croaker, California killifish, and yellowfin croaker. A negative correlation was found for jacksmelt, spotted turbot, and bay pipefish. This suggests that water temperature has a strong influence on many of the important fish species in the bay.

Allen (1999) also applied multivariate correlation analysis in comparing three prominent environmental factors of distance from the mouth of the bay (Station location), water temperature, and salinity with the log-transformed data for abundances at each station of the 35 most abundant fish species in the bay. These three factors accounted for nearly 95% of the variance in abundance of these individual species among stations for each monthly sampling period. Temperature and salinity alone accounted for almost 76% of this variance. The very high correlation coefficient values obtained emphasize the great influence that water temperature, salinity, and distance from the bay entrance have on fish assemblages in San Diego Bay.

Table 2-38. Southern species recorded in San Diego Bay in the literature from 1985 to 1999 (VRG 2006).

Common Name	Scientific Name	Citation	Collection Date
Anchoveta	*Ctengraulis mysticetus*	Duffy (1987)	1986?
Pacific cervalle jack	*Caranx caninus*	Duffy (1987)	1986?
Bonefish	*Albula vulpes*	Duffy (1987); Allen (1999)	1986;1995,19982
White mullet	*Mugil curema*	Lea et al. (1988)	May 1985
Milkfish	*Chanos chanos*	Duffy and Bernard (1985)	1985?
Pacific seahorse	*Hippocampus ingens*	Jones *et al.* (1988); Allen (1999)	1994-1999
Cortez grunt	*Haemulon flaviguttatus*	Lea and Rosenblatt (1992)	May 1991
Bigeye trevally	*Caranx sexfasciatus*	Lea and Walker (1995)	Nov. 1990
Mexican lookdown	*Selene brevoorii*	Lea and Walker (1995)	Nov. 1990
California halfbeak	*Hyporhamphus rosae*	Allen (1999)	1994 -1999
California needlefish	*Stronglyura exilis*	Allen (1999)	1994-1999
Shortfin corvina	*Cynoscion parvipinnis*	Allen (1999)	1996-1999
Banded guitarfish	Zapteryx exasperata	Allen (1999)	1995,1998
California butterfly ray	*Gymnura marmorata*	Allen (1999)	1998-1999
Red goatfish	*Pseudupeneus grandisquamous*	Allen (1999)	1998
Green jack 1	*Caranx caballus*	OREHP	1994-1999?
Middling thread herring	*Opistonema medirastre*	OREHP	1994-1999?
Pacific sierra	*Scomberomorus sierra*	OREHP	1994-1999?
Scalloped hammerhead	*Sphyrna lewini*	OREHP	1994-1999?

OREHP is the Ocean Resources Enhancement and Hatchery Program managed by Hubbs-Sea World Research Institute and the California Department of Fish & Game.

2.6.4.11 San Diego Bay as Important and Unique Fish Habitat

San Diego Bay serves as an important nursery for many species of fishes. Approximately 67% (2005), 62% (2008), and 80% (2012) of all fishes sampled in San Diego Bay were juveniles (VRG 2006, 2009, 2012). These results were similar to the 70% value reported for the 1994-1999 surveys (Allen 1999).

The abundance of young-of-the-year surfperch and topsmelt in north bay suggests the presence of a nursery. At least one commercially important species, the California halibut, has been shown to rely heavily on southern California bays and estuaries as nurseries.

Aside from eelgrass habitats, locations of other nursery areas in the bay have not been identified. However, the abundance of young-of-the-year surfperch and topsmelt in north bay suggests the presence of a nursery. Other sensitive areas may be locations of hard substrate, even artificial substrate such as riprap and piers, which support invertebrates necessary as prey for fish.

South San Diego Bay appears to be an important nursery area for juvenile California halibut and for the young of spotted and barred sand bass and other species (Macdonald *et al.* 1990; Ford 1994). Young-of-the-year and larger juveniles of the white sea bass have been taken in samples from south San Diego Bay during recent years. This is particularly significant because the population of white sea bass in southern California apparently has been reduced significantly by overfishing or other causes.

At SMNWR, juveniles of certain species take advantage of rich foraging areas and protection from predators (Johnson 1999). Despite the marsh's accessibility to fish being limited to high tide, only 16% of the time, the vegetated surfaces provide important forage such that fishes with access to the marsh consumed a greater amount of food and more diverse prey items than those that remained in subtidal habitats (Johnson 1999). California killifish, longjaw mudsucker, topsmelt, arrow goby, and cheekspot goby dominate the fish assemblage at SMNWR (Johnson 1999).

San Diego Bay remains abundant and diverse and highly productive fish habitat for bay/estuarine and nearshore fishes (Allen 1999). The bay contains extensive shallow water eelgrass habitat that supports a unique assemblage of juvenile and adult fishes. San Diego Bay serves as critical habitat for many fishes that, in turn support nearshore ecosystems as juvenile fishes migrate out of the bay as well as an important or endangered avian species that utilize forage fishes in the bay. Finally, the shallow, warm waters of the south San Diego Bay serve as a refuge for several southern "Panamic" species, and may be the primary habitat in California waters for many of these species.

2.6.5 Birds

2.6.5.1 Ecological Role in the Bay

The bay is a part of the Pacific Flyway used by millions of birds traveling between northern breeding grounds and southern wintering sites. It is one of a dwindling number of stopover sites used by migrants to replenish their energy during their long journey. It also supports large populations of over-wintering birds that depend on its resources for food, shelter, resting, and staging before migration. San Diego Bay provides the largest expanse of protected bay waters in southern California to migrants on the Flyway. The bay also serves as the northern range of some tropical species, including several that breed and nest locally. A look at historical accounts of use of the bay by birds provides some insight into its role prior to development, as described in Table 2-39.

More than 300 bird species have been documented to use the bay (see Appendix C). About 136 avian species that directly depend on the bay are found within the footprint of this INRMP. These species, and their status, distribution, and foraging needs in the bay are described in Appendix D. The majority of bay birds, representing 30 families, are migratory and may only stop to rest and feed, while others spend the winter or breed. Several are terrestrial birds of special concern or influence that are found about the bay but may not directly depend upon it. Resident birds live and breed in the area year-round. Migrants that would not usually be in the area, disoriented in their travel, on the edges of their range, or simply looking for suitable habitat are regarded as vagrants. Although vagrants are not considered ordinarily dependent on the bay, a considerable number of them pass through and visit each year.

Table 2-39. Historic changes in bay bird populations.

While we have only anecdotal information on historic use of the bay by birds, examining it in the context of broader, national trend provides some insight into the status of birds today in the bay.

In the latter half of the 1800s, San Diego's human population grew with statehood and took advantage of a large bird population for market hunting. Waterfowl most often killed were the most common: wigeon, pintail, and teal ducks that dabbled in shallow water. Canvasbacks were also abundant and rafted by the thousands, but being in the more open waters of the bay were not so easily killed by hunters (Minshall 1980, citing his own recollections of growing up in the area in the early 1900s). Black brant were also plentiful. Their pattern of flying in dense flocks and being less wary made them vulnerable to hunters. C.A. McGrew (1922) recalled when 50,000 to 100,000 black brant could be seen coming into the bay from the sea around the Spanish Bight in the 1880s and lamented *"reckless, idiotic shooting...has left the bay of one of its chief attractions."* Whimbrel, semipalmated plover and willet were plentiful shorebirds that also fell victim to gunners, and their populations were nearly decimated. The red knot was reported as "common" in the bay (Abbott 1939).

The American economy was prospering in the mid-1800s, with more dollars spent on nonessentials. This allowed the rise of a feather industry used to adorn women's hats and men's fedoras. By 1900, one out of every 1,000 Americans worked in the millinery trade and plumes sold for up to $80/ounce. This fashion depleted bird populations for 30 years, presumably those using San Diego Bay as well as nationally, as millions of birds were killed. Feathers of the great egret and snowy egret were especially favored, and by 1913, the egret population was decimated. The American Ornithologists Union, founded in 1883, campaigned to stop the industry as did the Audubon Society. The hobby of oology, specimen egg collecting, of the early 1900s also hindered the reproductive efforts of birds such as the black rail in San Diego Bay.

The federal government began to protect birds at the turn of the century with the writing of the Lacey Act of 1890, which addressed interstate transport of birds killed in violation of state laws. The Migratory Bird Treaty between the United States and Canada set hunting seasons for game birds and made hunting of shorebirds and other nongame birds illegal. Similar treaties were later signed with Mexico (1936), Japan (1972), and the Soviet Union (1976). The Migratory Bird Conservation Act of 1927 authorized the Department of Agriculture to acquire wetland to preserve for waterfowl habitat. In 1934, the Migratory Bird Hunting Stamp Act (Duck Stamp Act) provided means of raising money to fund land acquisition; $671 million dollars have been raised and more than 5.2 million acres purchased with Duck Stamp funds to date.

As activity in the bay increased and bayfront development altered habitats, the salt ponds (created in 1902) became more important to certain birds. The western shore still had shallow flats and marsh along the Silver Strand almost to Coronado with *"thousands of shorebirds feeding on the flats at low tide and great flocks of duck and brant feeding on eelgrass and sea lettuce so many they darkened the sky"* (Minshall 1980). As the tide receded, the birds would sort out by their foraging ability—the length of their legs, and length and shape of their bills. Dowitchers, red knots, Wilson's phalarope, greater yellowlegs, dunlins, and marbled godwits could be seen together.

In addition, the habitat remaining was becoming degraded. Sewage dumping into the bay had reached a level for which tidal flushing no longer compensated. Contamination from industrial operations fouled the water and bioaccumulated in marine life. In 1952, the San Diego RWQCB reported *"the presence of low dissolved oxygen concentrations and the effect on the fauna have unquestionably affected this area's suitability for migratory game birds."* By 1963, when the new sewage plant routed treated effluent out to sea, the CDFG declared that much of the bay was a virtual "marine desert."

Pollution and habitat loss were believed to be the cause of the black rails extirpation from San Diego Bay. Belding's savannah sparrow and the light-footed clapper rail suffered population declines with the loss and degradation of salt marsh. California least terns and western snowy plovers found sandy beaches crowded with humans and predators concentrated on the remaining nesting sites.

Despite difficulties, the list of birds that occur on the bay is about the same length, with some extirpations and some newcomers. However, relative abundances have changed, and total abundances appear to have diminished from anecdotal historic accounts. Anecdotally, there has been a shift towards relatively more generalist species or those tolerant of human presence. Many species have recovered from overshooting, and efforts are being made to recover wetlands and correct pollution. When eggs of the brown pelican, osprey, white-faced ibis, and the double-crested cormorant were found to be thin-shelled and the species threatened by failure to reproduce, attention was brought to agricultural runoff and DDT, and these problems were subsequently corrected. Black brant now have an abundant eelgrass habitat. To determine why abundance is changing, a look at a species' whole range is necessary, and international cooperation required.

When compared to midwinter populations of the SCB, the bay provided habitat for more than half of the entire midwinter duck population. The majority of the regional surf scoters (72%) and brant (66%) populations were present in central and south bay. Forty-four percent of the region's bufflehead population used central and south bay in 1994, as did a similar percentage of scaup (USFWS 1995a).

When compared to the 1994 winter waterbird population estimate of the Pacific Flyway and the State of California, the bay supported a substantial proportion of midwinter sea bird and waterbird populations. The bay surf scoter population comprised over 40% of the state's midwinter population and about 25% of the entire Flyway's population. Thirty-one percent of the midwinter brant population was in central and south bay (USFWS 1995a).

Fully one-third of birds dependent on San Diego Bay have been identified as sensitive or declining by the federal or state governments or by the Audubon Society.

Fully one-third of birds dependent on San Diego Bay have been identified as sensitive or declining by the federal or state governments or by the Audubon Society.

San Diego Bay provides breeding, wintering, and/or stopover habitat for most of the shorebirds identified in the U.S. Shorebird Plan as having primary importance within the region. Of the ten species for which coastal habitats in the Southern Pacific Region are especially important, the black-bellied plover (*Pluvialis squatarola*), western snowy plover, semipalmated plover (*Charadrius semipalmatus*), willet (*Tringa semipalmata*), marbled godwit (*Limosa fedoa*), black turnstone (*Arenaria melanocephala*), short-billed dowitcher (*Limnodromus griseus*), and red-necked phalarope (*Phalaropus lobatus*) are supported in San Diego Bay.

San Diego Bay contributes more protected, shallow bay habitat to the Pacific Flyway waterbird populations than any other bay or estuary situated along the 180-mile coastal region of southern California. The Central and South Bays make up approximately 65% (7,130 acres) of the entire open water habitat of the bay.

Habitat Partitioning

Habitat and foraging dependencies specific to San Diego Bay are, in general, only known in a broad sense and extrapolated from other locations. The use of various habitats by bay-dependent birds is summarized in Appendix D. Figure 2-23 is a simplified view of foraging habitat partitioning by birds. However, whether birds actually use an available site is much more complicated. Factors such as habitat fragmentation, parcel size and connectivity, juxtaposition of other habitats, predator-prey relations, competition, disturbance, and species behavior patterns all affect a site's value and carrying capacity for birds. Although some habitats may not be used very often, they could be of importance for use by a species of a much larger area and array of habitats. An example is the availability of roosting structures with relatively low human disturbance near foraging areas Ogden (1995) and USFWS (1995b) documented the use of various artificial structures around the bay for roosts, and use of dikes at the salt ponds has also been noted (USFWS 1994a). Ogden (1994, 1995) showed a significant preference of many waterbirds and sea birds for shallow, nearshore areas compared to deeper water.

Important bird movement areas, such as crossover points between the bay and ocean at Emory Cove and Delta Beach, have been identified (E. Copper, Ornithologist, *pers. comm.*). USFWS (J. Manning, USFWS, *pers. comm.*) observed that brant geese established a movement corridor between beds of eelgrass in south bay. For shorebirds, there is substantial movement between the Tijuana Estuary and the bay, and between the agricultural fields of the Tijuana River Valley and the bay.

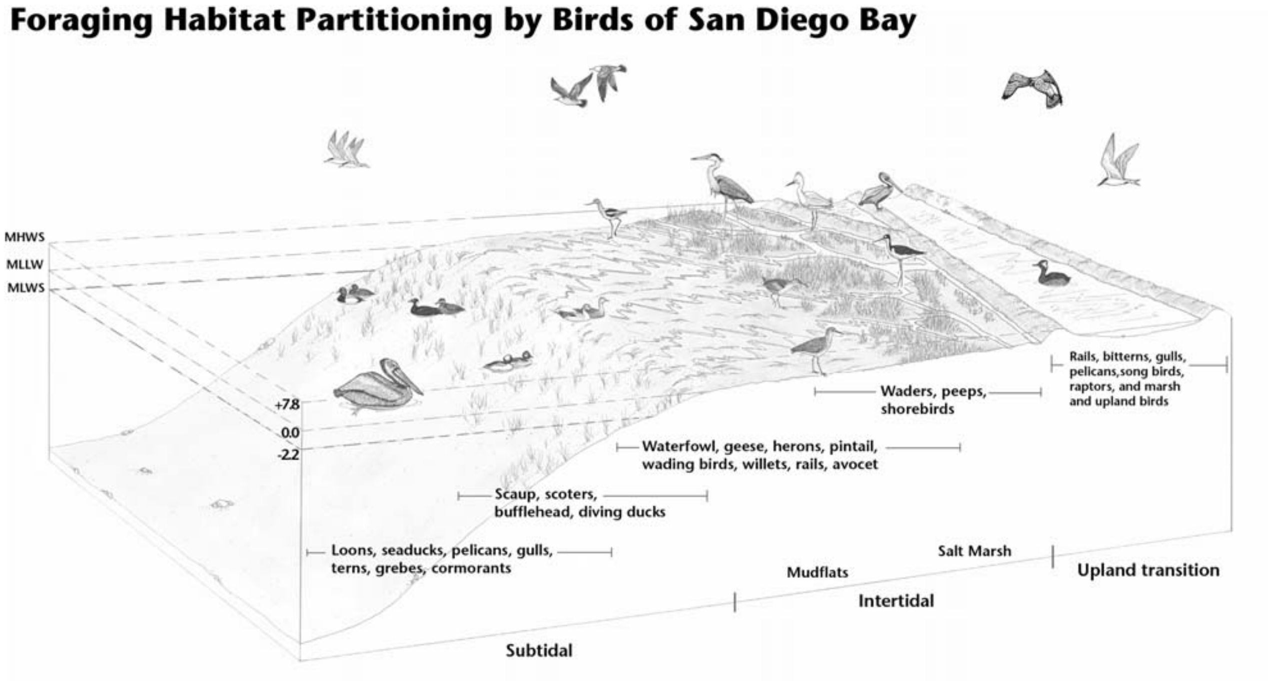


Figure 2-23. Foraging habitat partitioning by birds of San Diego Bay. Dabbling ducks forage in brackish water, unrelated to tidal elevation.

2.6.5.2 Abundance, Distribution, and Biodiversity

Table 2-40 compares the methods and level of effort by past avian surveys. The first, sponsored by the Navy and conducted by Ogden Environmental and Energy Services (Ogden 1994, 1995), covered waterbirds of north and central bay over the course of two years, 1993 and 1994. The second, conducted by the USFWS (1995a) surveyed waterbirds of south and central bay. The third, also conducted by USFWS (1994a), covered birds of the Salt Works. Most recently, efforts to cover the entire San Diego Bay, monthly over a single year, were developed and undertaken in both 2006-07 and in 2009-10 (TDI 2009 and TDI 2011)

Map 2-15 and Map 2-16 depict the survey routes and grids used to manage field team observations and data extrapolation for surveys conducted in 2009 and 2010 (TDI 2011). Map 2-17, Map 2-18, and Map 2-19 depict relative abundance and biodiversity of birds based on 2009-2010 surveys (TDI 2011).

The surveys of north (Ogden 1994), central (Ogden 1994, 1995; USFWS1995a), and south (USFWS1995a) bay did not account for use by shorebirds. Dabbling ducks were under-represented in south bay. Also, some terns and gulls were not identified to species. The biggest discrepancy between the Ogden and USFWS surveys in areas where they overlapped in central bay was the difference in scoter and scaup counts (scoters 78,309 vs 32,929; scaup 13,976 vs 1,035 for Ogden and USFWS, respectively). These occurred in different years (USFWS 1993; Ogden 1994), which most significantly seemed to affect the scoter counts. Otherwise these differences may be at least partly due to survey coverage and method. Ogden surveyed both shore and open water areas, whereas USFWS surveyed primarily in open water and did not survey Glorietta Bay and Seventh Street Channel, known scaup concentration areas. Scaup were shown to prefer shoreline areas in Ogden's 1993 surveys. The USFWS had less survey effort in central bay, spending 350 total hours on central and south bay together, while Ogden spent 290 hours in central bay alone.

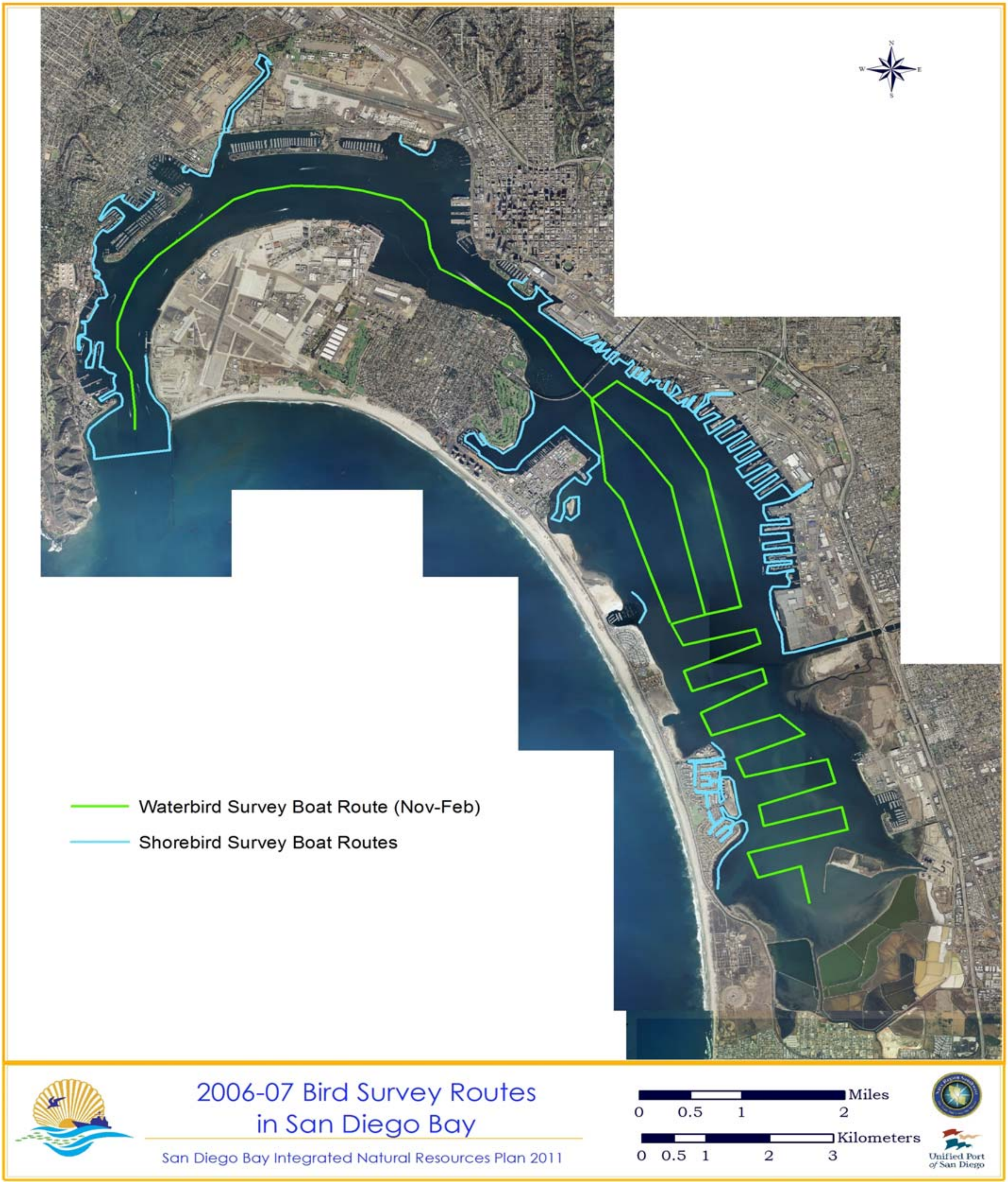
Table 2-40. Comparison of three concurrent surveys of bay avian conducted in 1993, one 1994 survey of Central Bay, and 2006-2007 and 2009-2010 bay-wide efforts.

Survey	Location and Area Surveyed	Survey Period	Total Observations	Methods Summary
Ogden 1994	North and central bay (3,937 acres [1,593 ha] in north bay).	Jan. 1, 1993–Dec. 31, 1993	208,564	Performed 48 surveys for north bay approximately once/week. Central bay surveyed approximately once/month. Made observations during boat transects traveling 5 to 15 mph with stops. The bay was stratified by grids into 1,000 feet (305 m) lengths across from shore to shore, then divided into depth categories (shallow, intermediate, deep), then further divided into marina, pier, and other shoreline categories. Did not identify most gulls and shorebirds to species.
USFWS 1995a	Central and south bay, excluding Coronado Yacht Club, 7th St. Channel, Coronado Cays, and diked ponds of Salt Works.	April 15, 1993–April 14, 1994	149,553 (52,853 waterbirds in central bay)	Performed 46 surveys approximately once/week totaling 350 field hours. Made observations from boat traveling 5 to 20 mph with 5 minute stops. Survey routes were 1,000 feet (305 m) widths. Staggered time of start at each location throughout the season. Observations recorded within a 500 feet (152 m) radius of the boat (18 acre [7 ha] circle). Did not record shorebirds, herons, egrets. Missed most ducks. Combined most gulls, terns, scaup, and western and Clark's grebe.
USFWS 1994a	Salt Works, Emory Cove, Marine Biological Study Area	Feb. 17, 1993–Feb. 2, 1994	522,553	Performed 52 surveys once/week. Biologists on foot covered four survey routes. Recorded tidal conditions at time of observation.
Ogden 1995	Central bay (4,298 acres [1,739 ha]) of water and shoreline habitat.	Jan. 1, 1994–Dec. 31, 1994	181,488 total birds (126,008 waterbirds)	Performed 47 surveys approximately once/week totaling 290 field hours. Same methods as for Ogden 1994.
Navy/Port 2006 - 2007	Shoreline, point counts, and central bay waterbird survey	March 2006-Feb. 2007	541,374 total birds (includes 31,791 waterbirds in the central bay surveys)	Performed monthly falling tide shoreline surveys (excluding May and July) and quarterly high tide surveys of the entire bay and Silver Strand shoreline, including 22 point count locations. Central bay waterbird surveys were also performed once monthly in winter (Nov.-Feb.). Field observation hours total over 700.
Navy/Port 2009 - 2010	Shoreline, point counts, and central bay waterbird surveys	March 2009-Feb 2010	491,317 total birds (includes 20,502 waterbirds in the central bay surveys)	Performed monthly falling tide shoreline surveys (excluding May and July) and quarterly high tide surveys of the entire bay and Silver Strand shoreline, including 22 point count locations. Central bay waterbird surveys were also performed once monthly in winter (Nov.-Feb.).

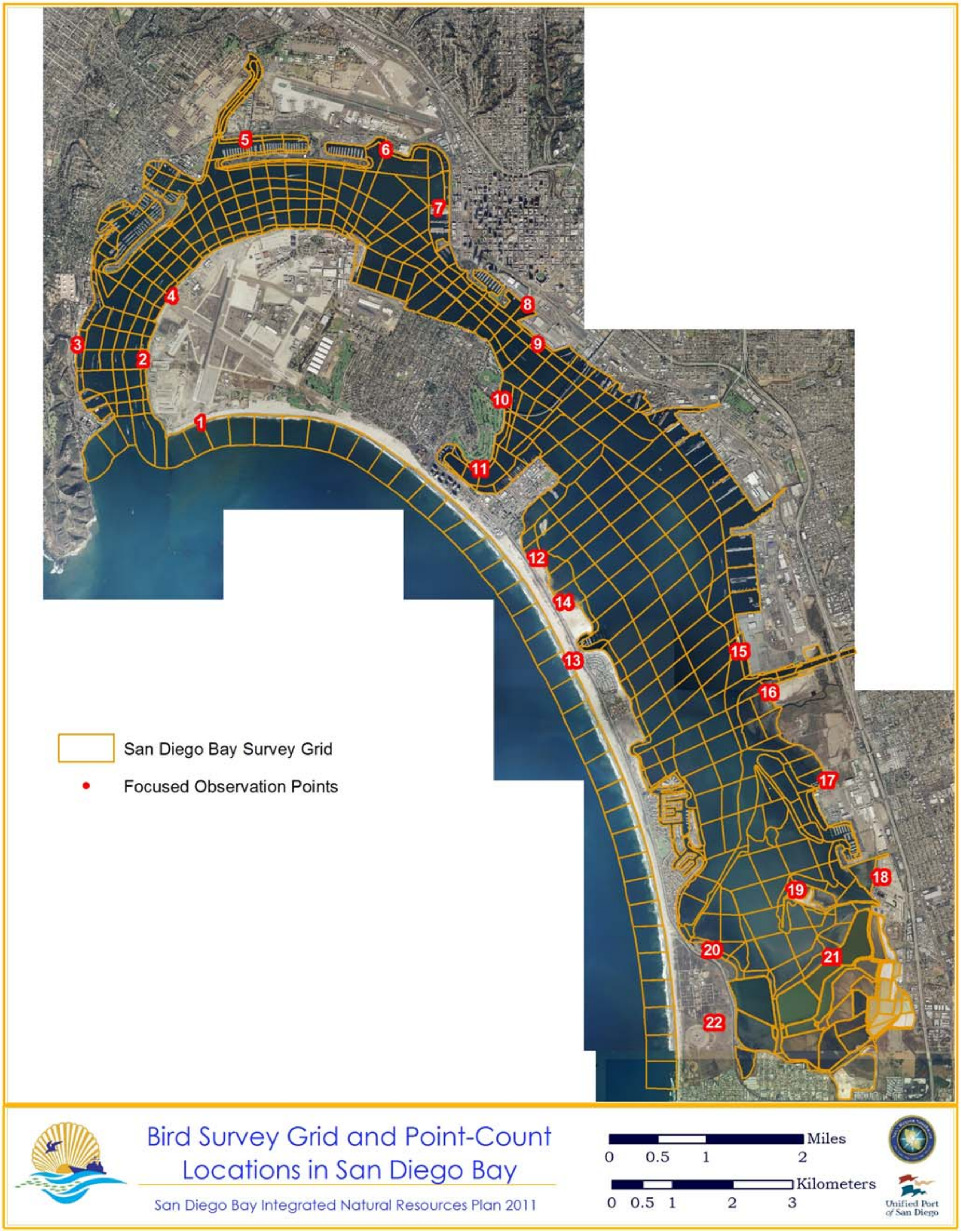
Ogden did not limit the survey time for collecting data (typical survey time: six hours), whereas USFWS limited field effort to approximately four hours per survey. USFWS' counts at each point location (18 acre [7 ha] circle) were restricted to five minutes to minimize errors from bird movement. Ogden counted all individuals without any time restriction. Certain well-recognized bird concentration areas appear under-represented in Map 2-17 and Map 2-18, such as off of Gunpowder Point and, on the west shore, off of Silver Strand State Beach (J.Coatsworth, San Diego Audubon Society, pers. comm.).

These separate surveys of avifauna of San Diego Bay in 1993–1994 resulted in an estimate of over seven million bird-use days per year, or an average of over 19,000 birds per day (with substantial peaks and lows), based on the average number of sightings during survey days (USFWS 1994b; Ogden 1995; USFWS 1995a).

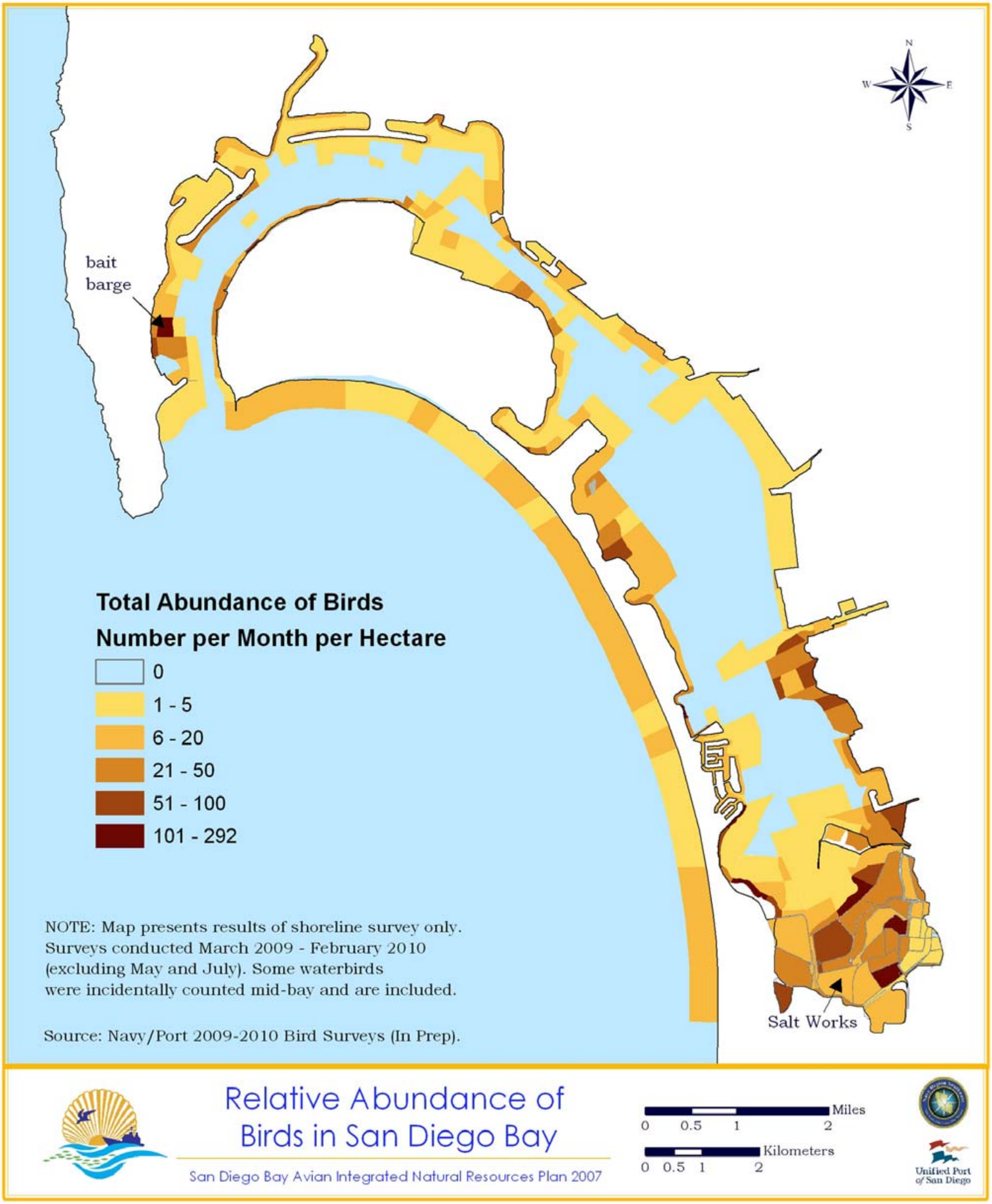
In the SCB as a whole, bird numbers and biomass are highest in the winter, when high-latitude nesters stop in the area. A very different assemblage of waterbirds occurs on the bay in spring and summer than in the winter when northern migrants dominate.



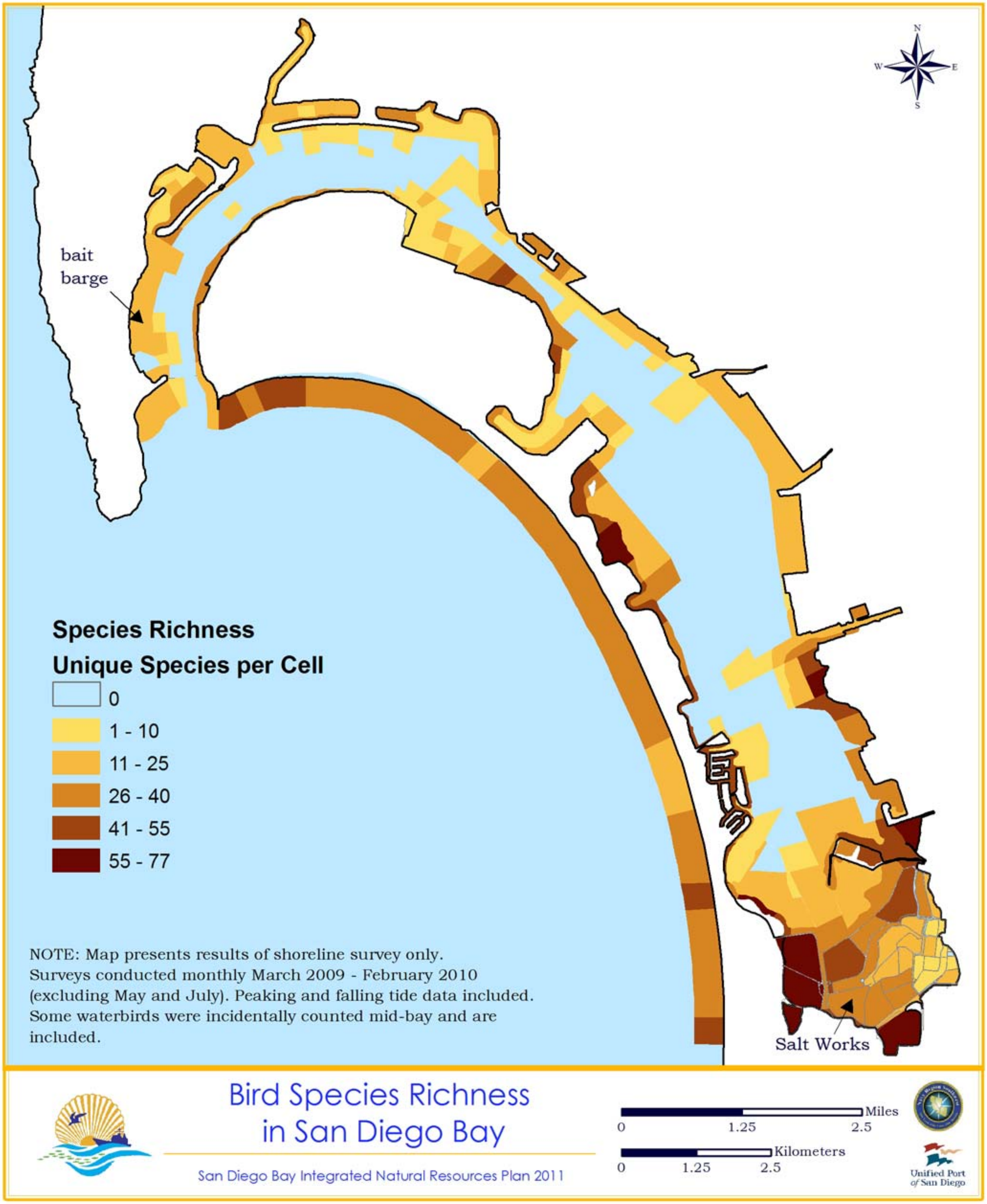
Map 2-15. Boat survey routes for the 2009-2010 shorebird and waterbird survey of San Diego Bay.



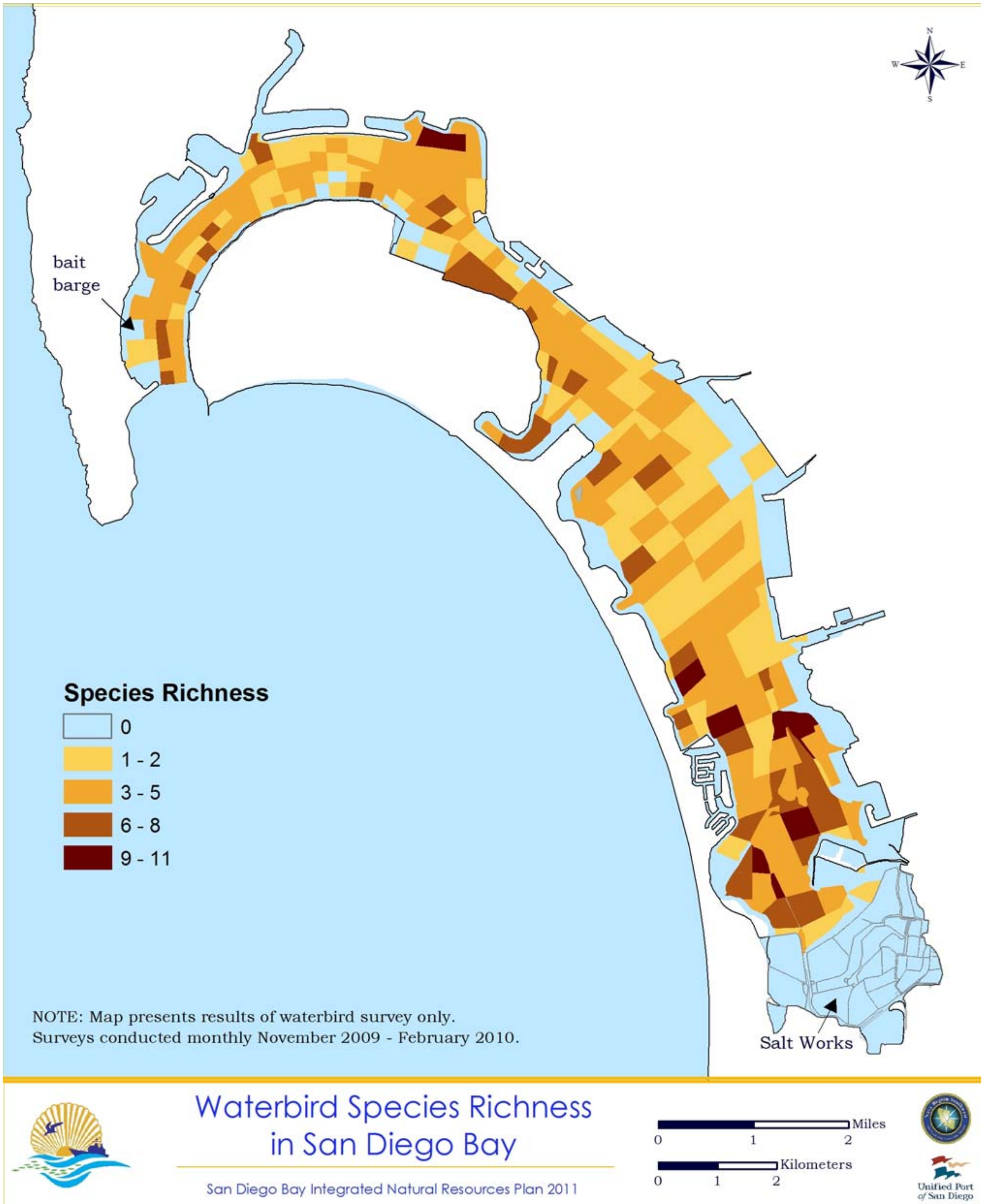
Map 2-16. Location of point-count stations and depiction of grid used to record and extrapolate results of the San Diego Bay avian survey 2006-2007.



Map 2-17. Relative abundance of shoreline surveyed birds based on 2009-2010 surveys.



Map 2-18. Biodiversity of birds based on 2009-2010 baywide shoreline surveys (Tierra Data Inc. in prep).



Map 2-19. Species richness of birds observed during the baywide waterbird surveys between November 2009 and February 2010 (Tierra Data Inc. in prep).

Waterfowl (Ducks, Geese, Coots, Grebes)

Table 2-41. Cumulative observations of the most abundant waterfowl.[a]

Species	Number of Observations in 1990s[a]	Number of Observations in 2006-07[c]	Number of Observations in 2009-10[c]
Surf scoter	94,240	49,315	55,775
Eared grebe[b]	40,433	4,197	18,112
Scaup (lesser and greater)	36,688	10,809	14,820
Bufflehead	20,803	4,341	4,921
Brant	9,095	7,035	7,625
Western grebe	8,934	17,521 (Western and Clark's)	16,445
American wigeon	3,636	10,591	6,654
Ruddy duck	3,528	767	394
Mallard	3,000	2,545	1,677
Red-breasted merganser	1,738	389	310
Northern pintail	1,395	1,291	1,108
Northern shoveler	939	1,295	1,877
American coot		1,783	1,116

a. Based on surveys conducted in 1993 and 1994 covering all areas of the bay (Ogden 1994 for North Bay, Ogden 1995 for Central Bay, USFWS 1995a for South Bay, USFWS 1994a for the Salt Works).

b. Observations made completely at the Salt Works by USFWS (1994a).

c. Based on surveys conducted by TDI (2009 and in prep).

Surf scoters

Most waterfowl nest in Canada and Alaska, visiting San Diego Bay during migratory stopovers. Waterfowl as a group have a range of diet preferences and foraging behaviors, with different species specializing in aquatic vegetation, aquatic invertebrates, grain, or molluscs and crustaceans. The red-breasted merganser (*Mergus serrator*), with saw teeth on the edges of its bill, which enable it to catch fish, is one of the few ducks specializing in eating fish.

Ogden (1994) found biodiversity in north bay to peak in January. The USFWS (1995a) found biodiversity of birds to peak in December to March in central and south bay, and reach a low point in June and July. Ogden (1995) found a slightly later peak in biodiversity in February and March, with a similar low point in June in central bay.

The most abundant birds on the waters of San Diego Bay are surf scoters. They make greater use of deep water than any other waterfowl.

Surf scoters were found to be the most abundant birds on the bay. They were the predominant species in both central and south bay. They appear from the surveys to be more widely distributed and make greater use of deep water than other waterfowl. They seem to prefer nearshore areas along the shoreline of NASNI of north bay and around the Submarine Base (SUBASE). Surf scoter have been declining in San Diego Bay (Macdonald *et al.* 1990).

Diving ducks feed by diving from the surface and swimming underwater. Those dependent on the bay include the greater scaup (*Aythya marila*) and, most abundantly, the lesser scaup (*Aythya affinis*), which primarily feeds on clams and snails, but also eats aquatic insects, crustaceans, and plants. Scaup also were relatively more abundant in central and south bay. Scaup are more heavily dependent on south bay than scoters and more restricted to the west side of central bay. Scaup are absent from April to mid-November. They have also been declining in the bay (Macdonald *et al.* 1990). The bufflehead feeds especially on the brine shrimp and brine fly larvae of Salt Works ponds.

Black brants depend upon eelgrass beds for food, and sometimes sea lettuce.

During the 1993–1994 surveys (Ogden 1994; USFWS 1994a; Ogden 1995; USFWS 1995a), black brant were found to be relatively restricted to south bay (USFWS' 6,929 cumulative observations and 2,166 at the Salt Works, compared to Ogden's 280 in central bay and none in north bay). Known areas for brant include off Delta beaches, Emory Cove, and the Otay River mouth, shores of Chula Vista bayfront from the D Street Fill south to F Street, and shallow waters between Chula Vista Marina and Emory Cove (E. Copper, Ornithologist, pers. comm.). Brant depend on eelgrass for food and USFWS' observations of their distribution overlapped that of eelgrass beds. However, this species has been observed feeding on sea lettuce in the bay (Moffitt

1938; Ogden 1994). Members of the family Anatidae typically have larger clutches than shorebirds and perhaps greater chance of recovery from impacts. A member of the same family, Canada geese (*Branta canadensis*) was more abundant historically than at present based on anecdotal accounts, but this species has also been recognized as declining on a regional basis.

The western grebe (*Aechmophorus occidentalis*) and Clark's grebe (*Aechmophorus clarkii*) winter in flocks and were relatively more abundant in north bay. The eared grebe (*Podiceps nigricollis californicus)*, which feeds more on insects than other grebes, was more abundant at the Salt Works.

Photo 2-11. Cormorants in San Diego Bay. Photo courtesy of John Lovio.

Dabbling ducks are concentrated at the mouths of the Sweetwater and Otay Rivers, J Street, the salt ponds, Shelter Island Yacht Basin, east and west basins of Harbor Island, Glorietta Bay, the shoreline of NAB, and seasonal wetlands at NRRF. Their numbers are under-represented in the table above because surveyors in south bay did not approach shoreline areas where these birds are known to concentrate (USFWS 1995a). They forage on aquatic plants at the water's surface or up-end with head and neck submerged and tail up, while finding food in the underwater mud. Several dabbling ducks have adaptations to their bills enabling them to strain planktonic food out of the water. Dabbling ducks on the bay include the cinnamon teal (*Anas cyanoptera*) with a small local breeding population, the northern shoveler (*Anas clypeata*), the American wigeon (*Anas americana*), the gadwall (*Anas strepera*), the northern pintail (*Anas acuta*), the green-winged teal (*Anas crecca*), and the mallard (*Anas platyrhynchos*).

Slender, long-legged shorebirds are seen primarily at the south end of the bay. Peak abundance is in August during the fall migration (USFWS 1994b). Shorebirds can be hard to identify in the field, so often go uncensused. Most are migratory and they are highly mobile, adding to the surveying difficulty. While some areas around the bay are predictable for seeing shorebirds at low tide, shorebird use of high-tide refugia and feeding areas can be hard to predict. In addition, human disturbance and predator movements can impact the use of any one area at any point.

Shorebirds

*Table 2-42. Cumulative observations of the most abundant shorebirds in 1993 [a] and again in 2006-2007[b] and 2009-10[b]. * - Birds that breed in San Diego Bay.*

Species	Number of Observations in 1993	Number of Observations in 2006-2007	Number of Observations in 2009-10
Western sandpiper	112,115	68,205	80,437
Red-necked phalarope	70,960	20,137	15,534
Peeps (western and least sandpipers undifferentiated)	45,884	10,515 (undifferentiated sandpipers) 2,627 (least sandpipers)	32,813 (undifferentiated sandpipers); 4,511 (least sandpipers)
Marbled godwit	32,099	27,614	19,301
Willet	28,073	17,218	11,931
Black-bellied plover	17,295	8,750	12,006
Dowitchers (long-billed and short-billed)	16,642	13,811	11,220
Black-necked stilt*	14,864	1,857	2,688
Dunlin	9,671	4,900	4,615
Red knot	5,964	4,785	3,738
American avocet*	5,935	1,030	717
Semipalmated plover	3,454	5,021	4,612
Killdeer*	1,172	876	1,497
Sanderling	826	13,821	11,111
Western snowy plover*		2,397	2,567

a. Based on 1993 Surveys by USFWS (1994a).

b. Based on surveys by TDI (2009 and in prep).

Shorebirds are difficult to survey because they are migratory and highly mobile.

Shorebird abundances have been impacted by the loss of intertidal flats for foraging, as well as upland transitional areas for nesting. Shoreline stabilization and bulkheads can preclude intertidal habitats, from which shorebirds get most of their nutrition. Bird use at the Chula Vista bayfront, examined over 1.5 years (Jones and Stokes Associates, Inc. 1988), was found to be highest where mudflat was the dominant habitat. Boland (1981) studied shorebird ecology of the Tijuana Estuary in 1980–1981. "The long-billed birds feed at their preferred tides with or without daylight and rest during unfavorable tides, while the short-billed birds feed all day, switching between tidal and nontidal habitats, and rest at night." The agricultural fields, riparian woodlands, and salt marshes of the Tijuana River Valley and Tijuana National Estuarine Sanctuary all lie a short distance to the south of San Diego Bay, and casual observations indicate regular movement of shorebirds back and forth between these nesting and foraging areas (USFWS, in conversation, 1996, cited in USFWS 1998).

The period of greatest competition among shorebirds for prey is midwinter.

Shorebirds normally redistribute themselves when feeding areas become scarce. However, when marshes and mudflats are as scarce and isolated as they are in southern California, and because only so much food is available, this normal redistribution may be impossible (Baird 1993). The removal of just a part of a feeding area may mean that the affected population will not be able to move to an already occupied habitat and, therefore, may move away from the area entirely. The period of greatest competition among shorebirds is midwinter (Quammen 1981, 1982, cited in Baird 1993). The reasons for this are that the actual prey biomass is lower (Baird *et al.* 1985), and the prey also make themselves less available by burrowing too deep or becoming less active. Greater minus tides in winter may partially offset this (Baird 1993). Choice of feeding location is influenced by soil resistance to mechanical probing, as well as prey density.

The largest family of shorebirds are the sandpipers. Western sandpiper is most abundant in the south bay along with least sandpiper (*Calidris minutilla*). Curlews dependent on the bay are the whimbrel (*Numenius phaeopus*) and long-billed curlew (*Numenius americanus*) (Photo 2-12). The latter often moves with the marbled godwit, a large sandpiper that forages by wading deeply with its head underwater for molluscs and crustaceans. Godwits were among the larger shorebirds that were taken by market hunters in the early 1900s and are now declining with loss of habitat at their nesting grounds. Phalaropes are different than other sandpipers as they forage while swimming, spinning in circles to stir up crustaceans. Turnstones, including ruddy turnstone (*Arenaria interpres*) and black turnstone and so called for their foraging behavior, may be seen on rocky sites favoring barnacles and limpets. Sanderlings (*Calidris alba*) are found more often on sandy beach than mudflats, where they chase the waves in search of sand crabs and other invertebrates.

Photo 2-12. Long billed curlew. Photo courtesy of Matt Sadowski.

See section 2.7.1.4 for detailed information on western snowy plover.

Plovers find their food by sight and glean the ground with their short straight bills. Of the plovers, black-bellied is the most common. The semipalmated plover was seriously depleted by overshooting in the 1900s, but it is now recovered. On the other hand, the western snowy plover remains a federally threatened species. This species prefers the open sandy beaches that are in high demand for human use in southern California, but will also utilize mudflats within the bay. Killdeer (*Charadrius vociferus*) are common and widespread, predominately in upland habitats. Black-necked stilts use their needle-like bill to feed on brine shrimp and brine flies. American avocets (*Recurvirostra americana)* also feed on brine shrimp and flies by moving their upturned bill from side to side, stirring up invertebrates and picking them out.

Shorebirds in decline on a regional basis include the American avocet, western snowy plover, and Wilson's Snipe (*Gallinago delicata*) (Baird 1993).

Photo 2-13. Avocet and brine flies. Photo Courtesy of Eileen Maher.

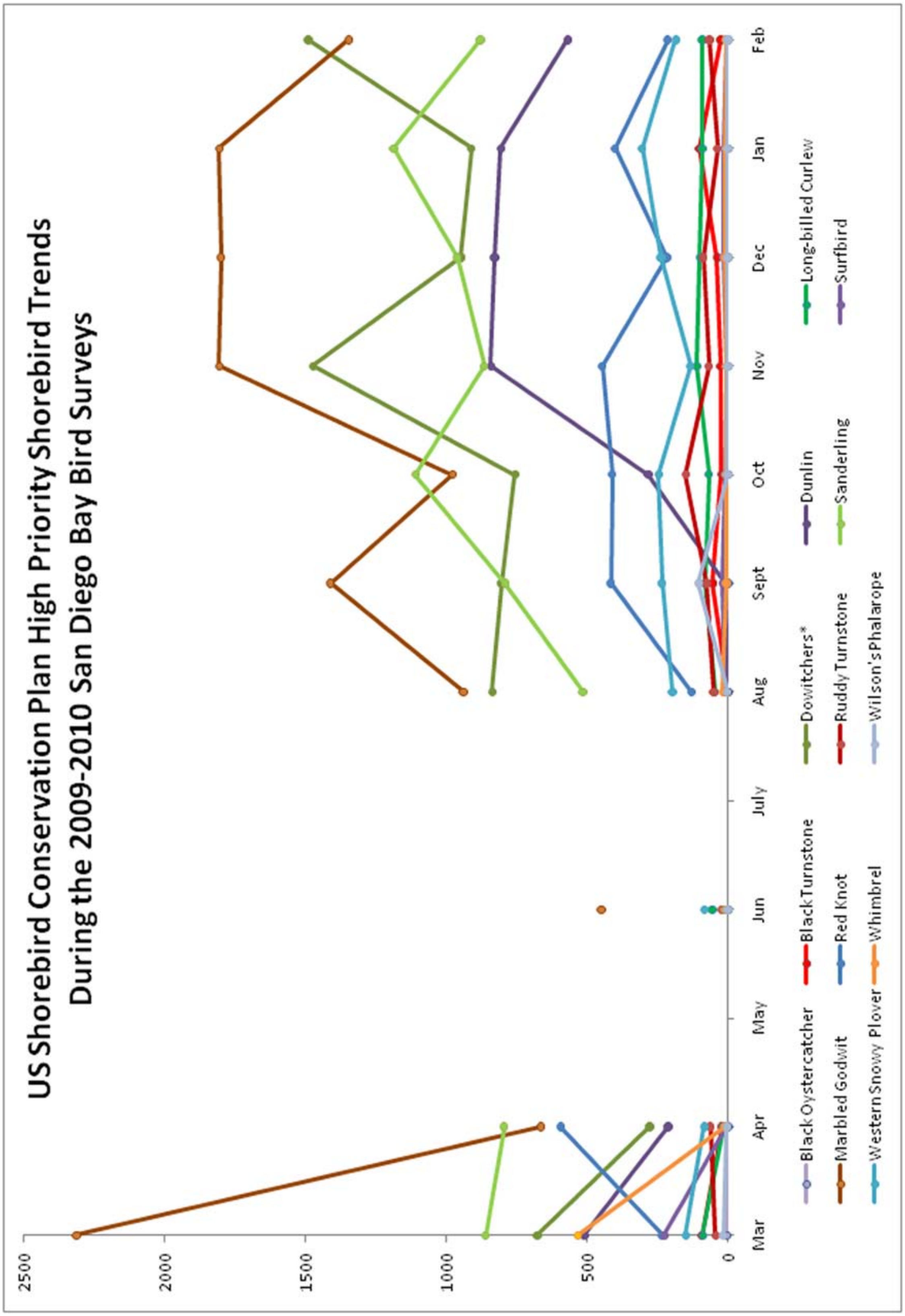


*Figure 2-24. Number observed of 13 species of shorebirds that are categorized as high priority in the U.S. Shorebird Plan, shore surveys March 2009-February 2010 (*Dowitchers includes both short-billed dowitcher and long-billed dowitcher).*

Sea Birds (Terns, Loons, Cormorants, Pelicans, Gulls)

Table 2-43. Cumulative observations of the most abundant sea birds in the 1990s[a] and again in 2006-2007[c] and 2009-2010[c].

Species	Number of Observations in the 1990s	Number of Observations in the 2006-2007	Number of Observations in 2009-2010
Brown pelican	19,102	10,319	11,007
Elegant tern	16,823	8,740	16,205
Royal tern		1,445	1,833
Heermann's gull	16,090	8,797	9,637
Double-crested cormorant	15,772	10,088	9,413
Brandt's cormorant	12,789	7,605	15,156
Forster's tern	10,076	3,575	3,315
Western gull[b]	8,483	26,162	27,746
Black skimmer	5,702	1,282	1,848
Gulls (undifferentiated)	4,697	1,179	235
Caspian tern	3,795	647	800
California gull	3,608	5,608	5,965
California least tern	1,670	1,108	675
Terns (undifferentiated)	1,633	272 (common terns)	245
Bonaparte's gull	1,494	69	129
Ring-billed gull		4,981	3,584
Common loon	351	126	133
Red-throated loon	186	54	90
Cormorants (undifferentiated)		806	128
Gull-billed tern	135	273	255

a. Based on surveys conducted in 1993 and 1994 covering all areas of the bay (Ogden 1994 for North Bay, Ogden 1995 for Central Bay, USFWS 1995a for South Bay, USFWS 1994a for the Salt Works).

b. Observations made by USFWS (1994a) only at the Salt Works, resulting in what is expected to be a substantial under-representation in numbers.

c. Based on surveys conducted by TDI (2009 and in prep).

Sea birds spend at least a portion of their lives on or near offshore waters. Many of them are diving birds that pursue fish and other prey underwater. They most commonly eat fishes, squid, and crustaceans (Baird 1993). Diving species of sea birds predominate in areas where certain processes maintain standing stocks of phytoplankton, making the water turbid (Briggs and Chu1987). The northern anchovy is one of the most common prey items for sea birds of the Bight. Abundance of northern anchovy larvae is tied to these areas of concentrated phytoplankton off the coast, and the large numbers of dinoflagellates that are a component of the phytoplankton and serve as food for anchovy larvae (Baird 1993). Sea birds using the bay are often foraging for schooling fishes such as anchovies.

The three 1993–1994 surveys show gulls, pelicans, cormorants, and loons all more abundant in north bay compared to central and south bay. Terns appear more abundant in north and central bay compared to south bay, probably due to increased foraging opportunities in these areas. Many sea birds use artificial hard structures for roosting and Salt Works dikes for roosting and nesting.

The brown pelican (Photo 2-14) uses subtidal waters for resting and foraging, as well as a staging area for fall migration. Juvenile pelicans use the bay as a dispersal ground to find new territory.

Photo 2-14. California brown pelicans. Photo courtesy of John Lovio.

Terns common in the bay include elegant tern (*Thalasseus elegans*), Caspian tern, Forster's tern (*Sterna forsteri*), gull-billed tern, royal tern (*Thalasseus maximus*), and California least tern. With the exception of the gull-billed tern, they feed on small schooling fish such as anchovies and top smelt. Breeding colonies of Caspian, Forster's, elegant, a few royal terns, a few gull-billed terns, and black skimmer (*Rynchops niger*) are found at the Salt Works. Elegant, Forster's, and royal terns benefit when nesting close to the more aggressively protective Caspian terns (USFWS 1994a). Predation by gulls, the peregrine falcon (*Falco peregrinus anatum)*, and terrestrial nonnative predators such as dogs and cats often reduce their reproductive success as well as that of the black skimmer.

The double-crested cormorant (*Phalacrocorax auritis*) may be found throughout the bay on docks, jetties, pilings, and boats where the opportunity to roost is available. While Brandt's cormorant (*Phalacrocorax penicillatus*) is seen over bay waters, it is typically on the ocean side, where it can take advantage of deep water for power dives up to 150 feet (46 m) below the surface for fish.

The 1993–1994 bay bird surveys as a group probably greatly underestimate the importance of gulls, since they generally were only well documented at the Salt Works. Gulls dependent on the bay include western (*Larus occidentalis*), ring-billed (*Larus delawarensis*), Heermann's (*Larus heermanni*), California (*Larus californicus*), Bonaparte's (*Chroicocephalus philadelphia*), glaucous winged (*Larus glaucescens*), herring (*Larus argentatus*), and mew (*Larus canus*). The western gull is the only resident breeder. Seen abundantly throughout the bay, this bird will eat almost anything, including fish, crustaceans, molluscs, echinoderms, small birds and eggs, carrion, garbage, and offal. Western gulls are known to nest around other nesting colonies, preying on eggs and chicks. The gulls' ability to consume a wide variety of foods gives them a greater flexibility; if one food source is impacted they may adjust their diet or move to another area. They help keep beach areas clean of edible garbage and cycle waste back into the nutrient cycle.

Loons find their food by diving under water. The common loon (*Gavia immer*) feeds mostly on fish in the winter, usually in shallow waters by itself. At night this species may gather in loose flocks.

Sea birds identified as declining in numbers in the Bight include Caspian, Forster's, elegant, and royal terns (Baird 1993).

Marsh Birds (Herons, Rails, Egrets)

Marsh birds were not targeted in the three 1993 surveys of San Diego Bay, nor in the 2006-2007 and 2009-2010 surveys; but herons and egrets are fairly visible and broadly distributed compared to other marsh birds, so any observations were recorded and are presented in Table 2-44.

Table 2-44. Cumulative observations of herons and egrets in the 1990s[a] and again in 2006-2007[c] and 2009-2010[c].

Species	Number of Observations in the 1990s	Number of Observations in 2006-2007	Number of Observations in 2009-2010
Great blue heron	2,716	893	840
Snowy egret[b]	2,015	1,950	1,161
Great egret	810	759	934
Black-crowned night heron	54	70	55
Belding's savannah sparrow		746	1,892
Little blue heron		59	50
Large-billed savannah sparrow		57	60
Green heron		52	22
Marsh wren		40	14
Reddish egret		36	5

a. Based on surveys conducted in 1993 and 1994 covering all areas of the bay (Ogden 1994 for North Bay, Ogden 1995 for Central Bay, USFWS 1995a for South Bay, USFWS 1994a for the Salt Works).

b. Observations made by USFWS completely at the Salt Works.

c. Based on surveys conducted by TDI (2009 and in prep). Survey did not target marsh birds so their numbers are likely underrepresented.

Egrets and herons feed on a variable mix of fish, crayfish, amphibians, snakes, terrestrial rodents, lizards, and insects. The black-crowned night heron (*Nycticorax nycticorax hoactli*) feeds mostly at night, feeding its young shrimp and fish, but adults have a broader diet of terrestrial rodents, amphibians, aquatic insects, and crustaceans. Rails consume decapods (shrimp, crayfish, crabs), small molluscs, aquatic insects, beetles, snails, spiders, and crustaceans. Marsh birds often fly a short distance inland to roost and nest in groves of trees, but return to the marsh every day to feed. Heron rookeries are known at NASNI, SUBASE, and Naval Station.

Egrets and herons feed on fish, crayfish, amphibians, and snakes, as well as terrestrial rodents, lizards, and insects. Rails consume decapods, molluscs, aquatic insects, beetles, snails, spiders, and crustaceans.

Marsh birds that are reportedly declining in numbers in the Bight include the great blue heron (*Ardea herodias*), light-footed clapper rail, Virginia rail (*Rallus limicola limicola)*, and black rail (*Laterallus jamaicensis coturniculus)* (Baird 1993). The tiny black rail is now extirpated from the bay, which was the southern end of its range.

2.6.5.3 Reproductive Ecology

San Diego Bay and the Bight are relatively unimportant as breeding areas for most migratory waterbirds. Few shorebirds breed in southern California, but exceptions are American avocet, black-necked stilt, snowy plover, least and spotted sandpiper (*Actitis macularius)*, willet, and black oystercatcher (*Haematopus bachmani*). The proportion of nesting species overall is also quite small in southern California compared to northern and central California (Briggs and Chu 1987).

Most sea birds migrate north or south to breed. Exceptions that breed completely within southern California are the black storm-petrel (*Oceanodroma melania)* and Xantus's murrelet. San Diego Bay breeding grounds for sea birds and shorebirds include NASNI, Silver Strand, NAB, salt works, and SMNWR. The South Bay NWR is a significant breeding ground for colonial nesting sea birds (USFWS 1993, 2006).

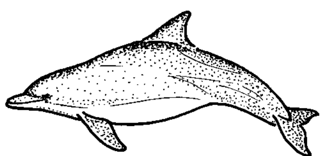
Sea birds that breed completely within southern California are the California least tern, brown pelican, black storm-petrel, and Xantus's murrelet.

Since 1999, the salt pond levees have been routinely monitored during the nesting season. The numbers and locations of nests per species that have been documented as a result of this monitoring are provided in Table 2-45. These data illustrate the variation in numbers of nests within the salt works from year to year. These variations could be affected by conditions within the site, but are more likely the result of changing conditions in adjacent areas, particularly the ocean, that cannot be controlled by management actions (USFWS 2006).

Table 2-45. Number of sea bird nests as a result of monitoring (Source: Patton 2006).

Number of Waterbird Nests at the South San Diego Bay Unit (1999-2005)							
	1999	2000	2001	2002	2003	2004	2005
Seabird Nesting							
California least tern	25	44	45	39	62	49	34
Gull-billed tern	29	27	47	39	59	49	73
Caspian tern	208-370	500-575	365-450	379	332	313	357
Royal tern	36	1-2	3	1-3	28-31	38	52
Elegant tern	3,100	86	107-110	37-100	10,300-10,500	1,020	3,050-3,200
Foster's tern	174-188	325-327	419-438	390+	266	275	415
Black skimmer	395-410	224-231	419-430	443+	541	496	752
Other Nesting Waterbirds							
Western snowy plover	0	1	3	3	0	2	4
Double-crested cormorants	80-84	41	39-53	49+	74-77	49	77

2.6.6 Marine Mammals



Coastal bottlenose dolphin

Marine mammals include those mammals that spend the majority of their lives at sea and are almost totally dependent on marine organisms for food. Common examples include seals, sea lions, dolphins, and whales. These mammals fall into the orders Carnivora (suborder *Pinnipedia*) and Cetacea. Food is variable, from plankton for filter-feeders, to benthic invertebrates of soft bottom areas for the gray whale, to fishes and squid for carnivores such as dolphins.

In San Diego Bay, two pinniped species occur: California sea lion and the Pacific harbor seal (*Phoca vitulina).* Pinnipeds are carnivores with both front and rear appendages in the form of flippers best suited for swimming, limiting locomotion on land. Annual pup counts for this group contain anomalously low years that seem to be correlated with El Niño events. The hypothesis is that the displacement of food fish species during calving/lactation periods causes a high pup mortality and/or lowered pupping levels.

Cetaceans are those marine mammals that possess a "blowhole," flippers as anterior swimming appendages, and horizontal flukes as posterior swimming appendages. They live their entire lives in the water column, with occasional strandings (cetaceans washed up on the beach). San Diego Bay is presently not a common habitat for these whales and dolphins, which primarily remain offshore in the open ocean except for the coastal bottlenose dolphin.

2.6.6.1 Mammals of Interest

Although 39 marine mammal species may be encountered in the Bight, only a handful are species of interest to San Diego Bay (Bonnell and Dailey 1993). Since no surveys of marine mammals had been performed in the bay their relative occurrence was estimated for the 2000 INRMP from interviews with marine mammal experts in the area (S. Ridgeway, SPAWAR, *pers. comm.*; R. Defran, SDSU, *pers. comm.*; J. Barlow and J. Cordaro, NMFS, *pers. comm.*; M. Fluharty, CDFG, *pers. comm.*). The make-up of marine mammal species known to occur and of interest within San Diego Bay has not notably changed since these interviews, but the population status for represented species has become increasingly accurate.

Merkel & Associates conducted five quarterly marine mammal surveys from February 2007 to March 2008 in the vicinity of the Point Loma Naval Complex. The first survey, conducted in February 2007, recorded five marine mammal species, including harbor seals, California sea lions, bottlenose dolphins, Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) and common dolphins (*Delphinus* sp.). In May 2007, only two of the five species previously observed within the study area were recorded, the California sea lion and bottlenose dolphin. An unidentified dolphin species was recorded during this same survey. Additionally, documentation of a Pacific white-sided dolphin within the study area was made during the May 2007 survey. In August and December of 2007, California sea lions were the only marine mammal species observed. In March 2008, three marine mammal species were observed, bottlenose dolphins, California sea lions, and harbor seals. The marine mammals observed during this study are common species found within coastal California waters and were expected to be observed both seasonally for some species and throughout the year for others (Merkel & Associates 2008).

Trends in increasing marine mammal populations especially with respect to pinnipeds remain of interest as a species as well as implications regarding applicable management practices for the bay and its stakeholders. Occurrence or probability of occurrence can be categorized into three levels:

Species known to be regularly encountered within the bay

- California sea lion
- coastal bottlenose dolphin

Species that are occasional-to-frequent visitors to the north channels of the bay

- Pacific harbor seal
- gray whale

Species that are found in the SCB, with potential for isolated occurrence in San Diego Bay

- northern elephant seal (*Mirounga angustirostris*)
- long-beaked common dolphin (*Delphinus capensis*)
- Pacific white-sided dolphin
- short-finned pilot whale (*Globicephala macrorhynchus*)
- minke whale (*Balaenoptera acutorostrata*)
- finback whale (*Balaenoptera physalus*)

2.6.6.2 Historical Changes for Marine Mammal Occurrence

Gray whales were historically common in the bay, but are no longer (Scammon 1874). Whaling for gray whales began offshore of California in the 1840s and probably within the bay around the same time (Leet *et al.* 1992). San Diego Bay peaked as a whaling center from 1850–1870, but declined by the 1890s. With waterfront development, shipping traffic, and increasing pollution levels, the bay was no longer a hospitable environment for gray whale calving in the early 20th century. Today, however, gray whales occasionally visit the bay, especially during their northward migration in the spring (S. Ridgeway, *pers. comm.*).

Risso's dolphin (*Grampus griseus*) was another historical inhabitant of the bay (Scammon 1874). In fact, this species was originally called the "San Diego Bay Grampus" by Scammon in the 1870s who observed them "passing into and out of the estuaries connecting with the main lagoon" and ascending the estuaries to feed on fish (Scammon 1874). Estuaries at the mouths of tributaries are no longer a dominant feature of the bay due to urbanization, with only Sweetwater and Otay Rivers retaining some estuarine behavior in their altered states. Today there are no identified dolphins of this species in the bay. They are now most commonly found in deep water habitat with warm temperate to tropical water conditions (Leet *et al.* 1992). Only the coastal bottlenose dolphin appears to be a regular cetacean inhabitant.

"San Diego Bay Grampus," now called Risso's dolphin, was a common marine mammal in the bay during the 1870s.

The bay probably never supported a breeding colony of harbor seals or sea lions due to beach access by land predators. The populations of these animals have likely fluctuated in San Diego Bay over the past two centuries in response to cycles of human pressures. Many pinnipeds were killed in California during the 1860s and 1870s for their oil or body parts, and many females were captured for displays or animals acts (Leet *et al.* 1992) until California law in 1938 gave them complete protection from hunting. Sport and commercial fishermen were allowed to kill sea lions and harbor seals for interfering with their operations until the 1972 Marine Mammal Protection Act (MMPA).

2.6.6.3 Ecological Roles in the Bay

Ecologically, the marine mammals occurring in or near San Diego Bay are high-order carnivores. With few exceptions, all derive their sustenance from several prey species, often with seasonal or spatial dynamics facilitating variations in prey abundance, partitioning of resources, and/or special nutritional requirements (pregnancy or lactation). This combination of food-related characteristics causes a great deal of complexity in both the specific contribution of each prey resource and the effect of this predation on each prey species population.

Examples of specific prey found in the bay are listed under individual marine mammal species accounts that follow.

2.6.6.4 Species Accounts

Descriptions follow about each species' occurrence, status, and their ecological contribution to the bay. The rare species listed above are not described due to their low abundance in the bay. Where possible, specific examples are given regarding the species in San Diego Bay.

California sea lion—*Zalophus californianus californianus*

Occurrence. California sea lions inhabit the entire western coast of North America from central Mexico through the Canadian coastline. These animals are most abundant in the Bight area during the May to July breeding period. The majority of the west coast population is in the Bight since most sea lions breed at the Channel Islands. This species is commonly seen in San Diego Bay.

Sea lions are most easily seen in the bay at their resting spots on rocks, buoys, and sometimes piers. They likely feed on octopus, shark, and fish within the bay.

Sea lions seek a variety of structures, such as rocks, piers, and buoys, for "hauling out" or resting periods in the bay. These behaviors can be destructive to structures due to the weight of the animal and fouling (M. Fluharty, *pers. comm.*). If sea lions find an easy food source at tourist spots or fishing piers, their presence can become a nuisance at certain areas in the bay as they have at marinas in Monterey and San Francisco Bay (Leet *et al.* 1992). Marina operators and commercial and sport fishermen tend to consider them a major nuisance, leading to some human-caused mortality.

Status. The Bight includes the southernmost breeding area for the "U.S. stock" (as opposed to the separate "western Baja California stock") and is estimated to be near 180,000 animals. During the 2001 breeding season, the minimum population size for California was determined from counts of all age and sex classes that were ashore at all the major rookeries and haul out sites. The minimum population size of the U.S. stock is 138,881 (NMFS unpublished data). It includes all California sea lions counted during the July 2001 census at the four rookeries in southern California and at the haul out sites located between Point Conception and the Oregon/California border. An additional unknown number of California sea lions are at sea or hauled out at locations that were not censused (NMFS 2007). Even considering decline years, the U.S. stock of California sea lions has experienced an annual average growth rate of 6.2% since 1983 (Carretta *et al.* 2004). The El Niño years cause a cyclical decrease in the food supply and a resulting decline in reproductive success and survival of sea lions. Fishery-related mortality from primarily gill net and long line fisheries take an average estimate of 1,476 (CV = 0.03) California sea lions annually (NMFS 2007). There is little concern at present about sustaining this species' population, particularly since the closure of set gillnet fisheries in the region (NMFS 1997b). Stable growth of regional populations likely is equally represented within bay populations. No estimate has been made of the California sea lion population in San Diego Bay.

Ecological contribution to San Diego Bay. California sea lions' food consists of squid, octopus, and a variety of fishes. While no studies have occurred of their diet in the bay, studies of food sources have been done in other California coastal areas (Antonelis *et al.* 1987; Lowry *et al.* 1987; Melin *et al.* 1993; Hanni and Long 1995; Henry *et al.* 1995). Fish species found in the bay that sea lions most likely feed on include spiny dogfish, jack mackerel, Pacific herring, Pacific sardine, and northern anchovy. They also eat octopus and leopard shark.

Coastal bottlenose dolphin—*Tursiops truncatus*

Occurrence. These animals occur worldwide and their distribution and taxonomy are still being resolved (Leatherwood and Reeves 1990). California contains coastal and offshore populations that the NMFS is currently managing as separate stocks (NMFS 1997b).

The coastal stock population is found within 0.6 mile (1 km) of shore and generally distributed from Point Conception through Ensenada, Mexico. These dolphins have been studied by R. H. Defran at SDSU since 1982, but mostly from the Scripps pier northward (Defran *et al.* 1986; Hanson and Defran 1993, Defran and Weller 1999). El Niño events seem to severely displace certain members of the population northward making it extremely difficult to account for them.

Status. While no studies have occurred of this species in San Diego Bay, they are observed almost every day, at least in the northern segment. Based on a comparison of mark-recapture abundance estimates in California for the periods 1987-89 ($\hat{N}$ = 354) and 1996-98 ($\hat{N}$ = 356), Dudzik (1999) stated that the population size had remained stable over an 11-year period. While the stock had a potential biological removal level (PBR) of only 1.3 animals per year during 1996, the removal of set gillnet fisheries in California in 1994 has reduced human-caused mortality (NMFS 1997b). Based on photographic mark-recapture surveys conducted along the San Diego coast in 2004 and 2005, the most recent estimate of population size is 323 dolphins (CV = 0.13, 95% CI 259-430; Dudzik *et al.* 2006). This estimate does not reflect that approximately 35% of dolphins encountered lack identifiable dorsal fin marks (Defran and Weller 1999). Based on a comparison of mark-recapture abundance estimates for the periods 1987-89 ($\hat{N}$ = 354),1996-98 ($\hat{N}$ = 356), and 2004-05 ($\hat{N}$ = 323), Dudzik *et al.* (2005) stated that the population size had remained stable over this period.

Pollutant levels, especially DDT residues, in southern California coastal bottlenose dolphins have been found to be among the highest of any cetacean examined (O'Shea *et al.* 1980; Schafer *et al.* 1984). Although the effects of pollutants on cetaceans are not well understood, they may affect reproduction or make the animals more prone to other mortality factors (Britt and Howard 1983; O'Shea *et al.* 1999). This population of bottlenose dolphins may also be vulnerable to the effects of morbillivirus outbreaks, which were implicated in the 1987–1988 mass mortality of bottlenose dolphins on the U.S. Atlantic coast (Lipscomb *et al.* 1994).

Ecological contribution to San Diego Bay. Specific prey items of bottlenose dolphins along the California coast were studied by Defran *et al.* (1986). San Diego Bay bottlenose dolphins forage on species such as jack mackerel, Cortez grunt, striped mullet, black croaker, white sea bass, white croaker, spotted croaker, yellowfin croaker, California corvina, queenfish, Pacific mackerel, Pacific bonito, and sierra.

Pacific harbor seal—*Phoca vitulina richardsi*

Occurrence. These animals range from Alaska to Baja California, but only 14% are found south of Alaska (Bonnell and Dailey 1993). As the name implies, harbor seals prefer inshore waters, being especially fond of protected inlets and embayments. They are observed in San Diego Bay on an occasional basis (S. Ridgeway, *pers. comm.*). In the Bight, they are most abundant during the peak haul out period (May to July) on the Channel Islands but are also encountered year-round (Stewart and Yochem1984; Bonnell and Dailey 1993). When the Spanish Bight still existed, it was a haul out area for harbor seals when sand islets were exposed at low tides (J. Coatsworth, *pers. comm.*).

Besides the Channel Islands and the Coronado Islands in Mexico, haul out sites include scattered intertidal sand bars, rocky shores, and beaches. A colony of harbor seals has created a nuisance at Children's Pool in La Jolla where the animal's feces have contaminated a popular beach (M. Fluharty, *pers. comm.*).

Pacific harbor seals have a stable status in the region and likely visit the bay to feed on octopus and various fishes.

Status. During the 19th century, this species was subjected to commercial hunting pressure and the population level of the extant stock was probably reduced to a few hundred individuals (Barlow *et al.* 1995). A 1995 estimate of the California stock of harbor seals was approximately 30,000, and the trend seems to be toward a slow increase except during El Niño years. The PBR for this stock is 1,678, with fishery mortality on the decline since gillnet fishery closures in 1994 (NMFS 1997b). Because of the way it was calculated (based on the fraction of seals hauled out at any time during a 24 hr day), Hannan's (1996) correction factor of 1.2 can be viewed as a minimum estimate of the fraction hauled out at a given instant. Based on the most recent harbor seal counts (26,333 in May–July 2004; Lowry *et al.* 2005) and Hanan's revised correction factor, the harbor seal population in California is estimated to number 34,233 (NMFS 2007).

Since 1990 there has been no net population growth along the mainland or on the Channel Islands. Although earlier analyses were equivocal (Hannan 1996) and there has been no formal determination that the California stock has reached OSP (Optimal Sustainable Population level as defined by the MMPA), the decrease in population growth rate has occurred at the same time as a decrease in human-caused mortality and may indicate that the population has reached its environmental carrying capacity (NMFS 2007).

Ecological contribution to San Diego Bay. Harbor seals prefer sheltered coastal waters and feed on schooling benthic and epibenthic fish species in shallow water (Bonnell and Dailey 1993). While not studied in the bay, specific prey species have been studied in other California waters (Stewart and Yokem 1985; Oxman 1993; Torok and Harvey 1994; Stewart and Yokem 1994; Henry *et al.* 1995). Of particular note to San Diego Bay are these potential prey species: specklefin midshipman, plainfin midshipman, jack mackerel, shiner surfperch, yellowfin goby, and English sole. Harbor seals also eat octopus, of which two species are found in the bay (R. Ford, *pers. comm.*). Although their ecological niche in the bay has not been studied, this pinniped is not likely to play a significant role (B. Stewart, Hubbs-Sea World Research Institute, *pers. comm.*) because of their low numbers. No habitat issues are known to be of particular relevance for this California stock (NMFS 1997b).

Gray Whale—*Eschrichtius robustus*

While rare, gray whales occasionally visit the north bay.

Occurrence. Before the 1870s, gray whales inhabited San Diego Bay during their winter calving season (Scammon 1874). Calving now occurs in shallow bays and lagoons of northern Baja California from early January to mid–February (Rice and Wolman 1971). They pass by the bay during their north bound (spring) and south bound (fall) migrations between Mexico and Alaska, though the majority follow an offshore instead of a nearshore route in the Bight region (Rice *et al.* 1984). However, they are occasionally seen in the north bay, particularly during their northward migration (S. Ridgeway, *pers. comm.*).

Status. The most recent abundance estimates are based on counts made during the 1997/98, 2000/01, and 2001/02 southbound migrations. Analyses of these data resulted in abundance estimates of 29,758 for 1997/98, 19,448 for 2000/01, and 18,178 for 2001/02 (Rugh *et al.* in press). The Eastern North Pacific stock of gray whales has been increasing in recent years while being subjected to known harvests. Based on currently available data, the estimated annual level of human-caused mortality and serious injury (130.4), which includes mortalities from commercial fisheries (7.4), Russian harvest (122), and ship strikes (1), does not exceed the PBR (442). Therefore, the Eastern North Pacific stock of gray whales is not classified as a strategic stock (NMFS, 2007). Since 1994, the species is no longer listed as endangered or threatened under the federal ESA (Small and DeMaster 1995).

Ecological contribution to San Diego Bay. Gray whales use their baleen to sift out crustaceans, molluscs, and other invertebrates that they suck from bottom sediments. Bay species of potential benefit to gray whales for food would include medium to large size bivalve molluscs and decapod crustaceans, depending on the spacing between the baleen elements. However, they are unlikely to be feeding in the bay.

2.6.7 Invasive Species

2.6.7.1 Biological Invasions Background

The introduction and spread of organisms to regions outside of their native range has emerged as an environmental, economic, and public health problem. Some studies have found that invasive organisms constitute the second greatest threat to biological diversity, ranking below habitat loss and degradation but far above pollution and over-harvesting (Wilcove *et al.* 1998; Pimental *et al.* 2000; Cohen *et al.* 2005; Takekawa *et al.* 2006). Nationwide, non-native species have contributed to 68% of the fish extinctions in the past 100 years and the decline of 70% of the fish species listed in the ESA (Wilcove *et al.*1998).

Aquatic invasive species (AIS) disrupt the balance of natural ecosystems by consuming or competing with native plants and animals, altering biogeochemical cycles, and reducing native biodiversity. They also threaten commercial, industrial, recreational, and agricultural activities by disrupting fisheries and agricultural production; clogging waterways; and rendering swimming, fishing, and boating areas unusable (CDFG 2006).

AIS also harbor parasites and diseases that could harm both native species and human health. A study of ballast water collected from vessels entering the Chesapeake Bay found that 14 of the 15 vessels sampled contained a strain of cholera never before identified in the United States (Ruiz *et al.* 2000). Toxic red tides have in some cases been caused by dinoflagellates introduced by ballast water or shellfish imports for aquaculture (Hallegraeff and Bolch 1991). Human neurotoxins produced by the dinoflagellates accumulate in clams or mussels, sickening and sometimes killing people that eat them. In 1991, the cholera-causing bacterium *Vibrio cholerae* was discovered in oysters and fish in Mobile Bay, Alabama. The U.S. Food and Drug Administration found the same strain of cholera in one-third of the ballast water of the ships arriving from South America (U.S. Federal Register 1991). Non-indigenous invaders in California include the organism causing sudden oak death, the Mediterranean fruit fly, West Nile virus, severe acute respiratory syndrome, Human Immunodeficiency virus, and the avian flu.

Moreover, the invasives are one of the most serious threats to the integrity of San Diego's coastal ecosystems (Zedler 1992a; Crooks 1997). This threat in San Diego Bay and throughout California is only likely to grow as global movements of goods, services, and people continue to rapidly increase.

Federal law defines "invasive species" as one that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. In other literature and in legislation, such invaders are also sometimes referred to as "nuisance" species.

Invasive species are different by definition than non-native, non-indigenous, alien or exotic species--terms that refer to species that humans have intentionally or unintentionally imported to areas outside their native range. Species that spread widely beyond the location of initial establishment, become locally abundant, or spread into natural areas are “invasive.” The definition of “invasive,” therefore, depends on time and spatial scales (Lodge *et al.* 2006).

2.6.7.2 History of Invasions

The first introduction of non-native marine species into San Diego Bay could have come from the ships used by the early Spanish explorers, as they were commonly riddled with shipworms, gribbles, and other fouling organisms. A fouling organism is an invertebrate, such as a barnacle or a shipworm, that bores into or encrusts on submerged surfaces such as boats or pilings. However, it will never be certain which species, if any, arrived during the explorer period. Some invasives have been around for so long that they were assumed to be native until genetic analyses proved otherwise (Crooks 1996; J. Crooks, Scripps Institute of Oceanography, *pers. comm.*; A. Cohen, San Francisco Estuary Institute, *pers. comm.*). In addition, advancements in genetics are rapidly changing the taxonomy of marine species and making it more challenging to develop an up-to-date, accurate inventory of species with which to determine what is alien or not.

California waters began to be infested on a large scale with the shipment of tens of thousand of barrels of oysters from the East Coast when the transcontinental railway came on line (Barrett 1963). Introductions have increased steadily except for spikes in the 1940s and the 1990s that may coincide with increases in international travel by ship. Lambert and Lambert (1998) reported the more recent rapid increase of invasive tunicates in southern California harbors and marinas. In San Diego County, the rate of newly found alien marine species was also shown to be expanding, as shown in Figure 2-25 (Crooks 1997). Today, state surveys have identified over 600 introduced, or likely introduced, species in California’s bays and estuaries (CDFG 2006).

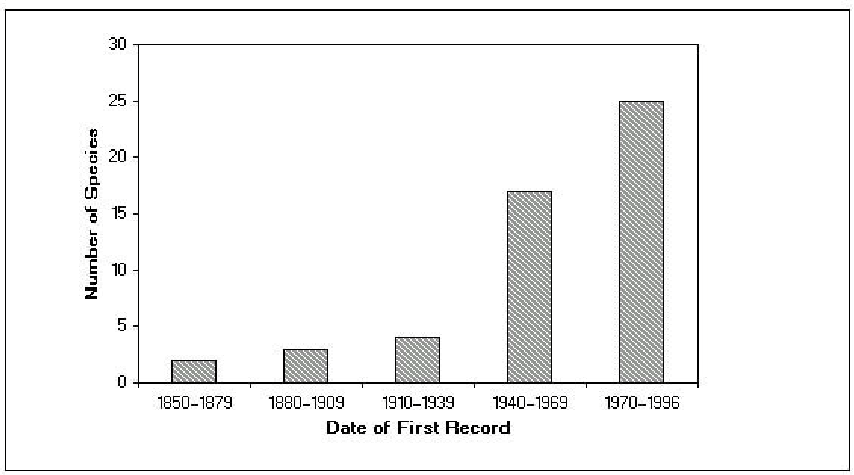


Figure 2-25. First records of marine non-indigenous species in San Diego Bay.

2.6.7.3 Likely Vectors of Invasive Species in San Diego Bay

Exotic marine species have arrived in San Diego Bay from all over the world through direct and indirect means and for intentional and unintentional purposes. Invasion risks stem from ballast water exchanges and hull fouling, as well as from aquarium, pet, nursery, aquaculture, and seafood industry trade. The following vectors could pertain to San Diego Bay:

- *Ships* due to planktonic and nektonic organisms in ballast water and attached and free-living fouling organisms on hull, on rudder, on propeller and propeller shaft, in seawater systems, seachests, in ballast tanks, and in ballasted cargo holds. Organisms may be associated with anchors, anchor chains, and anchor chain lockers, or cargo.
- *Dry Docks, Navigation Buoys and Marina Floats* due to attached and free-living fouling organisms.
- *Floating Marine Debris,* such as floating nets and plastic detritus.
- *Recreational Boats and Equipment* such as small recreational craft, snorkeling and SCUBA gear, fins, wetsuits, jet skis, and similar materials.
- *Fisheries and Marine Aquaculture* due to release of unwanted organisms by aquarists or bait fishermen; organisms associated with dunnage and containers; the processing of fresh or frozen seafood and subsequent discharge of waste materials to the environment, which may include associated living or encysted organisms; the movement of live bait subsequently released into the wild; and discarding of packing materials—such as seaweed and associated organisms—used with live bait and seafood
- *Aquarium Pet Industry* due to the movement and release of invertebrates, fish, seaweeds (algae) and seagrasses used in the aquarium industry (intentional or accidental escape).
- *Restoration Projects* due to the movement of marsh, dune, or seagrasses as well as associated organisms, reestablishment of locally extinct or decimated populations of native species, and accidentally transported associated organisms.
- *Intra-Coastal Spread By Unknown Mechanisms.* A number of marine aquatic invasives co-occur in the major ports, which may indicate intra-coastal spread of non-indigenous taxa (Foss *et al.* 2007). The mechanisms of this movement among California ports are poorly understood.
- *Natural Range Expansions.* Climate or current shifts, such as El Niño events, can cause a temporary shift in species composition. These new range extensions of species native to an adjacent regime (e.g. subtropical) are not considered “invasive” for the purposes of this INRMP. An example is the June 1998 influx of large numbers of pelagic blue crabs (*Callinectes arcuatus* or *C. bellicosus)* in San Diego Bay, an extension of the northern reach of their range probably due to warmer water and currents associated with the recent El Niño event (McKee-Lewis 1998).

This study found the primary introduction vectors likely in San Diego Bay to be hull/ship fouling, followed by ballast water, then aquaculture (Foss *et al.* 2007). Ballast water and hull fouling are discussed in more detail below.

Ballast Water

The state estimates that about 7.8 million metric tons of ballast water were discharged in California waters in 2004, and in 2005 such discharges reached 9.1 million metric tons (Takata *et al.* 2006). Live marine organisms ranging from plankton to adult fish are regularly transported from source to destination ports when ballast water is discharged (Carlton and Geller 1993; Cohen and Carlton 1995). Estimates suggest that more than 7,000 organisms are moved around the world daily in ballast water alone (Carlton 1999). California requires vessels arriving from outside the U.S. Exclusive Economic Zone (EEZ) to manage their ballast water. Similar rules became effective for vessels engaged in coastal travel in March 2006.

Even ballast water that has undergone exchange in the open ocean may contain harmful imported organisms (Burkholder *et al.* 2007). The physical and chemical conditions and the algal and bacterial assemblages in ballast water from 62 ballast tanks were characterized aboard 28 ships operated by the U.S. Military Sealift Command and the Maritime Administration sampled at nine ports on the west coast and four ports on the east coast. The ballast tank waters had been held for 2–176 days, and 90% of the tanks had undergone ballast exchange with open ocean waters. A total of 100 phytoplankton species were identified from the ballast tanks, including 23 potentially harmful taxa. Viable organisms comprised about half of the total cells. Species richness was higher in ballast tanks with coastal water and in tanks containing Atlantic or Pacific Ocean source waters rather than Indian Ocean water.

Hull Fouling

Organisms such as mussels, seaweed, anemones, and sea squirts with sedentary life stages can attach themselves to the hulls of commercial vessels or become entangled in nets, anchors, and other gear. Barnacles, other seaweeds, and bryozoans may in turn attach to mussel shells and seaweed fronds, while more mobile species such as shrimps, worms, and sea snails may hide in crannies created by larger fouling species (Takata *et al.* 2006). These organisms can survive for extended periods of time once secured to a vessel. They are introduced to new waterways once dislodged, disentangled, or by spawning in new ports (CDFG 2006).

In an expansion of California's ballast water management program, recent legislation directed a team of technical advisors to formulate recommendations to prevent introductions through vessel fouling, among other non-ballast shipping vectors. The report documents the following factors concerning this vector (CDFG 2006).

Fouling has long been a nuisance to mariners. It creates drag, reduces fuel efficiency, can strain engines, and clog seawater intake pipes meant to cool machinery. As a result, hull cleaning is a routine part of ship maintenance. Antifouling paints and other systems have long been available to reduce the problem. These coatings generally function by releasing low doses of compounds toxic to marine creatures. Vessels that move slowly, spend long periods in port, take shorter trips, or are not repainted or maintained regularly pose particular problems. These vessels tend to accumulate more total fouling but also a more diverse assemblage of fouling species. Areas on a vessel that are shielded from much water flow may foul even in cases where main portions of the hull are clean (Takata *et al.* 2006).

Environmental factors such as salinity and water temperature influence organism survival and thus introduction rates. Exposure to a wide variety of salinity and temperature fluctuations may kill many intolerant organisms. This may explain why less fouling is observed on vessels traveling on long voyages that cross a wide range of latitudes (Takata *et al.* 2006).

Fouling organisms and potential invasive species transfer from the vessel to coastal waters and ports via spawning or egg release, detachment (simply dropping off into the water), or mechanical removal (via scraping, in-the-water cleaning, or blasting in dry dock depending on clean up procedures). Because fouling is affected by the type of commerce and environmental conditions in a specific region, local field research on the topic can be quite valuable. In a 2004 Port of Oakland study, researchers found local fouling patterns to be somewhat different from those in other regions.

In a few extreme cases, the risk of species introductions has been observed to be perilously high. For example, the decommissioned USS Missouri was found to have accumulated at least 116 fouling species during the five years it spent in Bremerton, Washington before being relocated to Hawaii. A floating dry dock towed to Hawaii from San Diego in 1999 had high levels of fouling that included 34 non-indigenous species; a new species of algae became established as a result (Takata *et al.* 2006).

The majority of vessels in regular operation, however, are not at such extreme risk for fouling. Most hulls are cleaned and painted regularly for operational safety, to reduce maintenance costs, and to minimize drag-related fuel costs. Many spend as little time in port as possible and move cargo quickly for maximize profits. Consequently, the level of risk presented under more typical commercial vessel behaviors is unclear (Takata *et al.* 2006).

Though the state currently regulates ballast water and may soon regulate hull-fouling, it has no authority over vessels under 300 gross register tons in size, such as commercial fishing vessels.

2.6.7.4 Invasive Species of San Diego Bay

During Bight '98 (Bay *et al.* 2000), the nonindigenous bivalve *Musculista senhousia* was present in more than 70% of the samples, making it the most widely distributed trawl caught invertebrate in the bay. *Musculista senhousia* together with another non-indigenous species *Microcosmus squamiger* accounted for over 50% of the total catch.

With passage of the California Ballast Water Management Act of 1999, statewide focused surveys began for AIS. The CDFG, SWRCB, and the National Fish and Wildlife Foundation commissioned a Rapid Assessment Survey of selected sheltered waters between San Diego and Oxnard in the summer of 2000 (CDFG 2002; Cohen *et al.* 2005). In San Diego Bay, the sites sampled were the Chula Vista boat ramp (south bay), Fiddler's Cove (south-central bay), and Shelter Island (north bay). The SCCWRP performed another rapid assessment in 2007. For 22 sites in southern California, sampling was primarily of dock fouling along with adjacent soft-bottom habitat, nearby intertidal sites, and selected subtidal lagoon habitats. The largest number of non-indigenous species was on floating docks. Most of the exotic organisms collected are native to the northwestern Pacific, primarily the region including Japan, Korea, and northern China. A secondary group comes from the North Atlantic, and a smaller group from the southwestern Pacific (Australia and New Zealand) and the Indian Ocean. For the species collected, the number of initial records for both the Pacific Coast and southern California are greatest in the decades of the 1940s and the 1990s, possibly as a result of spikes in transport vectors during those periods (such as an increase in military vessel traffic with World War II in the 1940s and with commercial shipping and associated ballast water discharges from China, Japan, and Korea in the 1990s). About two-thirds of the organisms most likely arrived on the hulls of ships, while about two-fifths likely came from ballast water.

In 2005, CDFG's Office of Spill Prevention and Response (OSPR) conducted a state-wide survey. The OSPR study (Foss *et al.* 2007) combined numerous major and minor harbors and estuaries with a literature review to document the location of non-indigenous aquatic species in the estuarine and coastal waters of California. Although all areas of the coast showed some evidence of introductions, the totals were generally highest in the two major commercial ports, San Francisco and Los Angeles/Long Beach. San Diego Bay was sampled for epifaunal, benthic, and zooplanktonic species. Map 2-20 depicts the sites sampled, Figure 2-26 shows survey results, and Appendix F reports on the species found at each site. Two habitats, the crevices within the rocks and rip-rap of break-waters and the hard bottom benthic substrate, were not sampled in this study in San Diego Bay. Also, phytoplankton was not sampled even though it can be easily transported in ballast water.

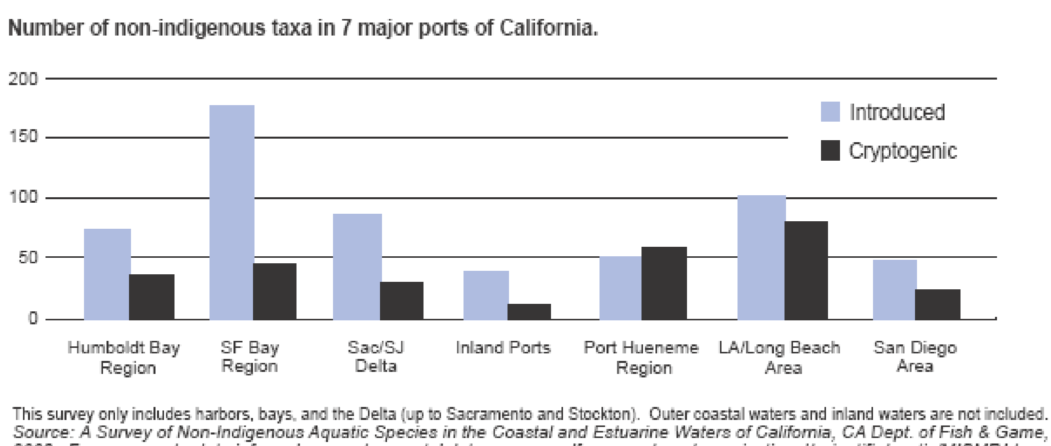
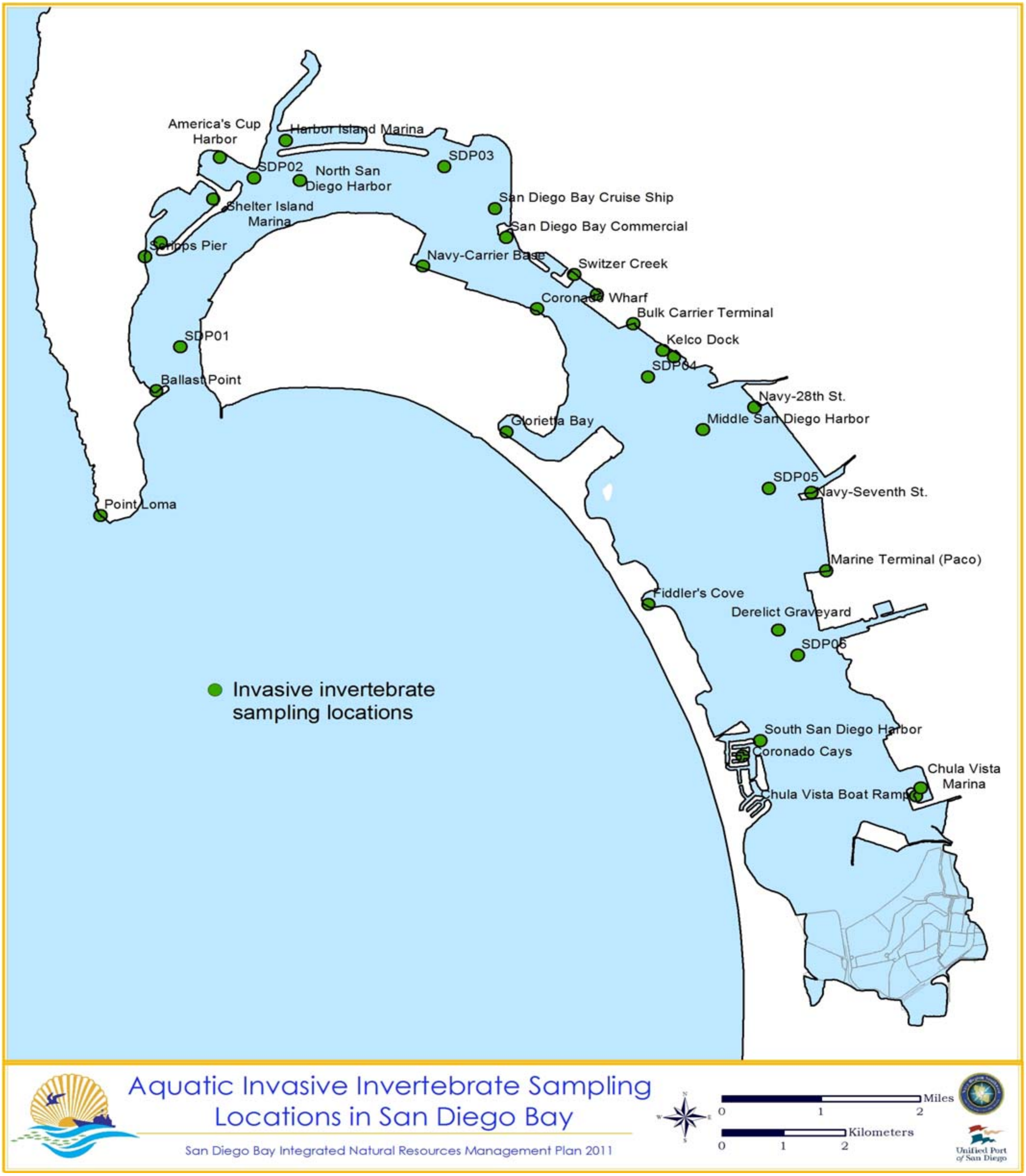


Figure 2-26. Survey results from CDFG (2002, 2006) reported in California Aquatic Invasive Species Management Plan (Draft 2006).



Map 2-20. Sampling locations for 2005 surveys for non-indigenous aquatic invasive species by the Office of Spill Prevention and Response (Foss et al. 2007).

The following lists incorporate the results of the CDFG work in 2000, that of OSPR in 2005, and in earlier studies. Local marine biologists (J. Crooks and L. Levin, Scripps Institute of Oceanography; S. Williams, SDSU; R. Ford, SDSU emeritus; G. Williams, Pacific Estuarine Research Laboratory-SDSU; A. Cohen, San Francisco Estuary Institute) and USFWS (2006) were consulted in the compilation. Table 2-46 lists invasive coastal terrestrial plants and Table 2-47, marine aquatic species. The nonnative marine species were found in benthic, fouling, and water column habitats. Coastal plant exotics are found in sand dunes, mudflats, salt marshes, riparian zones, filled wetland sites, upland transition zones, and restoration sites.

The majority of organisms introduced to the California coast are native to the northwest Atlantic, the northwest Pacific, and the northeast Atlantic, all regions from which California receives a considerable amount of ship traffic as well as the source materials for much of its aquaculture.

An exotic species that has invaded the salt marsh habitat of the Sweetwater Marsh Unit is the Australasian isopod *Sphaeroma quoyanum*. This organism burrows into the banks of the marsh's tidal channels and along marsh edge habitat often in very high densities, resulting in increased bank erosion and loss of salt marsh habitat (Talley *et al*. 2001; USFWS 2006).

Table 2-46. Invasive terrestrial coastal plants at San Diego Bay. Only plants with a Cal-IPC rating of moderate to high are included, with the exception of blackwood acacia, smilo grass, and Peruvian pepper tree, Russian thistle and southern cattail. None are federal noxious weeds.

Species	CA Invasive Plant Council[1]	CA Noxious Weed[2]
Plant Name	Rating	Yes/No
Acacia melanoxylon blackwood acacia	Cal-IPC Limited	N
Atriplex semibaccata Australian salt bush	Cal-IPC Moderate	N
Avena fatua wild oat	Cal-IPC Moderate	N
Brassica nigra black mustard	Cal-IPC Moderate	N
Bromus diandrus ripgut brome	Cal-IPC Moderate	N
Carpobrotus [*Mesembryanthemum] chilensis* sea fig	Cal-IPC Moderate	N
Carpobrotus edulis hottentot fig	Cal-IPC High	N
Centaurea melitensis star thistle	Cal-IPC Moderate	Y
Chrysanthemum coronarium garland chrysanthemum	Cal-IPC Moderate	N
Cortaderia jubata pampas grass	Cal-IPC High	Y
Eucalyptus ssp. gum	Cal-IPC Moderate	N
Foeniculum vulgare sweet fennel	Cal-IPC High	N
Hordeum murinum sterile barley	Cal-IPC Moderate	N
Lolium perenne English ryegrass	Cal-IPC Moderate	N
Mesembryanthemum crystallinum iceplant	Cal-IPC Moderate	N
Myoporum laetum Ngaio tree	Cal-IPC Moderate	N
Nicotiana glauca tree tobacco	Cal-IPC Moderate	N
Oxalis pes-caprae Bermuda buttercup	Cal-IPC Moderate	N
Pennisetum setaceum crimson fountaingrass	Cal-IPC Moderate	N
Piptatherum miliaceum smilo grass	Cal-IPC Limited	N
Salsola tragus Russian thistle/tumbleweed	Cal-IPC Limited	Y*
Schinus molle Peruvian pepper tree	Cal-IPC Limited	N
Tamarix spp. Tamarisk	Cal-IPC High	Y
Typha domingensis southern cattail	Not Listed	N

1. California Invasive Plant Council, Invasive Plant Inventory. **Cal-IPC High**-Species have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically. **Cal-IPC Moderate**-Species have substantial and apparent, but generally not severe, ecological impacts on physical processes, plant and animal communities and vegetation structure. Reproductive biology and other attributes are conducive to moderate to hgit rates of dispersal, though establishment is generally dependent upon ecological disturbance. Amplitude and distribution may range from limited to widespread. **Cal-IPC Limited**-Species are invasive but their ecological impacts are minor on a statewide level or there was not enough information to justify a higher score. Reproductive biology and other attributes result in low to moderate rates of invasiveness. Amplitude and distribution are generally limited, but these species may be locally persistent and problematic. http://www.cal-ipc.org/. Accessed December 2007.

2. Listed in California Administrative Code Title 3, §4500.Noxious weeds. http://ccr.oal.ca.gov/. Accessed December 2007.

* California Department of Food and Agriculture. Pest rating is based on the economic risks posed to the state. Russian thistle is rated 'C' = State endorsed holding action and eradication only when found in a nursery; action to retard spread outside of nurseries at the discretion of the commissioner; reject only when found in a cropseed for planting or at the discretion of the commissioner. http://cdfa.ca.gov/phpps/ipc/weedinfo/winfo_list-pestrating.htm. Accessed December 2007.

*Table 2-47. List of invasive marine species found in San Diego Bay.**

Species	
Marine Alga	
Caulacanthus ustulatus red algae	*Sargassum muticum*
Lomentaria hakodatensis red algae	*Undaria pinnatifida* wakame-brown kelp
Protozoans	
Lobochona prorates	
Cnideria	
Bunodeopsis sp. anemone	*Obelia* sp.
Diadumene lineatu anemone	*Tubularia crocea* naked hydroid
Gonothyraea clarki	
Ectoprocta: Moss animals	
Amathia convoluta wool bryozoan	*Tricellaria gracilis*
Bowerbanka imbricata	*Watersipora arcuata*
Bugula stolonifera	*Watersipora* sp. *A*
Cryptosula pallasiana	*Watersipora subtorquata*
Rhynchozoon bispinosum	*Zoobotryon verticillatum*
Schizoporella unicornis	
Polychaetes	
Branchiosyllis exilis	*Nicolea* sp. *A Harris*
capitellid (Capitella "capitata")	*Polydora ligni* spionid
Eteone aestuarina	*Pseudopolydora* spionid worm
Marphysa sanguinea eunicid	*Seudopolydora paucibranchiata* spionid
Myrianida pachycera	*Typosyllis nipponica* syllid worm
Neanthes acuminata nereid	*Vermiliopsis infundibulum*
Sponges	
Haliclona sp.	
Crustaceans: Cirripeds	
Amphibalanus amphitrite acorn barnacle	
Crustaceans: Maxillopods	
Oithona davisae	*Pseudodiaptomus marinus*
Oithona similis	
Crustaceans: Ostracods	
Aspidochoncha limnoriae	*Redekea californica*
Crustaceans: Amphipods	
Ampithoe valida	*Eochelidium* sp. *A*
Aoroides secundus	*Grandidierella japonica*
Caprella acanthogaster skeleton shrimp	*Jassa marmorata (falcata)*
Caprella scaura skeleton shrimp	*Monocorophium* gammarid amphipod
Chelura terebrans gammarid amphipod	*Podocerus brasiliensis*
Corophium acherusicum	*Pontogeneia rostrata* gammarid amphipod
Corophium heteroceratum	*Stenothoe valida*
Corophium uenoi	
Crustaceans: Isopods	
Iais californica	*Paranthura japonica*
Limnoria tripunctata gribble	*Sphaeroma quoyanum*
Limnoria quadripunctata gribble	*Sphaeroma walkeri*
Munnogonium wilsoni	
Crustaceans: Decapods	
Palaemon macrodactylus Oriental shrimp	
Crustaceans: Tanaidacea	
Sinelobus stanfordi	*Tanais* sp.
Molluscs	
Arca transversa	*Tapes semidecussata* Japanese littleneck
Catriona rickettsi nudibranch	*Geukensia (Modiolus) Ischadium demissum* * Atlantic ribbed mussel
Lyrodus pedicellatus southern shipworm	*Mytilus galloprovincialis* common mussel
Musculista senhousia Japanese mussel	*Teredo navalis* shipworm
Ostrea edulis European flat oyster	*Theora fragilis* (*lubrica*)
Tunicates	
Ascidia sp.	*Microcosmus squamiger*
Ascidia zara	*Molgula ficus*
Botrylloides diegensis	*Polyandrocarpa zorritensis*
Botrylloides perspicuum	*Styela canopus*
Botrylloides violaceus	*Styela clava*
Botryllus schlosseri	*Styela plicata*
Ciona intestinalis	*Symplegma brakenhielmi*
Ciona savignyi	*Symplegma reptans*
Diplosoma listerianum	
Marine Fish	
Acanthogobius flavimanus yellowfin goby	*Poecilia latipinna* sailfin molly
Lucania parva rainwater killifish	*Morone saxatilis* striped sea bass
Tridentiger trigonocephalus chameleon goby	*Dorosoma petenense* threadfin shad

** For updates and source, problems and effects of these species see: Aquatic Species Database: Aquatic Invasions Research Directory (AIRD). Host: Smithsonian Environmental Research Center. http://www.invasivespeciesinfo.gov/toolkit/main.shtm.*

2.6.7.5 Ecological and Economic Impacts

Non-indigenous species can have several different types of impacts on native species (Lafferty and Kuris 1996; L. Levin, *pers. comm.*), and San Diego Bay currently faces a number of these:

- No detectable effect or nonreproducing populations;
- Replacement of a functionally similar native species through competition;
- Inhibition of normal growth or increased mortality of the host and associated species;
- Serious species competition caused by extremely high population densities from lack of natural enemies;
- Development as novel predators or novel prey;
- Creation or alteration of original substrate and habitat;
- Hybridization with native species;
- Direct or indirect toxicity (e.g. toxic diatoms);
- Reduced diversity and abundance of native plants and animals (due to competition, predation, genetic dilution, smothering and loss of habitat to invasive species);
- Degradation of wildlife habitat;
- Alteration of the native food web and declines in productivity;
- Changes in biogeochemical cycles (including nutrient cycling and energy flow);
- Losses in fisheries production;
- Impairment of recreational uses such as swimming, boating, diving and fishing;
- Degradation of water quality;
- Threats to public health and safety (via parasites and disease);
- Loss of coastal infrastructure due to fouling and boring organisms;
- Blockage of outlets, such as storm drains and other pipes;
- Shoreline, bank, and levee erosion and destabilization; and
- Increased costs to business, agriculture, landowners, and government for invasive pest control, treatment and clean up.

A National Research Council report (1995) stated that non-native species are one of the most serious potential threats to native marine species. Several studies on the San Francisco Bay and Delta estuary have described the known impacts of introduced species that now dominate many important habitats in that ecosystem in terms of species, number of organisms, and biomass (CDFG 1994; Cohen and Carlton 1995). That estuary has been invaded by at least 234 non-natives, with over 100 different species of aquatic invertebrates alone. A new species moves in every 14 weeks and some say it is the most invaded ecosystem in the world (DeSena 1997). Some of the problematic marine invasives that have become established are the European green crab (*Carcinus maenas),* which preys on the young of native Dungeness crab, an important commercial fishery; the Asian clam *(Corbula amurensis),* which has altered the food web of the San Francisco Bay estuary (Miller *et al.* 1998; Veldhuizen and Hieb 1998); and the Chinese mitten crab *(Eriocheir sinensis),* which undermines the stability of levees and shorelines with its burrows. The mitten crab arrived in San Francisco Bay by around 1992 and gradually spread upstream into the Delta and tributary waters (it breeds in brackish water and migrates upstream to grow to maturity in fresh water). In its peak year it clogged the fish screens at the main federal water project pumps, with approximately 20,000 crabs per day arriving at the screens during the crab's fall migration. The green crab spread into central California from San Francisco Bay (Grosholz and Ruiz 1995). It arrived in San Francisco Bay by around 1990 and was subsequently reported from Morro Bay in south-central California to Vancouver Island in British Columbia. An array of non-native clams, copepods, and plants are implicated in the sharp recent decline of endangered Delta smelt. Meanwhile, other invasive aquatic plants continue to infest many of California’s riparian areas and marshes (CDFG 2006).

The local anemone *Bunodeopsis sp.* is considered to be a public nuisance by the City of San Diego because it stings humans who touch it; it is also destroying eelgrass beds in Mission Bay though not in San Diego Bay so far for unknown reasons (Sewell 1996; S. Williams 1999). Often marine pests are invasive species that have become overpopulated because they lack their own native conditions, such as a local predator, or can more readily exploit the current habitat condition than can a native species. Invasive plants that have become "naturalized," or extensively spread throughout the native plant community, can become difficult, if not impossible, to eradicate. In contrast, eradication efforts for the New Zealand mangrove (*Avicenna marina),* which was introduced in Mission Bay over 30 years ago, have been quite successful (L. Levin, *pers. comm.*). Fortunately, the propagules of this species have limited dispersal capabilities. In comparison, little experience exists in trying to eradicate or control nonnative marine animals. On a positive note, tunicates (ascidians) are able to remove and sequester heavy metals and other pollutants from harbor waters. The excessive populations of non-indigenous tunicates at marinas could be used as biological monitors or as a means of heavy metal removal (with removal of the organism) from the ecosystem (Monniot *et al.* in Lambert and Lambert 1998). In San Diego Bay, invasive tunicates, shipworms, gribbles, and hydroids are commonly found on or in pilings.

Ecosystem-level changes in the bay's intertidal habitat are being caused by the invasive Japanese mussel, Musculista senhousia.

Many problems are being, or can be, caused by nonnative species in San Diego Bay. The most studied invasive locally is probably the Japanese mussel *Musculista senhousia,* which is found in both Mission Bay and San Diego Bay (Takahashi 1992; Crooks 1996; Scatolini and Zedler 1996; Crooks 1997). Its rapid spread, recent population explosion, and extreme densities (up to 27,000 mussels/m^2 in the intertidal zone and up to 178,000/m^2 carpeting the shallow subtidal bay bottom) have attracted attention. Research has shown that its effects can be both negative and positive (Crooks 1998b). While its dense mats can crowd out native clams and dominate marsh restoration sites, the mats also provide a new habitat that supports greater species diversity and densities of native macrofauna than other areas. However, the mussel's dense beds can inhibit growth and vegetative propagation of eelgrass (Reusch and Williams in Crooks 1997; Reusch and Williams1998, 1999). If the eelgrass beds are dense and unfragmented, however, the mussel starves. The mussel has established so well in San Diego that its removal is considered impossible.

Another invasive species in the bay producing "ecosystem-level effects through habitat alteration" is the isopod *Sphaeroma quoyanum* (Crooks 1997). Though known to be in the bay since 1927, it was not detected as a problem until the early 1990s. High densities (>10,000/m^2) were observed in the banks of the salt marsh in Paradise Creek, causing the overlying vegetated marsh flat to slump into the creek and the creek to widen. This recent ecological release after a long lag period since the species' introduction also illustrates one of the problems in dealing with nonindigenous species—their potential for impact may be underestimated.

The economic impacts of marine aquatic species invasions are also growing. In 2004, the escaped aquarium alga *Caulerpa taxifolia,* which has overrun aquatic ecosystems in the Mediterranean Sea, was found in southern California. Efforts to eradicate it have cost $7 million to date (CDFG 2006). Pimentel (2001) estimated environmental losses to the U.S. totaling $1 billion a year from introduced fish, $2.13 billion from arthropods and $1.3 billion from mollusks. In an earlier study for the U.S. Congress, the Office of Technology Assessment attempted to quantify economic impacts of 111 species of invasive fish and 88 species of mollusks. Of these, only four fish species and 15 mollusk species resulted in major negative impacts—including the sea lamprey, zebra mussel, and Asian clam. The Office of Technology Assessment estimated that the cumulative loss to the U.S. for the period 1906–1991 for three harmful fish species was $467 million (1991 dollars) and $1.27 million for three aquatic invertebrates. Aquatic and riparian plant species can be equally high-impact, especially salt cedar (*Tamarisk* sp.), purple loosestrife (*Lythrum salicaria*), melaleuca (*Melaleuca quinquenervia*), and hydrilla (*Hydrilla verticillata*), among others. Spending on aquatic plants control in the U.S. is estimated at $100 million per year (Lovell *et al.* 2006).

2.6.7.6 Potential Near-Term Invasives to San Diego Bay

Species that could invade California in the future are worrisome. For example, the freshwater zebra mussel *(Dreissena polymorpha)* colonizes pipes and constricts the flow of water in equipment. Within twelve years of arriving in North America from Europe in ship ballast water, it had spread to at least 20 states. Battling the mussel now costs millions every year. Though not yet found in California, it has been intercepted at border inspection stations. If the mussel becomes established in state waters, it could cripple the irrigation network supporting California's $30 billion agriculture industry, as well as the infrastructure that transports drinking water around the state (CDFG 2006.)

The expansion of the global economy will bring along increased international shipping throughout the Pacific Coast and probably the Port. Such shipping continues to have the potential to expand the rate of ballast-water introductions of invasive species. For example, resting spores of a toxic *Alexandrium* species of dinoflagellate were introduced to the harbor of Hobart, Tasmania through ships' ballast water and the risk presently exists for a similar introduction from ships visiting San Diego Bay (Hallegraeff and Bloch 1991). Pollution, which the bay suffers from for certain constituents, can also favor invasions by opportunistic species, such as the amphipod *Grandidierella japonica* (Fairey *et al.* 1996).

One scenario that could occur in the bay is for open intertidal habitat to be transformed into dense meadows of tall grass by the invasive cordgrass *Spartina alterniflora* or its hybrid with the native species *S. foliosa* (Daehler and Strong 1997). This alteration would impair the many invertebrate and bird species dependent on the bay's unvegetated mudflats, located primarily in the south bay. *Spartina densiflora,* a native of Chile, currently outcompetes native pickleweed in San Francisco Bay and could transform marshes of San Diego Bay if allowed to be introduced.

Possible management strategies to prevent invasions are discussed and proposed in Chapter 4: Ecosystem Management Strategies.

Certain invasive pest species may be some of the most likely ones to appear in San Diego Bay in the near future (Zedler 1992a; Lafferty and Kuris 1996; Sewell 1996; J. Crooks, *pers. comm.*). These include:

Plants

- Cajeput tree, *Melaleuca quinquinervia*—now in San Diego County landscaping and Tijuana Estuary;
- Oriental cattail, *Typhus orientalis*—now spreading rapidly in Australian salt marshes;
- Cordgrass, *Spartina densiflora, S.anglica, and S. alterniflora*—now on the U.S. west coast, potentially outcompeting native species or overtaking mudflats;
- Japanese eelgrass, *Zostera japonica*—now in Pacific Northwest; and
- Caulerpa, *Caulerpa taxifolia* invaded Aqua Hedionda lagoon in San Diego County in 2000 and is suspected at various southern California bays and harbors.

Animals

- African clawed frog, *Xenopus laevis*—now in Otay River drainage (Somma 2007) and in a brackish marsh near Interstate 5 near Sweetwater Marsh (Pacific Southwest Biological Services, Inc. 1990, cited in USFWS 2006);
- Green crab, *Carcinus maenus*—now in San Francisco Bay;
- Chinese mitten crab, *Eriocheir sinensis*—now in San Francisco Bay Delta;
- Asian clam, *Potamocorbula amurensis*—now in San Francisco Bay;
- Copepod, *Pseudodiaptomus marinus*—now in Mission Bay;
- Calanoid copepod, *Tortanus dextrolibotus*—now in San Francisco Bay Delta; and
- Mysid shrimp, *Acanthomysis* sp.—now in San Francisco Bay.

The ecological ramifications of the introduction of any of these species could range from minor to very significant, depending on local conditions and natural competition. Based on experience in San Francisco Bay, the species of greatest ecological impact are probably the invasive cordgrass, Chinese mitten crab, green crab, and Asian clam. Food webs and habitats were strongly altered and populations of indigenous species of the same niche were depressed (CDFG 1994; Veldhuizen and Hieb 1998).

2.7 Special Status Species

There are many listed and sensitive species that occur in and around San Diego Bay. There are five federally listed species occurring within the San Diego Bay area. Of these, two are in salt marsh habitats (light-footed clapper rail, salt marsh bird's beak), two occur on sandy beaches (California least tern, western snowy plover), and the only marine species is the eastern Pacific green sea turtle which is a year-round resident in warm water of south bay.

In addition to the federally listed species described above, there are a number of other special status species occurring within the San Diego Bay area. Eleven of these species can be found in salt marsh habitats, four occur on sandy beaches, six on intertidal flats, six on dunes, and four on coastal strand or beach habitats. Six also utilize uplands and grasslands to some extent. Four species occur on the Salt Works levees (black skimmer, elegant tern, gull-billed tern, western snowy plover), and one (double-crested cormorant) primarily utilizes artificial structures.

Special status species are listed below in Table 2-48, and Appendix E contains narratives on species not listed under the state or federal ESAs but that are considered Special Status species.

Table 2-48. Special status species in San Diego Bay.

Species*	Status
BIRDS	
American merlin (*Falco columbiarus columbiarus*)	CSC
American oystercatcher (*Haematopus palliatus*)	HC
American peregrine falcon (*Falco peregrinus anatum*)	Recovered, BCC, CE, CFP, MSCP
American white pelican (*Pelecanus erythrorynchos*)	CSC
!ashy storm-petrel (*Oceanodroma homochroa*)	CSC, BCC
!bald eagle (*Haliaeetus leucocephalus*)	FT, CE, CFP, BEPA, MSCP, RSD
!bank swallow (*Riparia riparia riparia*)	CE, RSD
!Barrow's goldeneye (*Bucephala islandica*)	CSC, RSD
Belding's savannah sparrow (*Ammodramus sandwichensis beldingi*)	CE, MSCP
black oystercatcher (*Haematopus bachmani*)	BCC, HC
black skimmer (*Rynchops niger niger*)	BCC, CSC
black storm-petrel (*Oceanodroma melania*)	CSC
black turnstone (*Arenaria melanocephala*)	BCC, HC
burrowing owl (*Athene cunicularia hypugaea*)	BCC, CSC, MSCP
!cactus wren (*Campylorhynchus brunneicapillus sandiegoense*)	BCC, RSD
California brown pelican (*Pelecanus occidentalis californicus*)	MSCP
California gnatcatcher (*Polioptila californica californica*)	FE, CSC, MSCP
California gull (*Larus californicus californicus*)	CSC
California horned lark (*Eremophila alpestris actia*)	CSC
California least tern (*Sterna antillarum browni*)	FE, CE, CFP, MSCP
California rufous-crowned sparrow (*Aimophila ruficeps canescens*)	CSC, MSCP
Canada goose (*Branta canadensis*)	MSCP
common loon (*Gavia immer*)	CSC
common yellowthroat (*Geothlypis trichas*)	BCC
Cooper's hawk (*Accipiter cooperii*)	MSCP
double-crested cormorant (*Phalacrocorax auritus*)	CSC

Table 2-48. Special status species in San Diego Bay. (Continued)

Species*	Status
dunlin (*Calidris alpine arcticola/pacifica*)	HC
elegant tern (*Sterna elegans*)	BCC, CSC, MSCP
!ferruginous hawk (*Buteo regalis)*	CSC, MSCP
!fulvous whistling-duck (*Dendrocygna bicolor*)	CSC, RSD
!golden eagle (*Aquila chrysaetos canadensis*)	CSC, CFP, BEPA, MSCP
gull-billed tern (*Sterna nilotica vanrossemi*)	BCC, CSC
!harlequin duck (*Histrionicus histrionicus*)	CSC
large-billed Savannah sparrow *(Ammodramus sandwichensis rostratus)*	CSC, MSCP
!laughing gull (*Larus atricilla*)	CSC
Lawrence's goldfinch (*Carduelis lawrencei*)	BCC
least Bell's vireo (*Vireo bellii pusillus*)	FE, CE, MSCP
!least bittern (*Ixobrychus exilis hesperis*)	CSC
light-footed clapper rail (*Rallus longirostris levipes*)	FE, CE, CFP, MSCP, RSD
loggerhead shrike *(Lanius ludovicianus)*	CSC, BCC
long-billed curlew (*Numenius americanus*)	BCC, CSC, MSCP, HI
marbled godwit (*Limosa fedoa fedoa)*	BCC, HC
mountain plover (*Charadrius montanus*)	BCC, CSC, MSCP, RSD
northern harrier (*Circus cyaneus hudsonius*)	CSC, MSCP
osprey (*Pandion haliaetus carolinensis*)	CSC
!prairie falcon (*Falco mexicanus)*	BCC, CSC
purple martin (*Progne subis subis)*	CSC, RSD
red knot (*Calidris canutus roselaari)*	BCC, HC
reddish egret (*Egretta rufescens dickeyi)*	MSCP
ruddy turnstone (*Arenaria interpres*)	HC
sanderling (*Calidris alba*)	HC
sharp-shinned hawk (*Accipiter striatus velox*)	CSC
short-billed dowitcher (*Limnodromus griseus*)	BCC, HC
short-eared owl (*Asio flammeus flammeus*)	CSC
surfbird (*Aphriza virgata*)	HC
Swainson's hawk (*Buteo swainsoni*)	CT, BCC, MSCP
tricolored blackbird (*Agelaius tricolor*)	CSC, BCC, MSCP
!Vaux's swift (*Chaetura vauxi vauxi)*	CSC
western sandpiper (*Calidris mauri*)	HC
western snowy plover (*Charadrius alexandrinus nivosus*)	FT, CSC, MSCP, HI
whimbrel (*Numenius phaeopus hudsonicus*)	BCC, HC
white-faced ibis (*Plegadis chihi*)	CSC, MSCP
white-tailed kite (*Elanus leucurus*)	CFP
Wilson's phalarope (*Phalaropus tricolor*)	HC
!wood stork (*Mycteria americana*)	CSC
yellow warbler (*Dendroica petechia*)	CSC
yellow-billed cuckoo (*Coccyzus americanus occidentalis*)	BCC, C, CE, RSD
yellow-breasted chat (*Icteria virens auricollis*)	CSC
MAMMALS	
California sea lion (*Zalophus californicus*)	MMPA
common bottlenose dolphin (*Tursiops truncatus*)	MMPA
common dolphin *(Delphinus delphis)*	MMPA
^gray whale (*Eschritius robustus)*	MMPA
Pacific harbor seal (*Phoca vitulina)* (MMPA)	MMPA
Pacific white-sided dolphin (*Lagenorhynchus obliquidens)*	MMPA
^Risso's dolphin (*Grampus griseus)*	MMPA
INVERTEBRATES	
Gabb's tiger beetle *(Cincindela gabbi)*	FSC
globose dune beetle *(Coelus globosus)*	FSC
mudflat tiger beetle *(Cincindela trifasciata sigmoidea)*	CSC
San Diego fairy shrimp (*Branchinecta sandiegonensis*)	FE
sand dune tiger beetle *(Cicindela latesignata latesignata)*	CSC
sandy beach tiger beetle *(Cicindela hirticollis gravida)*	FSC
wandering saltmarsh skipper (*Panoquina errans*)	FSC

Table 2-48. Special status species in San Diego Bay. (Continued)

Species*	Status
REPTILES	
Coronado skink (*Eumeces skiltonianus interparietalis*)	CSC
Eastern Pacific green sea turtle (*Chelonia mydas*)	FT
Hammond's two-striped garter snake (*Thamnophis hammondii hammondii*)	CSC
San Diego horned lizard *(Phrynosoma coronatum blainvillei)*	CSC, MSCP
silvery legless lizard *(Anniella pulchra pulchra)*	CSC
PLANTS	
Brand's phacelia (*Phacelia stellaris*)	FC, CNPS List 1B.1
coast woolly head *(Nemacaulis denudata* var. *denudata)*	CNPS List 1B.2
Nuttall's lotus *(Lotus nuttalianus)*	CNPS List 1B.1, MSCP
Palmer's frankenia *(Frankenia palmeri)*	CNPS List 2.1
salt marsh bird's beak *(Cordylanthus maritimus* ssp. *maritimus)*	FE, CE, CNPS List 1B.2, MSCP
San Diego barrel cactus (*Ferocactus viridescens*)	MSCP
snake cholla (*Opuntia parryi* var. *serpentina*)	MSCP

**Other species with some sensitive status but not considered a management concern in San Diego Bay: black-crowned night heron (Audubon Watch List); California black rail (RSD, CT) (currently extirpated). Cooper's hawk (upland) Coastal dune milk vetch (CNPS List 1/CE) (presumed extirpated in San Diego Co.) San Diego barrel cactus (CNPS List 2) (an upland species but known to occur at NRRF)*

State codes: CE = California Endangered CT = California Threatened CSC = California Species of Concern CFP = California Fully Protected Species
Federal codes: FE = Federal Endangered FT = Federal Threatened C = Candidate Species BEPA = Bald Eagle Protection Act BCC = Birds of Conservation Concern MMPA = Marine Mammals Protection Act
U.S. Shorebird Conservation Plan (2004) High Priority Shorebirds: HC = High Concern, HI = Highly Imperiled
Local codes: RSD = Rare in San Diego County MSCP = Covered under the Multiple Species Conservation Plan
CNPS codes: 1B = Plants rare, threatened, or endangered, in California or elsewhere 2 = Plants rare, threatened, or endangered in California, but more common elsewhere 1 = Seriously endangered in California 2 = Fairly endangered in California

!Incidental, not regularly occurring at San Diego Bay
^Extirpated from San Diego Bay

2.7.1 Federally Listed Species

2.7.1.1 Eastern Pacific Green Sea Turtle—*Chelonia mydas*

Photo 2-15. Pacific green sea turtle. Courtesy of Eileen Maher.

The only marine reptile found in bay waters is the eastern Pacific green sea turtle (Photo 2-15) (Macdonald *et al.* 1990). This species is the same as the Atlantic green sea turtle, but the east Pacific stock has a distinctive color morphology (S. Eckert, Hubbs-Sea World Research Institute, *pers. comm.*). Recent genetic studies confirm this same species status though some biologists continue to refer to this stock as the black sea turtle, *Chelnia mydas agassizii* or *C. agassizii,* and conservation planning efforts consider this population as a distinct management unit (P. Dutton, NMFS, *pers. comm.*; NMFS and USFWS 1998).

This species is found in warm waters throughout the world where the turtles tend to follow the 64° F (18° C) isotherm temperatures in the ocean (S. Eckert, *pers. comm.*). This eastern Pacific stock uses nesting beaches primarily located along the Pacific Coast of the Mexican state of Michoacan and also rookeries in Isla Revillagigedos off southern Baja California (NMFS 2008.). They commonly range into the Sea of Cortez and southeast to Central and South America (Macdonald *et al.* 1990). Turtles in the eastern North Pacific have been sighted from Baja California to southern Alaska when temperatures are supportive (NMFS 2008). San Diego Bay, however, represents one of the turtles' northernmost dwelling habitats. As populations along the California coast are rare, their occurrence in San Diego Bay is considered "noteworthy" and "extremely interesting" (Macdonald *et al.* 1990; S. Eckert, pers. comm.). Genetic analysis of local turtles reveals that a few appear more closely related to the Hawaiian/central Pacific stock (P. Dutton, pers. comm.).

While the green sea turtle is federally listed as threatened under the ESA, the Florida and eastern Pacific stock, with a breeding population off the Pacific coast of Mexico, is listed as endangered (NMFS and USFWS 1991). The species is imperiled throughout its world range. The worldwide population is estimated at 88,520 nesting females (Spotila 2004). Currently between 200 and 1,000 green sea turtles nest on beaches in the continental United States; no green sea turtles have been documented to nest on the west coast. Green sea turtles are capable of transoceanic migrations, but use coastal and open ocean waters within several hundred to one thousand kilometers of nesting grounds. In the eastern North Pacific, green turtles have been sighted from Baja California to southern Alaska, but most commonly occur from San Diego south (NMFS 2008). In 2004, the International Union for Conservation of Nature and Natural Resources evaluated the health of worldwide green sea turtle population, and based on a 48-67% decline in nesting females over the last three turtle generations, listed the population as endangered. In Mexico, the breeding population is also declining, suffering as much as a 94% decrease in annual nesting female subpopulation size over the past three turtle generations, or since 1873 (MTSG 2004). As a result, an eastern Pacific green sea turtle recovery plan was prepared just for this stock (S. Eckert, *pers. comm.*; NMFS and USFWS 1998). The number of turtles using the bay is dynamic but is estimated to range from 30 to 60 animals, increasing to nearly 100 during peak migratory time periods based on tagged animals recovered in and around the South Bay Power Plant cooling channel (P. Dutton and J. Seminoff, *pers. comm.*).

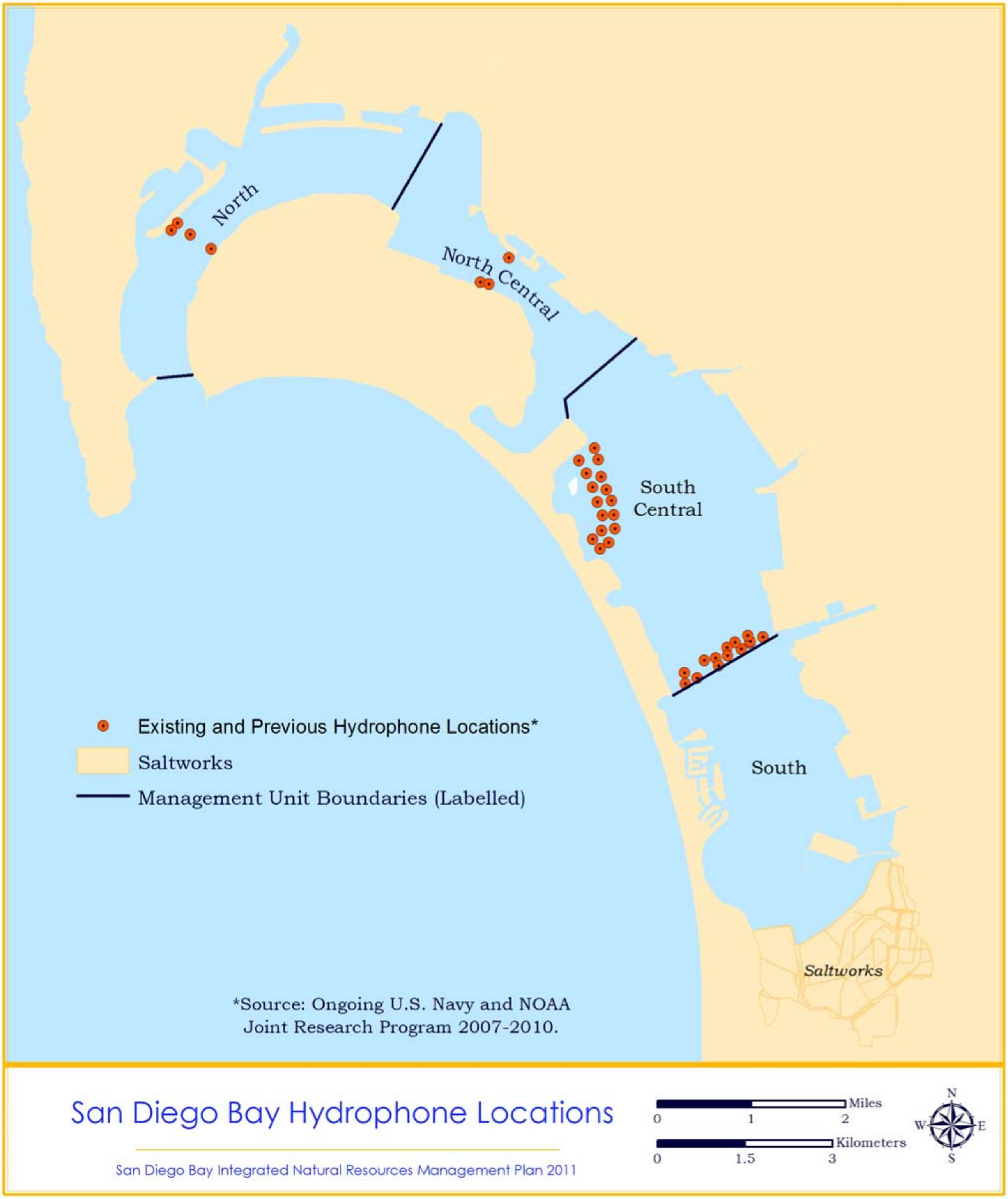
History and Background

Many scientists previously believed that the green sea turtle was not historically a resident of San Diego Bay, but now they have concluded that it would naturally have sought out the bay, at least during the summer months (Macdonald *et al.* 1990; S. Eckert, and P. Dutton, *pers. comm.*). In 1857, numbers of these turtles were first brought up from Mexico and temporarily kept in pens within the bay before being shipped north for sale in San Francisco (Stinson 1984). This practice apparently continued for many decades, as a photograph dated 1910 can be seen at the San Diego Maritime Museum showing stacks of sea turtles piled up on a bay wharf "awaiting shipment." Even a cannery featuring canned turtle soup existed in San Diego at one time (P. Dutton, *pers. comm.*). Some of these animals escaped and became inhabitants of the bay.

San Diego Bay conditions were unintentionally altered to provide attractive year-round habitat for this warm water seeking reptile. In the 1920s, SDG&E built a power plant on Broadway in downtown San Diego and added its Silvergate plant on the eastern shore in 1941 (Smith and Graham 1976). In 1951 these power plants created a thermal discharge that was up to 15°F (9°C) warmer than the intake temperature as the result of their water-cooling system, though they are not in operation today (Terzich 1965). In 1960, SDG&E began operating a larger, new power plant in the south bay, which expanded into additional units over the next several years. The first report of sea turtles in the plant's warm water discharge channel was made in 1968 as part of a study of the ecological effects of the discharge (Ford 1968). Water temperatures at the surface ranged from 95°F (35°C) at the outfall to 82°F (28°C) at the end of the 6,000 feet (1,829 m) channel, compared to 79°F (26°C) in the central bay (Ford *et al.* 1970). Operational effects of the power plant's thermal effluent were recently reevaluated (McDonald *et al.* 1994).

A specific study of the green sea turtle in the bay was conducted in the early 1980s as a master's thesis at SDSU (Stinson 1984). Since 1989, the turtles in San Diego Bay have been monitored for various organizations to determine their status, size and sex ratios, physical condition, origins, movements and migration, and feeding habits (Dutton and McDonald 1990; McDonald and Dutton 1992, 1993; P. Dutton, *pers. comm.*).

An ongoing study amongst the Navy/Port/NMFS initiated tracking effort to determine the level of movement of the eastern Pacific green sea turtle within San Diego Bay. Approximately 18 turtles in San Diego Bay are tagged with devices that can be read by listening stations (hydrophones) in the water. The hydrophones are located in various areas throughout the bay in complementary two-stranded arcs or lines typically stretching from one side of the bay to the other Map 2-21. This double line functions as a gate. If a tagged turtle enters this area, a signature will be left on the hydrophones it passes, documenting where it entered the area and where it exited. This presence/absence determination will help guide planning for constituent actions and construction, as well as guide remediation studies. NOAA's objectives in the effort are to determine spatial and temporal population distributions, preferred habitat, ingress, and egress into San Diego Bay.



Map 2-21. Past and present hydrophone locations utilized to track Pacific green sea turtles movements in Sand Diego Bay.

Both adults and juveniles have been sighted, with individuals seen throughout the summer and winter at the SDG&E channel, the South Bay, and around Coronado Bridge near a thick stand of eelgrass (Ford and Chambers 1973; Stinson 1984; Macdonald *et al.* 1990; McDonald and Dutton 1992). Even in temperatures as cold as 58°F (14.4°C), turtles are actively swimming in the bay. They do not breed or nest in San Diego Bay because they need undisturbed beaches for nesting (Macdonald *et al.* 1990).

Because they need undisturbed beaches for nesting, Pacific green sea turtles do not breed or nest in the bay, but somewhere along the coast of Mexico.

Currently, the two closest breeding populations to the San Diego Bay are located in Mexico at Isla Revillagigedos and Michoacan; both populations considered endangered by NMFS (NMFS 2008). Population estimates from index calculations estimate there are 900 and 1400 individuals, respectively. Aggregations of green sea turtles are well documented at year-around feeding areas such as those located on the west coast of Baja California, in the Gulf of California (Sea of Cortez), and along the coast of Oaxaca (NMFS and USFWS 1998). Bahia de Los Angelos in the Gulf of California is an important foraging area for green turtles (Seminoff *et al.* 2003).

The population of eastern Pacific green sea turtles in San Diego Bay numbers approximately 30 to 60 individuals; however, there is limited information about their movements or behavior. It is unknown how often green sea turtles leave the bay or where they abide when outside of the South Bay Power Plant channel. Female eastern Pacific green sea turtles are believed to migrate from San Diego Bay to nesting grounds in Mexico prior to nesting season, while the male adults and subadults continue to reside within the bay. Eelgrass beds and associated algae and invertebrates known to be food for turtles are extensive in the south and south central San Diego Bay. Recent information on turtle foraging (Seminoff *et al.* 2006) has broadened the general understanding of targeted food items as well as expanded the idea that adult green sea turtles are more omnivorous than previously thought. Considering recent foraging studies (Seminoff *et al.* 2006), resident turtles within the bay may be utilizing invertebrates within deeper areas of the bay in conjunction with eelgrass and algae as food sources. Recent tracking studies have documented turtle movements during the winter and spring of 2008 outside south bay to an extent that previous assumptions in regard to resting and foraging patterns within San Diego Bay need to be reevaluated.

Tagged individuals are known to return to the bay in subsequent years for unknown reasons (Stinson 1984). Residency time in the bay is unknown. The local population may be a closed genetic unit that does not return to breeding grounds, or there may be significant migration (S. Eckert, *pers. comm.*). Based on the number of juveniles observed during the late 1980s and early 1990s, there is some recruitment into the population (McDonald and Dutton 1992). Warm water El Niño events could stimulate an increase in migrations. Considering the large geographic regions the green sea turtles inhabit seasonally, as well as during their life cycle, tagging investigations tracking movements in the eastern Pacific, as well as San Diego Bay, are vital to understanding current and future resident green turtle population trends.

Ecological Role in the Bay

Sea turtles are primarily herbivore grazers of marine algae and grasses although recent stable isotope diet analysis suggests various invertebrates may be consumed by the San Diego Bay population (P. Dutton and J. Seminoff, *pers. comm.*). During the day, the bay green sea turtles reside in the deeper portion of the South Bay Power Plant warm water discharge channel, while at night, they feed on eelgrass beds in the south bay, such as by Coronado Cays (Stinson 1984). Stomach content analysis revealed that they also eat red alga (*Polsiphonia* sp.), eelgrass, sea lettuce *(Ulva* sp.*),* and various invertebrates within the south bay (McDonald and Dutton 1992; P. Dutton and J. Seminoff, *pers. comm.*). Recent studies investigating daily movements and activity ranges of green sea turtles at Bahia de Los Angeles, a neritic foraging area, documented dispersal of turtles while resident at coastal foraging areas (Seminoff *et al.* 2006). Data suggested that green sea turtles traversed large distances over limited temporal durations visiting multiple habitats. Contrary to previously perceived movement patterns, Seminoff and Jones (2006) found that in general, green sea turtles at Bahia de los Angeles moved throughout the diurnal cycle with greater distances covered during diurnal versus nocturnal periods. It is unknown whether they feed within the warm water discharge channel. Young turtles are carnivorous from hatchling

The warm water effluent of the South Bay Power Plant power plant has allowed the green sea turtle to remain in the bay during cooler winter months, and the warmer environment appears to have stimulated growth rates in the turtles to twice that of non-bay turtles.

until juvenile size and gradually become herbivorous; they are also described as opportunistic feeders, eating jellyfish, ctenophores, bivalves, or gastropods if readily available (S. Eckert, *pers. comm.*). The warmer environment of the channel appears to have stimulated growth rates in the turtles that are twice that of non-bay turtles, possibly by increasing their digestive efficiency (McDonald and Dutton 1992). San Diego Bay is unique in the eastern Pacific as having the only thermal gradient where turtles can select their optimum space (S. Eckert, *pers. comm.*). The warm water effluent of the power plant has allowed the green sea turtle to remain in the bay during the normally cooler winter months. When temperatures rise in the channel, turtles disperse in the bay; in fact, none were observed when channel temperatures exceeded 85 to 90° F (29 to 32° C), which is approaching their lethal limit (McDonald and Dutton 1992, 1993). Their crucial habitat zones in other parts of the bay in the warmer months are not known.

The turtle has no natural predators in the bay. Mortalities tend to be caused by collisions with boats or ships (McDonald and Dutton 1992). Unlike the Hawaiian stock where tumors on green turtles are now epidemic in polluted waters, the San Diego Bay population has shown only a few individuals to have fibropapilloma tumors, which usually begin in the eye area (McDonald and Dutton 1990; P. Dutton, *pers. comm.*).

2.7.1.2 California least tern—*Sterna antilarium browni*

Prey species of the California least tern require eelgrass, although the terns show no preference for feeding in eelgrass locations.

The California least tern is a federal and state endangered species that has been listed since 1970. California least terns are coastal and nearshore foragers and surface-feeding fish eaters. They are opportunistic in their search for prey, eating fish that are small enough to catch including anchovies and smelt (*Atherinops* sp.) (Baird 1997). There is some indication that piers, docks, sea walls, and other artificial structures along the shoreline may attract California least terns, as these structures act as artificial reefs for juvenile schooling fish, which terns feed upon (Baird 1997). California least terns also frequently forage in the open waters of the ocean and bay. Areas used for foraging will often vary from year to year, depending upon stage of breeding and prey species availability (Baird 1997). The presence of eelgrass is important as habitat for several prey species, such as northern anchovy, topsmelt, and jacksmelt (Baird 1997). However, least terns do not demonstrate any preference for feeding in eelgrass.

Adult California least terns and their young eat small marine fish found in surface waters of the bay during their nesting season. Generally, they return to successful breeding sites each year.

Nesting terns concentrate in the San Diego County area, with fewer nest numbers both to the north and to the south (USFWS 2006). County trends are similar to those of the state as a whole, with the largest colonies at Marine Corps Base Camp Pendleton near Oceanside, and at NBC in San Diego Bay. The number of least terns in the San Diego Bay area has increased in conjunction with the statewide increase, along with the proportion these represent of the statewide numbers (Table 2-38).

*Table 2-49. San Diego Bay and Naval Base Coronado California Least Tern Pair and Occupied Site Trends**

	San Diego Bay California least tern pairs		San Diego Bay	NBC California least tern pairs	
Year	Minimum (% of statewide)	Maximum (% of statewide)	Occupied Sites?	Minimum (% of statewide)	Maximum (% of statewide)
2000	757 (17)	765 (16)	7 (a,c,d,e,f,g,i)	669 (15)	669 (14)
2001	871 (19)	873 (18)	8 (a,b,c,d,e,f,g,i)	769 (16)	769 (16)
2002	705 (20)	712 (20)	8 (a,c,d,e,f,g,h,i)	605 (17)	605 (17)
2003	1308 (20)	1331 (19)	8 (a,c,d,e,f,g,h,i)	1119 (17)	1119 (17)
2004	1245 (20)	1294 (19)	9 (a,c,d,e,f,g,h,i,j)	1041 (16)	1041 (15)
2005	1375 (20)	1440 (20)	8 (a,c,d,e,f,g,h,i)	1135 (17)	1135 (15)
2006	1611 (23)	1638 (22)	8 (a,c,d,e,f,g,h,i)	1356 (19)	1356 (19)
2007	1452 (22)	1503 (22)	8 (a,c,d,e,f,g,h,i)	1149 (17)	1149 (16)
2008	1813 (26)	2038 (26)	8(a,c,d,e,f,g,h,i)	1573 (22)	1795 (23)
2009	1949 (27)	1949 (27)	8(a,c,d,e,f,g,h,i)	1721 (24)	1721 (23)

** Totals do not include nesting from the Tijuana Estuary National Estuarine Research Reserve site. Statewide and some NBC data from California least tern annual reports. NBC data also included from Navy/Copper unpublished data.*

? Occupied Sites (data from California least tern Annual Reports):

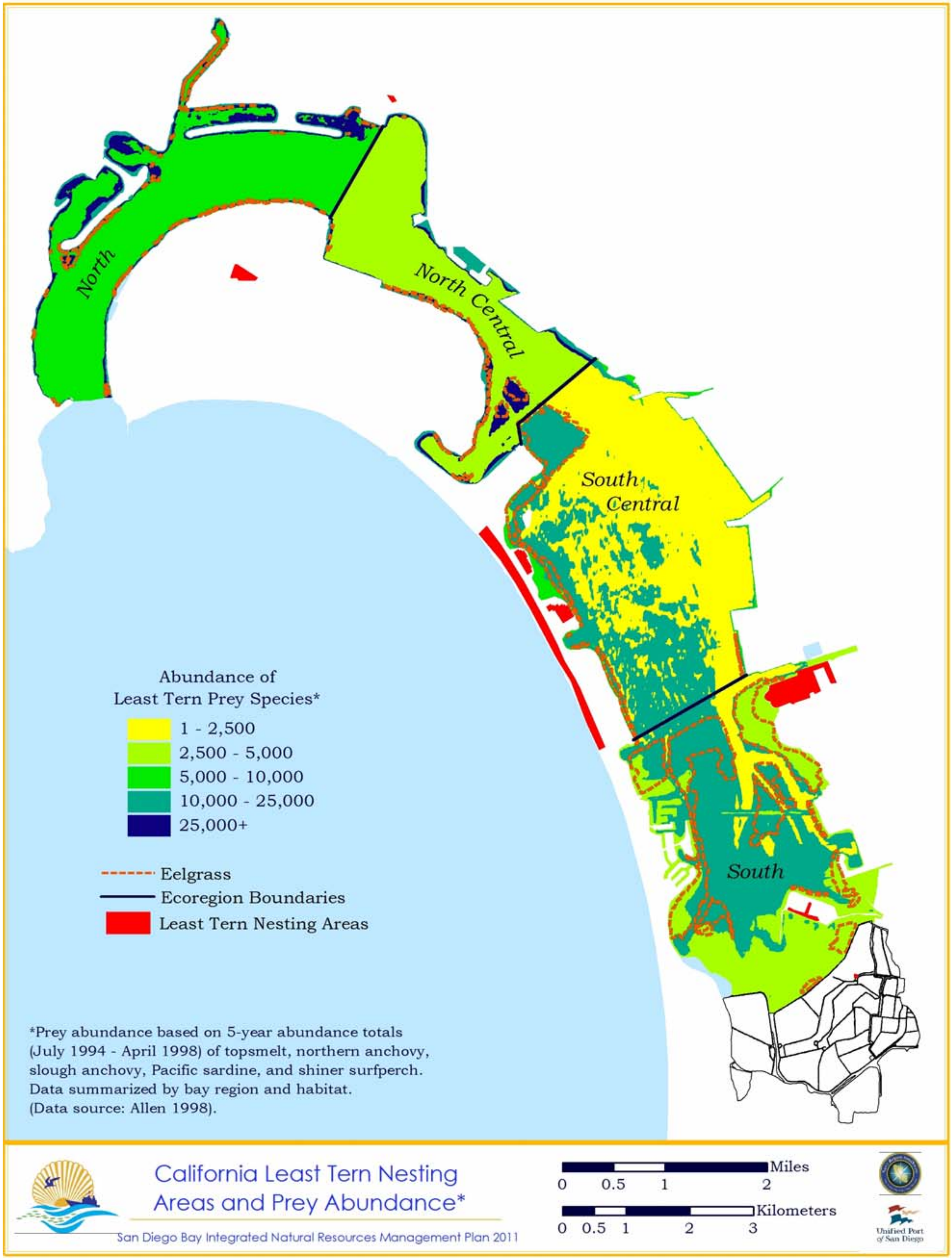
a) Lindbergh Field, b) Former NTC, c) NASNI, d) Delta Beach North, e) Delta Beach South, f) NAB Ocean, g) D Street Fill/Sweetwater Marsh National Wildlife Refuge, h) CVWR, i) South San Diego Bay NWR - Saltworks, j) Silver Strand State Beach

California least terns nest in colonies at several areas on the beaches adjacent to San Diego Bay (Map 2-22). Open sandy or gravelly shores with light-colored substrates, little vegetation, and nearby fishing waters are used for nesting (Minsky 1987). California least tern nests are simple depressions in the substrate either lined or unlined with shell debris. Average clutch size is about two eggs per nest, and the chicks hatch in about 21 to 28 days. Another twenty days are required for fledging. During the nesting season, adult terns and their young feed almost solely on small marine fish (smelt and anchovies) in the surface waters (top 6 feet [2 m]) of the bay, river mouths, and near-shore ocean waters adjacent to the Silver Strand. California least terns generally will return each year to breeding sites that have been used successfully in the past (Atwood and Massey 1988). California least terns over-winter in Central America and breed mainly in Baja California and southern California, but a few colonies exist in the San Francisco Bay area, especially one large one at Alameda Point (Caffrey 1993). They are present in San Diego Bay from about mid-April to late August.

The primary cause of the decline of the least tern remains human disturbance, especially due to habitat loss, pollution, and rendering the habitat unsuitable for nesting or foraging by coastal developments over the past years. Predation of California least terns at all stages of their life cycle is also an important aspect in their decline. Over 35 species are known or suspected to be predators of least terns (Marschalek 2006). However, since their listing as endangered in 1970, their numbers have increased (Figure 2-27). The number of least terns in the San Diego Bay area has increased in conjunction with the state-wide increase. After a period of apparent instability during the eighties, the population has been increasing with San Diego Bay-wide breeding numbers climbing from 141 pairs in 1991 to 1,813 - 2,038 pairs in 2008. San Diego Bay terns also increased in relative range-wide importance. In 1996, the breeding number of least terns in San Diego Bay was estimated at 436 pairs or 13% of the range wide population. In 2001, the breeding number of terns in San Diego Bay was estimated at 871-873 pairs, or approximately 18-19% of the state-wide population, and in 2006 it was estimated at 1,611-1,638 pairs, or approximately 22-23% of the state-wide population. Recently, least terns have nested at seven to nine locations around San Diego Bay. As listed in USFWS (2006a), these are: North Delta Beach, South Delta Beach, NAB ocean beaches, NASNI, as well as Lindbergh Field, the South Bay NWR (formerly Western Saltworks), CVWR, D Street Fill/Sweetwater Marsh, and Silver Strand State Beach (a single record of a pair in 2004).

Nesting colonies have spread to almost all beaches along the ocean side of Silver Strand Training Complex (SSTC) where nest numbers have increased over the past decade in the same fashion as the number of tern pairs described above. The number of California least tern nests on NBC lands has increased overall from 187 nests in 1993 to 1,810 nests in 2008. This increase in nests could be partially due to re-nesting efforts after predation or disturbance events. Nest data records for each location on Navy managed beaches is used to estimate take as well as to gauge the success of various management strategies. The number of mated pairs on SSTC-N from 1990 to 2007 showed an overall increasing trend. Over the same period of time the number of fledglings produced by these nests varied considerably, as it has statewide (Figure 2-27).

Conditions such as El Niño can still impact least tern reproductive success due to effects on anchovy abundance, flooding, or other disruption of nesting sites (Fancher 1992). Additional threats to the California least tern include the urbanization of nesting habitat, recreational use of nesting areas, and invasive weeds in nesting areas (Baird 1997; Copper and Patton 1997). The presence of larger terns can also be detrimental. For instance, California least terns at Bolsa Chica were displaced by larger terns and Caspian terns, while the gull-billed tern has been preying on California least tern eggs and/or chicks.



Map 2-22. Approximate California least tern prey locations, based on fish abundance estimates, and nesting areas in San Diego Bay.

California least tern numbers have increased since being listed as endangered. However, threats still exist.

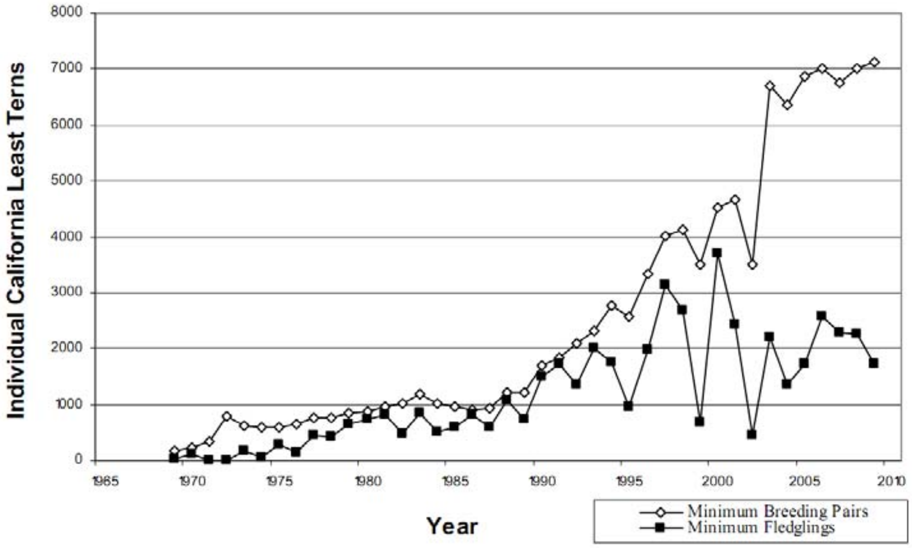
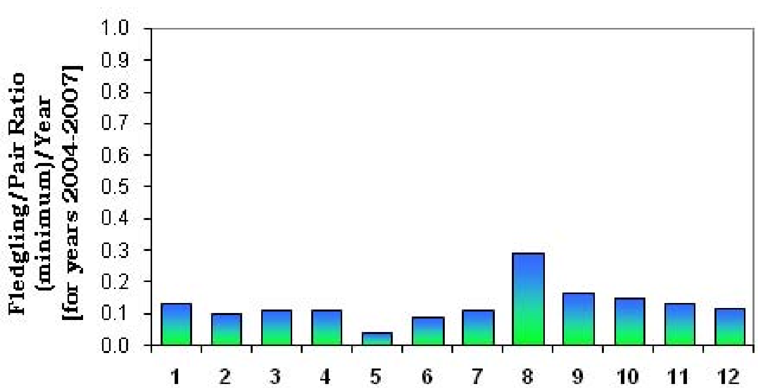


Figure 2-27. Statewide population trend in the California least tern, graph from Marschalek 2010.

Most nesting sites in the San Diego Bay region have experienced decreased fledgling production in recent years, even while actual nest numbers at some sites have been increasing. (Figure 2-28 and Figure 2-29; Table 2-50). In 2010, however, sites managed by the Navy experienced a decline from 1586 pairs (1866 nests) to 1153 pairs (1199 nests), but the number of fledglings increased from 72 to 245 (U.S. Navy unpubl. data).



1 Sweetwater NWR
2 Chula Vista NWR
3 Tijuana Slough NWR
4 Salt Works
5 FAA Island
6 North Fiesta Island
7 Mariner's Point
8 Lindbergh Field
9 NAS North Island
10 North Delta Beach
11 South Delta Beach
12 NAB Ocean

* *Fledging success defined as number of fledges per pair (minimum), averaged over the years 2004–2007. Some sites may have a relatively high fledging success rate, but fewer nests, such as Lindbergh Field.*

*Figure 2-28. Mean annual fledging success for least tern nesting sites in San Diego Bay and vicinity in 2004-2007.**

Intensive management of the California least tern has proven effective in increasing their population and in securing terrestrial habitats around the bay where other species also benefit, including snowy plovers and horned larks. The Navy and Port, as well as the Airport, currently fund intensive monitoring and management of its nest sites around the bay.

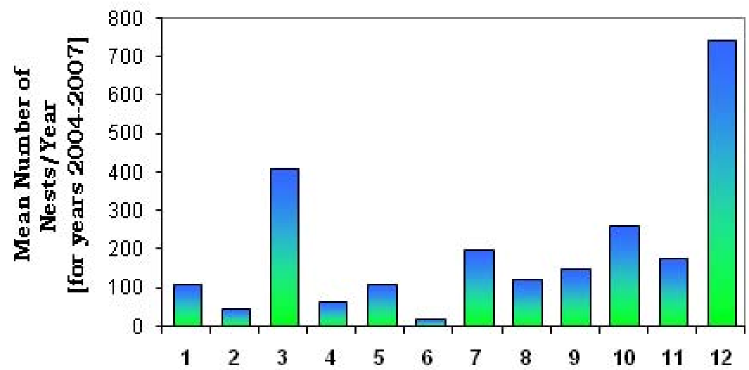


Figure 2-29. Mean number of California least tern nests in San Diego Bay and vicinity, 2004-2007.

Table 2-50. Estimated colony size (minimum breeding pairs), nest production, and fledging success (minimum) at least tern nesting sites in San Diego Bay, Mission Bay, and Tijuana Slough. Data from Marschalek 2006, 2007, 2008, 2009, and 2010, and U.S. Navy unpubl. data.

San Diego Area	2005			2006			2007			2008			2009		
Nesting Site	Pairs	Nests	Fledges	Pairs	Nests	Fledges	Pairs	Nests	Fledges	Pairs	Nests	Fledges	Pairs	Nests	Fledges
FAA Island	5	6	0	60	104	2	22	28	2	0	0	0	25	38	0
North Fiesta Island	0	0	0	24	30	4	20	39	6	10	10	0	36	45	12
Mariner's Point	223	281	50	70	120	0	75	105	20	12	14	0	8	14	0
Lindbergh Field	121	157	45	114	131	54	120	135	34	122	139	115	136	145	36
NASNI	126	134	20	170	180	35	115	123	31	104	146	25	122	125	30
North Delta Beach*	315	351	35	201	223	42	207	224	50	272	295	30	344	413	10
South Delta Beach*	192	215	20	141	155	25	147	156	35	163	174	35	206	235	10
NAB, ocean*	502	569	70	844	1047	104	680	782	115	912	1056	65	914	1093	22
SMNWR	77	101	9	88	100	18	100	130	25	133	148	17	129	132	19
Chula Vista NWR	44	57	2	12	15	2	33	46	0	28	33	2	37	48	4
Salt Works	23	34	2	41	82	6	50	97	13	79	102	6	62	78	4
Tijuana Slough NWR	326	458	38	303	371	57	188	291	29	177	201	45	247	294	27
TOTALS	1954	2363	291	2068	2558	349	1757	2156	360	2012	2318	340	2265	2660	174

2.7.1.3 Light-footed clapper rail—*Rallus longirostris levipes*

The light-footed clapper rail is a federal and state endangered species that is currently found from Santa Barbara County to San Quentin, Baja California. It lives, nests, and forages entirely within the salt marsh, preferred habitat being large estuaries dominated by cordgrass and pickleweed (Jorgensen 1975). The light-footed clapper rail is not a strong flyer and does not migrate. Clapper rails require cordgrass of the lower marsh habitat for nesting and an abundance of intertidal marine invertebrates for its food supply (Massey *et al.* 1984; Zedler 1993b). It will feed on insects, small fish (including larval fish), and some plant material. Clapper rails tether their nests with cordgrass so that they do not wash away or become inundated during high tide (Massey 1979). Cordgrass also is used to form a canopy over the nest to hide it (Massey *et al.* 1984; Zedler 1993b). They lay generally six eggs from March through May, and the chicks hatch from April to June (Unitt 1984). Adjacent middle and upper marsh and upland transition habitat is important as a safe area during very high tides, large storms, or as a temporary refuge if lower marsh habitats become degraded (Zembal *et al.* 1989). During surveys from 1980 to 2009, baywide pair counts of the light-footed clapper rail have ranged from a high of 24 in 1984 to a low of two in 2005 (Zembal *et al.* 2010). Seven pairs were detected in 2009: five at Sweetwater Marsh, one at the Otay River mouth, and one at the South Bay Marine Reserve (Zembal *et al.* 2010).

The Chula Vista Nature Center supports a wetland aviary for the captive breeding of the light-footed clapper rail. The first pair was brought into captivity in December 1998 and the second pair in November 2000. The first captive-hatched chicks were produced in 2001. In 2006, there were six pairs of light-footed clapper rails in captivity (seven individuals from the Upper Newport Bay and five individuals hatched in captivity). In 2006, eight rails were released from captivity (three at Point Mugu and five at the San Elijo Lagoon), bringing the total number of rails released to 146 between 2001 and 2006. During these years 70 rails were released at Point Mugu representing nearly half of the total number of released rails (Zembal *et al.* 2007).

The clapper rail occurs on two NBC installations, at the Outlying Landing Field at Imperial Beach, which is out of this INRMP footprint, and NRRF. NRRF has historically held zero to five pairs of rails since surveying began in 1980 and has held at least one rail 19 out of 26 survey years (Zembal *et al.* 2007). Since 1994, only one unpaired clapper rail was detected in 1997 and one pair in 1998. No clapper rails were detected between 1999 and 2004. During focused surveys in July 2005, one adult clapper rail with a downy chick was detected at NRRF (Hoffman 2007). One to two pairs have been detected here from 2006 to 2009, with none in 2008 (Zembal *et al.* 2010). This sporadic appearance and disappearance is common in this species life history and at NRRF may be partially due to the ease in which the rail can be targeted by predators in this marginal habitat. The NRRF population, while not contributing significantly to the overall population, still provides an insurance against extirpation and a preservation of genetic diversity (Hoffman 2007; Zembal *et al.* 2007).

In recent decades, there has been a dramatic decline in the population of light-footed clapper rails due to destruction of salt marsh habitat. Predation by raptors and mammals are the main causes of nest failure. Storm events and watershed runoff also contribute.

Light-footed clapper rails have declined dramatically in recent decades due to destruction of salt marsh habitat (Garrett and Dunn 1981; Macdonald *et al.* 1990). The entire southern California population crashed from 277 pairs in 1984 to 142 pairs in 1985, partly due to tidal closure of the Tijuana Estuary (Zedler 1992b). Statewide, only 325 light-footed clapper rails, nesting in 14 wetlands, were known to exist in 1996 (USFWS data). Over half the population of clapper rails occurs at Upper Newport Bay. Tijuana Estuary supports the second largest population in existence, approximately 90 birds in 1998, and these could be a source population for dispersing the clapper rail into areas of the bay restored to appropriate habitat (B. Collins, *pers. comm.*). In the San Diego Bay area, clapper rails have been found in various locales, including the Sweetwater Marsh, an area on the Sweetwater River near Plaza Bonita, at the South Bay Ecological Study Area, and the last 300 feet (91 m) of the Otay River (Wilbur *et al.* 1979; Macdonald *et al.* 1990; Notable Discoveries 1998; USFWS data; J. Coatsworth, *pers. comm.*). Surveys of the Otay River channel have periodically located nesting pairs of clapper rails between 1984 and 1998. In 1984, five nesting pairs were identified, while in 1998 only two pairs were located. Clapper rail surveys of the Otay River have identified zero to two pairs since 2000 (Zembal et al. 2010). Tidal inundation, which can carry off or drown eggs, and predation by raptors and mammals are the main causes of nest failure (Macdonald *et al.* 1990). Raptor predation is believed to play a large role in light-footed clapper rail mortality at the largest bay population in the SMNWR (Zembal *et al.* 2010). Large storm events may destroy nests and make the habitat unsuitable for clapper rail use (Zedler 1993b). Lower marsh habitats can also be damaged from watershed runoff and made unsuitable for nesting (Zembal *et al.* 1989).

Since the light-footed clapper rail is sedentary, the discontinuity of remaining salt marsh habitat restricts genetic exchange when breeding. Efforts are needed to reduce sedimentation and the channel filling of marshes.

The discontinuity of marsh habitat patches restricts genetic exchange of the light-footed clapper rail when breeding, since the bird is sedentary. Inadequate tidal flushing can also result in the loss of both salt marsh cordgrass habitat and the invertebrates upon which rails feed. Adequate tidal flow also prevents stagnation of the salt marsh and maintains salinity levels of the soil and water. For successful nesting to occur, high marsh areas must be protected from predators and disturbance. Efforts are needed to reduce sedimentation and channel filling of marshes caused by storms and flooding. Any species management plan must address the need to maintain salt marshes of adequate size and species diversity. Educating the public to the bird's sensitivity to human and domestic animal disturbance is also important (Macdonald *et al.* 1990).

2.7.1.4 Western snowy plover—*Charadrius alexandrinus nivosus*

The western snowy plover is a federally threatened bird species that nests in colonies on sandy beaches along the west coast of the United States and into southern Baja California (USFWS 1997b). Larger concentrations of breeding birds occur in the south rather than the north, suggesting that the center of the plover's coastal distribution lies closer to the southern boundary of California (Page and Stenzel 1981). Prior to 1970, snowy plovers bred at 53 locations along coastal California (Page and Stenzel 1981). Presently, breeding occurs at only 20 locations, representing a 62% decline in breeding sites. The greatest losses of habitat have occurred in southern California, predominately in Orange and Los Angeles Counties. In all of these areas, the plovers' absence can be correlated with industrial or residential development and/or heavy recreational use of former beach nesting areas (Page and Stenzel 1981). The plover is a common winter migrant, winter visitor, and a declining, local resident in San Diego County.

They occur on the beaches in the San Diego Bay area and on the salt work levees in the south bay (Jehl and Craig 1970). Vegetation and driftwood are generally sparse or absent from plover nesting sites. Plovers may nest several times during the breeding season, which extends from March into mid- to late September (Warriner *et al.* 1986; Terp 1996; Copper 1997a,b). There are usually three eggs per clutch, and the chicks hatch in approximately 27 days, leaving the nest within hours to search for food (Unitt 1984). The male plovers tend to care for the chicks, while the females will often nest again with a new mate (Terp 1996). Adults and chicks feed on terrestrial and aquatic invertebrates such as amphipods, sand hoppers, and flies (Cramp and Simmons 1983). Kelp wrack provides an abundant food source of the invertebrates that frequent these kelp piles. Mudflats are also used for foraging (A. Powell, USGS, *pers. comm.*).

The western snowy plover population is present year-round; however, an estimated 70% migrates in winter.

The western snowy plover nests on undisturbed, flat areas with loose substrate, such as sandy beaches and dried mudflats along the California coast. Sand spits, dune-backed beaches, sparsely to unvegetated beach strands, open areas around estuaries, and beaches at river mouths are the preferred coastal nesting areas of the snowy plover (Page and Stenzel 1981; Wilson 1980; Powell *et al.* 1997). Other areas used by nesting snowy plovers include dredge spoil fill, dry salt evaporation ponds, airfield ovals, and salt pond levees (Widrig 1980; Wilson 1980; Page and Stenzel 1981). These cited studies observed snowy plovers moving between salt pannes, tidal flats, and beaches, indicating these areas function together in providing habitat for the species.

The majority (78%) of the coastal breeding colonies in California occur on eight sites from San Francisco Bay to Oxnard and the Channel Islands (USFWS 1997b). There were an estimated 143 snowy plovers in San Diego County in 2005 and 236 in 2006 during the breeding season (http://www.friendsofthedunes.org/snowy_plover/). Of the 126 nests in the county in 2006, approximately 54% were at Camp Pendleton, 6% at Batiquitos lagoon, and 34% were in the San Diego Bay area at several sites (in decreasing order of importance—NAB Coronado [Ocean], NASNI, Silver Strand State Beach [Ocean], NRRF, Saltworks, and NAB Coronado [Bay])(http://www.friendsofthedunes.org/snowy_plover/). An estimated 70% of the snowy plover population migrates in the winter, but the remainder are present all year (A. Powell, *pers. comm*). The San Diego Bay area also serves as the over-wintering grounds for plovers from Monterey Bay and Oregon (A. Powell, *pers. comm.*). San Diego Bay now holds much of the remaining nesting grounds for snowy plovers in Southern California (A. Powell, *pers. comm.*), where annual counts of snowy plovers are conducted at California least tern nesting areas around San Diego Bay (E. Copper, *pers. comm.*). Surveys during these winter window timeframes recorded a decline from 209 birds in 2006-2007 to 169 in 2010 around San Diego Bay (USFWS 2011). As its natural nesting areas have come under development or heavy human usage, the undeveloped Naval training beaches have become increasingly important for this species locally. The snowy plover is considered by P. Unitt (2004) to be one of the "scarcest and most threatened breeding birds in San Diego County."

Based on breeding season window survey data collected between 1977 and 1989, the breeding population of snowy plovers in California, Oregon, and Washington experienced a 17% decline (Page *et al.* 1991). Using the same techniques, the breeding population in California declined from an estimated 1,565 adults in 1980 (Page and Stenzel 1981) to 1,386 adults in 1989, with a 55% decline occurring in north San Diego County and a 41% decline at San Diego Bay (Page *et al.* 1991). Between 1991 and 2004, however, the western snowy plover population has increased range-wide and exceeded the demography predictions estimated in 1980.

Since 2004, the total estimated population of western snowy plovers has fluctuated from a high of 2,651 in 2004 to a low of 1,998 in 2007, with an estimated 2,271 in 2010 (USFWS 2011). The coastal U.S. population has been split into six recovery units, each with its own population goal. San Diego Bay is a contained within Recovery Unit Six, which includes Los Angeles and San Diego counties, with a goal of 500 breeding adults (USFWS 2007). In 2009, the population of Recovery Unit Six was estimated at 334 birds (USFWS 2010), which increased to an estimated 404 birds in 2010 (USFWS 2011). Table 2-40 shows breeding season survey results for sites around San Diego Bay.

Table 2-51. Western snowy plover breeding season window survey results for sites around San Diego Bay. Estimated total is obtained by multiplying total observed by a factor of 1.3. Data from USFWS.

Site	2005	2006	2007	2008	2009	2010
SMNWR	0	0	0	0	2	0
CVWR	0	0	0	0	0	0
SD NWR/ Salt Works	0	4	6	6	3	7
NAB North Island	4	22	4	15	17	23
NAB - Ocean	21	36	11	33	28	10
NAB - Delta Beach	0	2	2	0	0	0
Silver Strand - Ocean	5	9	7	15	10	8
Silver Strand - Bay	0	0		0	0	0
NRRF	0	8	3	8	8	8
Total Observed	30	81	33	77	68	56
Estimated Total	39	105	43	100	88	73

The Navy began managing the western snowy plover at its properties in San Diego Bay in 1992, prior to the listing of the species as federally threatened in 1993. Nest numbers on NBC lands for the western snowy plover have shown an overall increase from 11 in 1992 to 73 in 2006. In 2006 the snowy plover nested in three main areas; these include NASNI, the ocean side training lanes of NAB Coronado, and on the ocean-side Navy beaches. There were 80 western snowy plover nests documented in 2005 on NBC, representing a decrease of 32% from the 116 snowy plover nests present in 2004. The 2005 nesting remained more or less steady in 2006 when there were 73 nests documented on NBC, with mortality of some adults due to unknown causes. This worrisome decline continues with birds found sick and dying. No reason for the decline has been isolated. There were 32 adults found dead in San Diego Bay in 2006, including 19 from NAB Coronado. There were 20 the previous year. Nesting numbers decreased again in 2007, down to 42, but have since rebounded to 91 in 2008, 134 in 2009, and 108 in 2010. Since this species will re-nest after a failed attempt, nesting numbers are not always a good indication of the total population, and maximum active nest number is often used as a pair estimation instead. In 2009, this was 33 nests and in 2010, this was 32.

Human activities during nesting season should be limited. Nesting areas with predator control programs in place have shown marked improvements in reproductive success over unprotected sites (USFWS 1997b).

Its preference for nesting on sandy beaches has led to its decline along the west coast, where much of its habitat has been developed or is subject to moderate-to-heavy human use (Copper 1997b; A. Powell, *pers. comm.*), especially since plover nests and chicks can be difficult to detect (Terp 1996). Foraging areas have also been compromised by development and human recreational use. Human disturbance is the primary cause for the beginning of the decline of the snowy plover and remains the primary cause for their decline up to now. Predation by birds and mammals (especially ravens, crows, and red fox) is the primary cause of reproductive failure for plovers (Copper 1997a,b; USFWS 1997b). A significant problem in San Diego County is predation of eggs by ravens and crows (B. Collins, *pers. comm.*). Nesting areas with predator control programs in place have shown marked improvements in reproductive success over unprotected sites (USFWS 1997b). Trash accumulation on the beaches can also act as an attractant to certain predators such as ravens and crows (USFWS 1998).

2.7.1.5 Salt marsh bird's beak—*Cordylanthus maritimus maritimus*

Salt marsh bird's beak is a federally endangered species that is found in the saline and alkaline habitat of the high salt marsh (Hickman 1993; CNPS 1994). It is an annual, hemiparasitic plant that can tap into the roots of other plants to derive nutrition and water, possibly resulting in increased biomass and longer growing seasons than might be possible without this trait (Zedler 1996). The species ranges from San Luis Obispo County into Baja California (Reiser 1994). It inhabits a narrow elevation range in coastal salt marshes coinciding with the upper limit of high spring tide. It blooms from May to October (CNPS 1994).

Its abundance can vary significantly from year to year. Entire colonies have disappeared and reappeared two years later at Tijuana Estuary (Pacific Estuarine Research Laboratory [PERL] 1996). Reduction and expansion of the salt marsh bird's beak population in SMNWR appear to be related to fluctuations in annual rainfall. Increases in plant cover can also reduce seed germination (PERL 1996). The particular requirements of this species include suitable hosts (it may prefer salt grass and shore grass), open canopies, soil moisture, appropriate salinities, low herbivory, and pollination success (Dunn 1987; Macdonald *et al.* 1990; Zedler 1992b; Zedler 1996). At SMNWR, some patches of bird's beak have been affected by seed predation by the salt marsh snout moth (*Lipographis fenestrella*), the degree of effect apparently being tied to flowering time of the patches (Zedler 1996). The abundance and species composition of pollinators, though, appear to have the greatest influence on reproductive success of bird's beak at SMNWR. Pollinators of bird's beak appear to be bees of the genera *Bombus*, *Halictus*, *Lasioglossum*, *Anthidium*, and *Melissodes* (Lincoln 1985; Zedler 1996). When pollinators of patches of bird's beak included Halictine bees, seed set was lower than when one or more of the genera was present, and overall pollinator visits were correlated with proximity to pollinator nests, bird's beak patch area, and clustering of patches rather than the density of individual patches (Zedler 1993a; Zedler 1996). Tidal inundation during the growing season is also necessary for the plant's survival. However, high mortality can occur as a result of unusually high tides and groundwater flooding (Vanderwier and Newman 1984; Zedler *et al.* 1992).

Fifty years ago, the species was found in eighteen southern California coastal marshes and was characterized as a "frequent" inhabitant of those in San Diego County (Purer 1942). Aside from the reintroduced population at SMNWR, only three populations are known in San Diego County: one at the Tijuana Estuary one at NRRF in Imperial Beach and the other at the E Street Marsh in Chula Vista (Reiser 1994; Zedler 1996). Additional populations still persist in scattered locales throughout its original range. Management of this plant has involved vegetation monitoring since 1979. Salt marsh bird's beak had not been observed at SMNWR since 1987, but was reestablished there in 1991 to fulfill a California Department of Transportation mitigation requirement. Monitoring of these plants has indicated that, although seed set was almost as high as the natural population for some colonies, for others it was very poor. Concern over the ability of the SMNWR population to become self-sustaining encouraged the Department of Transportation to fund a study on factors affecting reproductive potential of bird's beak. This research project has resulted in valuable information on the ecology of the plant and implications for its management. The reestablishment of bird's beak at SMNWR has been successful according to the mitigation criteria (three year period with at least 100 plants), with an estimated 14,000 plants in 1994 (Zedler 1996). Additional enhancement of salt marsh bird's beak on nearby Port land, funded by the Port, involving seeding and planting of bird's beak within the Department of Transportation mitigation site and adjacent areas. This resulted in limited success do to local drought conditions. The success of the San Diego Bay population in terms of long-term stability is still not certain as there seems to be variation in population size from year to year and on longer time scales, due to unknown factors.

2.7.2 State Listed Species

Belding's savannah sparrow—*Ammodramus sandwichensis beldingi*

Belding's savannah sparrow is a state endangered bird and formerly a federal Category 2 species that inhabits the salt marshes bordering coastal estuaries. It is a year-round resident of the salt marsh, mainly using the midmarsh pickleweed habitat. Belding's savannah sparrow nests in patches of pickleweed, boxthorn, or other plants of which its nests are built. It feeds on insects from most areas of the salt marsh, as well as in mudflat and dune habitats (Zedler 1992b). It will also feed on *Salicornia* when insects are scarce. Eggs are laid from mid-March to July, and the young are fledged in late April to August (Unitt 1984). This species can actually drink sea water as it possesses a highly efficient urinary system for concentrating sea salts.

The Belding's savannah sparrow is an excellent indicator species for overall marsh quality because it spends its entire life in salt marsh habitat. Additionally, it is more easily seen than the secretive light-footed clapper rail. Availability of undisturbed marsh land is the main limiting factor (Macdonald *et al.* 1990).

There were an estimated 199 breeding pairs around San Diego Bay in 1977 (Massey 1977) and 230 in 1988 (Zembal and Massey 1988). Belding's savannah sparrow surveys conducted every five years since 1986 show a regular presence, but fluctuating numbers, within the San Diego Bay NWR. Habitat fragmentation, disturbance/predation, and changing conditions within the marsh are contributors to these fluctuations. The 2001 survey (Zembal and Hoffman 2002) identified 109 territories within the SMNWR, including seven in Paradise Marsh, 93 in Sweetwater Marsh, and nine at the F and G Street Marsh. Populations in 1996 included 17 nesting pairs in the salt marsh strips along the dikes at the salt ponds, and 31 nesting pairs in the 27 acre (11 ha) area on the southeast corner of the study area between Emory Cove and the salt ponds (USFWS 1996). The county population is currently estimated at 1105 pairs. Ninety-eight territories were identified within the South San Diego Bay Refuge unit, with Belding's concentrated along the Otay River Channel, where 58 territories were observed. Another 27 territories were identified within the ribbon of pickleweed that grows along the outer levees of the salt works. Thirteen territories were identified within the drainage channel that flows through the salt works between Ponds 15 and 28. Four territories were identified at the J Street Marsh, located just south of the Chula Vista Marina, and 26 territories were found at the South Bay Biological Study Area (Zembal and Hoffman 2002). According to surveys conducted in 2001 by Zembal and Hoffman, marshes adjacent to San Diego Bay supported 109 sparrow nests, the South Bay Marine Biology Study Area had 26 nests, and the South Bay Salt Works had 102 nets, for a total of 237 nests (Unitt 2004). It has been estimated that one acre (0.4 ha) of upper salt marsh habitat can support fourteen breeding pairs (Massey 1979).

This subspecies is sedentary and no movement has been observed between different populations, even when only a few miles apart. This makes the sparrow very sensitive to the fragmentation of its habitat. There are only1,182 hectares of salt marsh remaining in the county (Unitt 2004), and 437 (37%) of these are located around the San Diego Bay (see Map 2-13). This bird is also vulnerable to development, blockage of lagoon mouths, disturbance by domestic dogs, and trampling (Unitt 2004). Additionally, the Belding's savannah sparrow is vulnerable to predation since its nests are placed on or near the ground. Common predators include crows, skunks, rats, weasels, and domestic cats. The primary reason for the declines of this species, though, is habitat loss (Zedler 1992b; Small 1994).

2.7.3 Candidate species

"Candidate species are plants and animals for which the Service has sufficient information on their biological status and threats to propose them as endangered or threatened under the ESA, but for which development of a listing regulation is precluded by other higher priority listing activities" (USFWS 2007).

Brand's phacelia—*Phacelia stellaris*

Brand's phacelia is a candidate species on the federal level (USFWS) and is considered a 1B.1 species by the CNPS (rare, threatened, or endangered in California, or elsewhere-Seriously endangered in California). It has a S1.1 State Rank defined by fewer than six occurrences or less than 1,000 individuals or less than 2,000 acres (CNPS 2007). It is recommended for California endangered status (Reiser 1994).

Brand's phacelia is extremely rare. It is an annual forb in the Hydrophyllaceae (waterleaf family). It is known from only five remnant occurrences in the U.S. from a historical range extending from Los Angeles County to the Mexican border and inland to Riverside County. Four of the five remaining populations are in San Diego County. The locations from Los Angeles County are uncertain and might be extirpated (CNPS 2007). This small annual forb has symmetric purple flowers and has been observed in Riverside, Los Angeles, San Bernadino, and San Diego counties. It can be found at NASNI and, recently discovered, at Charlie and Bravo training areas on the Silver Strand (Map 2-23). Brand's phacelia also occurs on the 40-acre leased area to the State of California (California Natural Diversity Data Base [CNDDB] 2009) just south of the mapped locations in Charlie and Bravo training areas. It is known from washes and openings in coastal sage scrub where the preferred sandy soils can be found and from coastal dunes. About 5,000 Brand's phacelia were estimated on NASNI in 2004 (RECON 2005). The recent finds in Bravo and Charlie training areas total over 2,000 individuals in 2009; locations are spread out and range from single individuals to one aggregate of 57 individuals and the primary aggregation of over 2000 individuals. Two additional locations near the Silver Strand are at Mission Bay (CNDDB 2009).

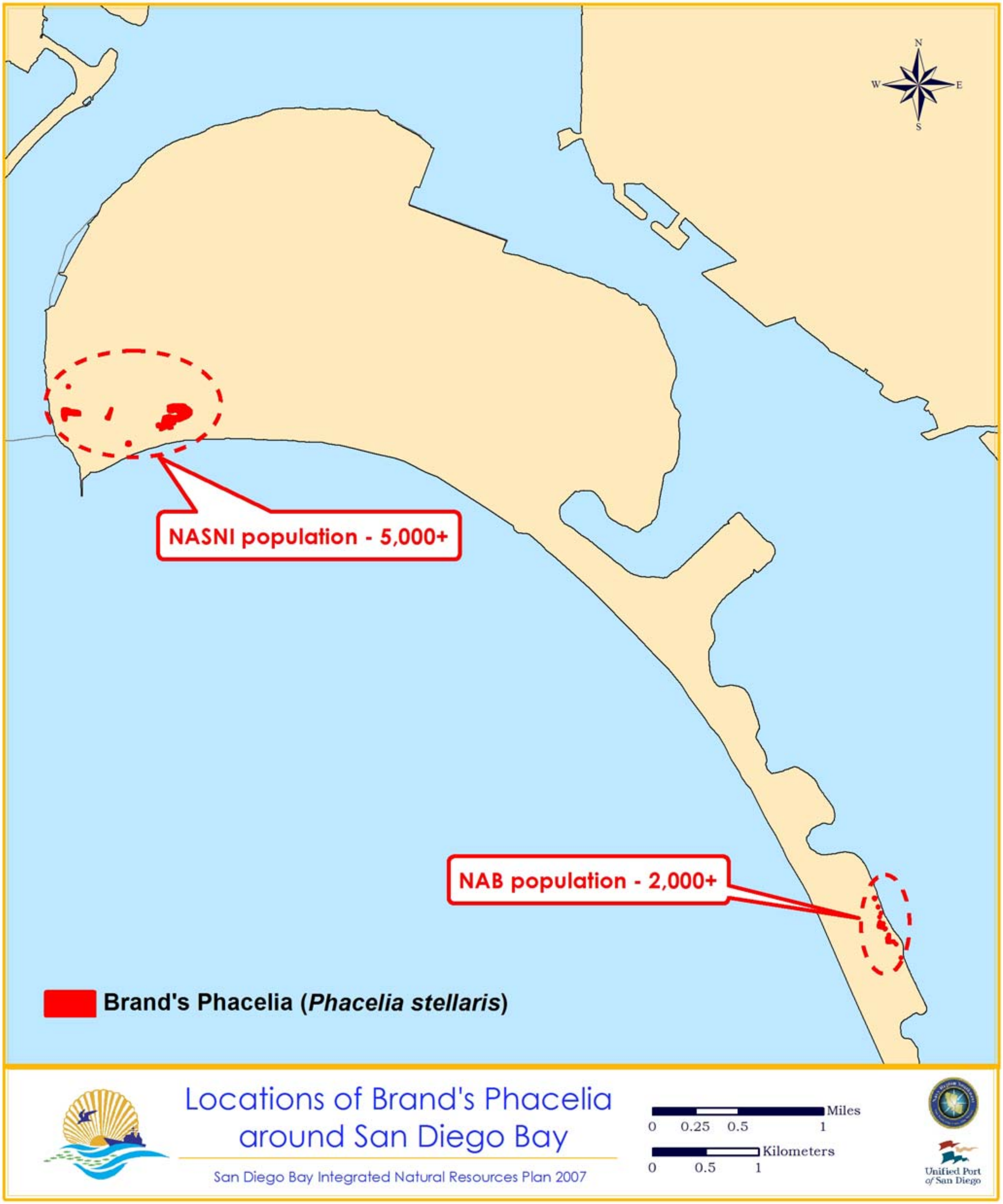
Herbarium specimens have been collected from the bed of the San Diego River, on the Silver Strand, and at Crown Point and from Baja California (Reiser 1994.) In San Diego County, it is currently known from four locations: Border Fields State Park, the mouth of the Santa Margarita River, NASNI, and the Silver Strand. It is found on NASNI around the southern end of the airfield growing along with coast woolly-heads and Nuttall's lotus, both considered rare by the CNPS. Approximately 5,000 individuals were inventoried by RECON and might constitute the biggest population in the country (RECON 2005).

2.8 The Ecosystem as a Functional Whole

2.8.1 Ecosystem Attributes

In the previous sections of this chapter, San Diego Bay was looked at by components. We now view it as an integrated ecosystem with interacting parts. Ecosystems have the following types of organization:

- Structural (what the parts are), such as their size, acres of each habitat, numbers of species and their relative abundance, etc.
- Functional (what the parts do), such as the way they process solar energy into food chains, nutrient cycling, tidal energy and sediment transport, competition, and recoverability from disturbance.



Map 2-23. Brand's phacelia locations around San Diego Bay. Data from RECON 2005 and U.S. Navy unpubl. data.

Pressures are exerted on an ecosystem's integrity primarily by way of physical restructuring (such as loss or modification of habitat), impacts on the food web and other community functions (such as by introduction of invasives), and modification of natural disturbance regimes (such as weather extremes or climate cycles). This section describes our more substantial knowledge regarding the physical restructuring of the bay and relatively little knowledge on the effects on functional organization, or on disturbance regimes.

Table 2-52 is an example of how complex a diagnosis of effects can be on a single species group, without consideration of ecosystem-level or cumulative effects.

2.8.2 Physical Structure

The physical structure of the bay and its habitats is already described (see, for example, Section 2.3: Physical Conditions of the Bay and Section 2.5: Bay Habitats and Map 3-1 on changes in the historic footprint of the bay). One aspect of restructuring that has occurred is habitat loss. Others are change in pollutant load, sediment condition, hydrology, and morphology (such as fetch, exposure, cross-sectional depth profile, mean-depth to maximum-depth ratio, inlets and outlets, channels and islands), and adjacent upland to wetlands ratio (Adamus *et al.* 1987).

While we can describe the current physical parameters of the bay and generally how they have changed, based on sporadic surveys we do not understand the strength of the dependency that biota have on these various physical factors. Therefore, we can only suggest what the significance of these changes are over time. The bay now is much smaller and deeper, traversed by channels, and contains more hard substrate. While in the past invertebrates requiring hard substrate had difficulty finding a home here, they now have abundant substrate around the bay's perimeter stabilization structures, piers, docks, and the hulls of boats and ships. Large stream systems no longer contribute sediment, organic material, or much water to the system for flushing out pollutants. Water quality has improved since a historic and biota-devastating low in the 1940s through the 1960s.

Severe losses of shallow-water, intertidal, and upland transition habitats have, beyond a doubt, reduced the bay's carrying capacity, especially for migratory and some resident birds and mammals, and probably as a nursery and feeding ground for fish and shellfish.

However, severe losses of shallow-water, intertidal, and upland transition habitats have, beyond a doubt, reduced the bay's carrying capacity, especially for migratory and some resident birds and mammals, and probably as a nursery and feeding ground for fish and shellfish. Carrying capacity is also, however, a matter of nutrient availability and the rate at which nutrients are made available for primary production. How these have been affected by historic changes and, more importantly, how these can be best managed, has never been examined.

2.8.3 Community Organization

The way living things organize themselves can be an indicator of whether a system is healthy or degraded. A measure of this organization might be the percent of species in a system that is sensitive to toxics or other stressors, percent invasive introductions, relative species dominance, relative abundance, biodiversity within a taxonomic group, total biomass of a taxonomic group in an area, size class, and diversity of functional feeding strategies. External pressure on community organization may be exercised by overharvesting, introduction of exotics, and many other means.

A fundamental way biological communities organize themselves is by food webs. A food web must have primary producers to capture energy from the sun (algae, vascular plants, phytoplankton), a means of energy transfer by feeding, and nutrient cycling between the biotic and abiotic environment by excretion, bacteria, fungi, and detritus to provide nutrients back to primary producers. Figure 2-30 shows an example of a simplified San Diego Bay food web.

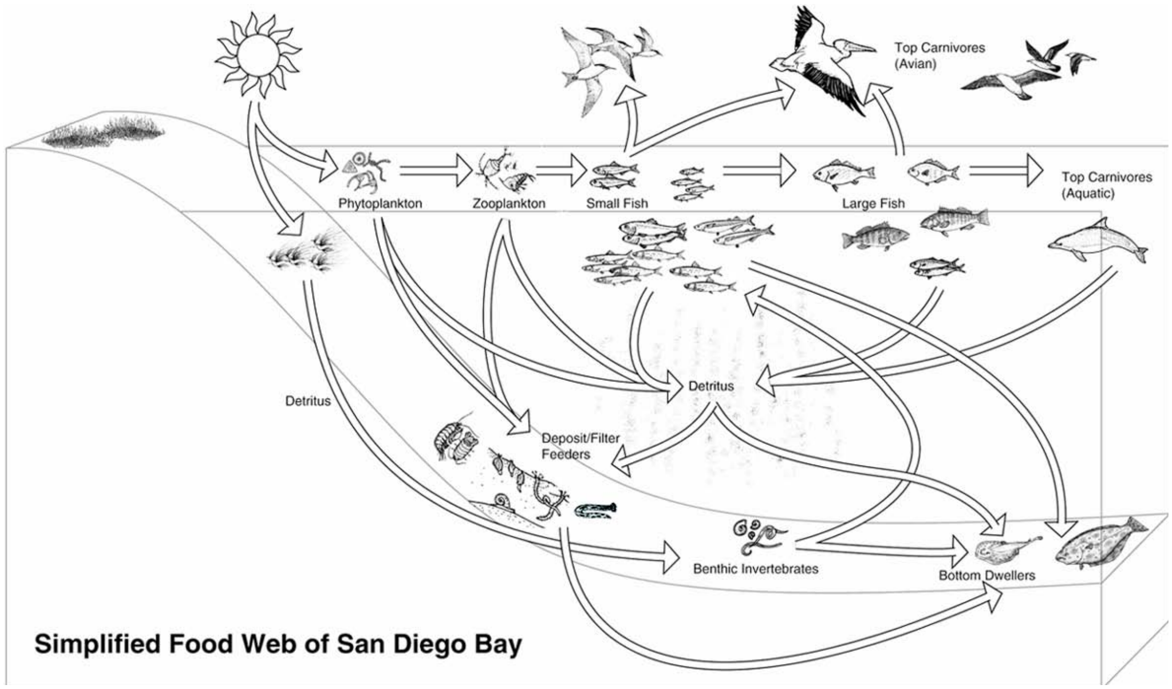


Figure 2-30. Simplified San Diego Bay food web.

The different habitats of the bay are linked by these nutrient cycles and food webs. As tides and currents move water among the habitats, dissolved and particulate organic matter and nutrients also flow among the sites. Fish and shellfish move among the communities as water covers their habitats. Birds will often feed in one habitat and nest in another, which expands the range of energy flow among habitats.

2.8.3.1 Nutrient Cycling

The amount of energy generated by photosynthesis is limited by the supply of nutrients, usually nitrogen, to the zone where light can penetrate. This is because while only carbon dioxide, water, and sunlight are needed to make simple sugars by photosynthesis, nutrients are needed to convert these sugars into organic compounds, such as proteins and nucleic acids. A limited nutrient supply, in turn, limits the food available to consumers. An understanding of nutrient dynamics will give the resource manager more predictive and cause-effect capability about the abundance and distribution of organisms.

Studies conducted over a one-year period (Lapota *et al.* 1993) showed that stormwater flows that supply nutrients to the bay may drive productivity. Other than these observations, nutrient availability has only been looked at in the salt marsh. It is likely that the nitrogen budget of the bay's marshes is dependent on bacteria and fungi that recycle nitrogen from decaying organic matter and other microbes that fix nitrogen from the air. Compared with marshes of the Atlantic coast, the nutrient levels and nitrogen-fixation rates are very low. The reason for the lower nitrogen-fixation rates was explored experimentally and shown to be related to concentrations of soil organic matter (Zalejko 1989) and also related to coarse soil texture (Zedler 1991).

Detritus derived from eelgrass probably represents the largest single source of energy-rich organic material available to the bay.

Most energy flowing through the bay passes through detritus-based food chains to consumer animals. Decaying algae is probably the most significant source of dissolved organic carbon consumed by microorganisms and invertebrate larvae. Currently, eelgrass leaves decompose and add a large amount of detritus to the ecosystem. Because much of the energy flowing through the bay food webs is derived from detritus, eelgrass is important to productivity of the ecosystem as a whole. Detritus derived from eelgrass probably represents the largest single source of energy-rich organic material available to the bay. A large amount of energy is lost or exported from the bay after it is consumed by migratory birds and fishes.

It is also likely that organic matter from decaying marsh plants and leaves entering from riparian drainages supported a much more productive detrital food chain than exists today.

2.8.3.2 Primary Production

As with other ecosystem-level processes in San Diego Bay, primary productivity has been studied very little. The major primary producers are marsh grasses, eelgrass, macroalgae, algae, and diatoms that live on mud and phytoplankton adrift in the water (such as blue-green algae, green algae, and diatoms). Large concentrations of plankton produced in bays are sought out as a preferred food supply to sustain young anchovies, smelt, herring, and other juvenile and adult fishes.

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Studies on primary productivity have been conducted in the salt marsh (Zedler 1991). If comparable to other coastal embayments, productivity would be expected to be highest in the salt marsh, next in eelgrass, and lowest in mud or sand. However, the relative importance of different primary producers can vary: cordgrass productivity has been found to be lower than in other marshes of the Atlantic and Gulf coasts, possibly due to hypersalinity during droughts of southern California summers. Instead, open canopies of cordgrass admit light to the marsh bottom where abundant mats of filamentous, blue-green, and green algae and diatoms abound on nutrients carried in by the tides. The algae provide a matrix where dozens of species of diatoms can take hold. In both nearby Tijuana Estuary and Mission bay, studies found the epibenthic, green algae to predominate only in winter, with blue-green algae and phytoplankton dominating in summer under conditions of high light and high temperatures (Rudnicki 1986; Fong 1991). By transforming sunlight and nutrients into biomass, algae provide food for invertebrate grazers such as worms and snails. Invertebrates provide biomass and an essential source of oil and protein for fishes and birds.

The spatial distribution of phytoplankton has not been looked at in the bay. In other bays and estuaries, the slowest current, longest residence times for phytoplankton occur in dead-end sloughs and on flooded islands, where phytoplankton are far more abundant than in deep, dredged channels. In quiet waters that are shallower, warmer, richer in nutrients, and have lower tidal circulation, plankton blooms are much more pronounced.

Phytoplankton and water quality studies along the bay’s longitudinal cross-section over a year-long period (Lapota *et al.* 1993) provide some insight into seasonal dynamics of phytoplankton. Blooms peaked in January. This contrasts with peak blooms of the Tijuana Estuary. There, seasonal peaks in chlorophyll and cell counts occurred in spring when weather was warm and tidal action minimal, and prevailing winds caused algal mats to accumulate. At other times, tides continually dilute and export algae and maintain clearer water.

2.8.3.3 Energy Transfer Through Food Webs

Powered by the sun, primary producers are at the base of the food web, transforming solar energy and combining simple nutrients from the soil and water into the organic compounds that form consumable biomass. Some plant tissue is consumed directly, such as the black brant feeding on eelgrass, dabbling ducks on sea lettuce, or the globose dune beetle consuming ragweed leaves. However, most vegetation dies uneaten. The dead vegetation is attacked by decomposing bacteria and eventually breaks down into small, nutrient-rich, bacteria-coated detrital particles. This is then combed from the water column by filter-feeders or is gleaned off the surface by deposit-feeders.

Zooplankton feed on phytoplankton. In shallow water such as San Diego Bay, the filter feeding benthic invertebrates may compete directly with zooplankton for food. This situation is not present in offshore waters due to separation of layers exposed to light from the substrate below where invertebrates live (Nybakken 1997). Young predatory fish, shrimp, and benthic invertebrates feed on zooplankton. Invertebrates are then fed upon by carnivorous molluscs, bat rays, leopard sharks, bottom feeding fish like flounder and halibut, and shorebirds.

The food chain depicted in Figure 2-31 depicts trophic levels from producers to a top predator. The illustration is very simplified and glosses over complexities such as predator-prey relationships that change throughout an animal's life history and microbial portions of the food chain that have only recently been discovered in the field of marine biology (Castro and Huber 1997). This microbial portion refers to the flow of energy from phytoplankton, dissolved organic matter, bacteria, protozoan grazers, and zooplankton.

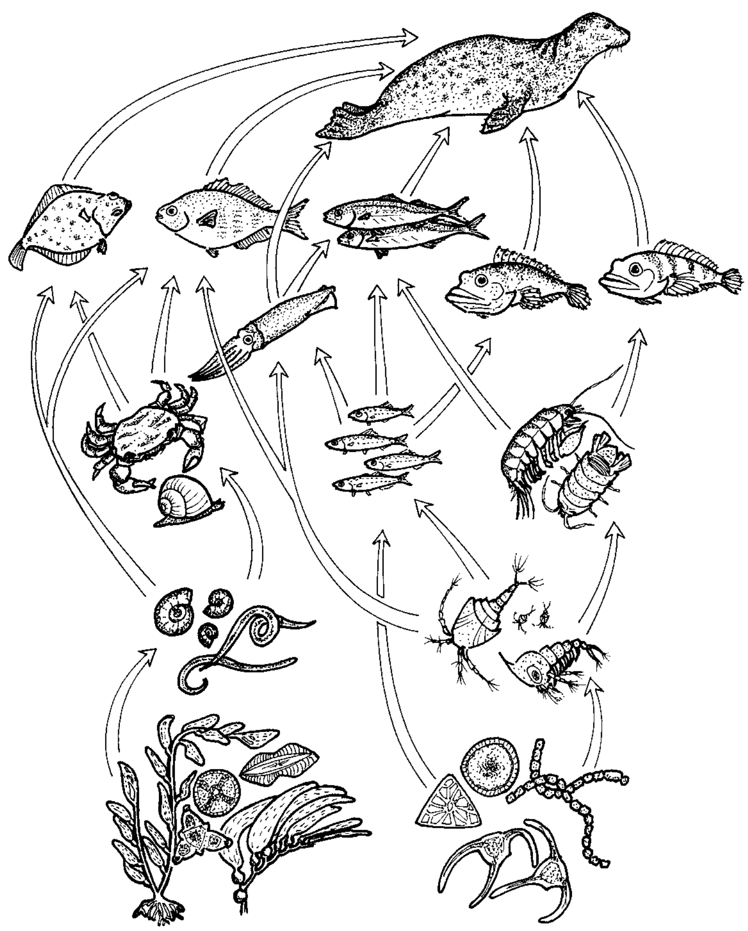

Figure 2-31. This simplified food web represents trophic levels from producers to a top predator, such as a harbor seal.

The role of shorebirds in energy and nutrient transfer in intertidal habitats of southern California is substantial. They remove 17-40% of all invertebrate animal production on their wintering grounds. Sea birds are also important members of the upper trophic levels and are responsible for removing anywhere from 14 to 29% of various fish stocks.

We have an understanding of bay food webs based on general knowledge of predator-prey relationships, but little specific data on the bay's relative contribution to supporting resident and migrant species nor on how it may change due to natural cycles or anthropogenic change. Baird (1993) examined the literature on the trophic importance of birds in the SCB. The energy transfer from invertebrate to bird predator varies widely from place to place, and no absolutely clear relationship seems to exist between productivity of prey and prey consumption by birds (Baird 1993). Shorebirds are one of the major paths of energy flow from intertidal benthic invertebrates (Goss-Custard 1977; Baird *et al.* 1985). They reportedly have removed up to 90% of the standing crop of prey, such as large *Hydrobia* or *Nereis*, during a single winter (Evans *et al.* 1979). A more conservative estimate is probably 35 to 60% (Goss-Custard 1977; Baird *et al.* 1985). Taking into consideration studies from Europe where this has been examined in more depth than in southern California, it is safe to say that shorebirds consume from 17 to 40% of all invertebrate annual production on their wintering grounds (Baird *et al.* 1985). Sea birds are also important members of the upper trophic levels and are responsible for removing anywhere from 14 to 29% of various fish stocks (Robertson 1972; Furness and Cooper 1982; Furness and Ainley 1984, all cited in Baird 1993).

2.8.3.4 Biodiversity

Biodiversity has ecological importance and direct human benefits. The term is difficult to work with in a management context because it can be measured at a number of scales including genetic, species, population, and ecosystem scales. Different scales are appropriate for different management decisions. The term also has many definitions from the perspectives of many knowledgeable individuals and should only be used with reference to an explicit management objective.

The biodiversity of the bay in a qualitative or quantitative sense is not discussed in this INRMP; however, information is provided from which such discussion may be based. A compiled comprehensive species list for the bay (Appendix C) and an inventory of invasive species introductions (see Section 2.6.7: Invasive Species) are included herein. While a few species extirpations are known, many more invasive introductions are known. We do not know relative abundances or total abundances for the past or present, except for a few highly visible species. We do know that the upland transition, intertidal, and shallow habitats have experienced dramatic losses overall and in proportion to deep water habitat, and that the carrying capacity of these now-scarce habitats has to have been reduced in comparison to historic values.

2.9 State of Ecosystem Health: Information Needs Assessment

We need to develop specific, unambiguous criteria that relate ecosystem processes to some measures of bay health. This can only be done by developing information about the bay as a whole over the long term, rather than only about its individual parts, or on scales and time frames typical of routine projects.

One of the purposes of promoting an ecosystem vision for this INRMP is to help establish criteria for managing human use of the bay as a whole. Since we cannot return to the historical bay as a desired "normal" reference condition, we need to develop specific, unambiguous criteria that relate ecosystem processes to some measures of bay health, taking into consideration the current ecological context of the bay and human standpoint of bay users. This can only be done by developing information about the bay as a whole over the long term, rather than only about its individual parts, or on scales and time frames typical of routine projects. Cumulative effects assessment, in particular, centers on understanding the complexity of interconnections among environmental variables and parameters over regional or extended time and space scales.

Ecosystem health may be described as a combination of vigor (energy flow, which means productivity and nutrient cycling), organization (complexity with respect to species number and variety and intricacy of interactions such as competition, mutualism, symbiosis, and interdependence between biotic and abiotic elements of the ecosystem) and resilience (capacity to recover from stress) (Rapport *et al.* 1998). It can also mean the sustained maintenance of ecosystem services to humans-such as detoxification of pollutants, water purification, military support, fisheries, boating, birdwatching, and the like. Human use can result in a reduction in quantity and quality of these services.

A fundamental problem is that current data sets have little predictive power. Much of the data for San Diego Bay have been collected in response to regulatory requirements rather than ecosystem status and trends questions. Natural resource work has been done episodically for academic or regulatory reasons, for example development of restoration methods to address compliance requirements, various masters theses, Port construction, or Navy work in relation to Navy activities. As a consequence, our understanding about the quality of habitats and about population trends is episodic and patchy. We can say the most about how to conserve habitat values and acreages that remain. We can say little about cause and effect, ecosystem processes, or anything much more than acreage changes and a list of species.

A fundamental problem is that current data sets have little predictive power. Much of the data for San Diego Bay have been collected in response to regulatory requirements rather than ecosystem status and trends questions.

The following discussion on information needs to describe the "State of the Bay Ecosystem" is organized in two primary parts: (1) what we need to know, and (2) what we currently understand. Individual studies describing our current state of knowledge are cited earlier in this chapter and are not repeated here.

2.9.1 What We Need to Know to Describe the State of the Bay Ecosystem

Table 2-52 is a synthesis of ecosystem-level management issues. Other management issues are addressed in later chapters. This table looks at two fundamental ways that human activities can affect San Diego Bay: by altering the physical structure of habitats and populations or by altering the interconnections among habitats and populations (i.e. nutrient exchange, food webs, competition) that also support the ecosystem vigor, organization, and resilience described above. The table then asks whether these things are changing in San Diego Bay, which is the other key information element needed to support management decisions.

Table 2-52. Information needs to evaluate whether the San Diego Bay ecosystem health is adequately functioning.

Key Ecosystem-level Management Issues	Key Questions to Address Management Issues	Example Information Needs
1. What is the condition of the bay ecosystem, and what is the relative importance of factors that contribute to it?	Are habitats, singly and together, providing their full benefit with respect to supporting fish and wildlife populations, food chain pathways, elemental/nutrient cycling, and natural diversity? How do human activities such as military support, commercial shipping, recreation, and fisheries affect the continued viability of specific aspects of ecosystem functionality? What specific factors of ecosystem functionality are presently threatened? What is the relative importance of substrate, tidal flushing, nutrient flows from stormwater, predation, competition, or other parameters in contributing to or moderating these threats? What is the relative importance of climate cycles or naturally episodic events in structuring the ecosystem and driving change?	■ Habitat quantity. ■ Habitat use. ■ Models relating habitat use to the level and spatial pattern of basic indices of environmental structure: temperature, salinity, dissolved oxygen, nutrients, water transparency, sediment quality. ■ Abundance and spatial pattern of populations. ■ Species or functional diversity. ■ Models of adequate buffers, corridors, or connections to other habitats. ■ Habitat maturity (stability of plant composition, density, and size). ■ Recolonization, reproductive, and growth rates.
2. What is the trend of the ecosystem due to human activities?	Are basic markers of environmental structure changing, such as temperature, salinity, dissolved oxygen concentration, nutrients, and water transparency? Are the abundance, composition, or spatial distribution of populations changing? What are the correlations between changes in environmental structure and populations? Is productivity and nutrient cycling changing? Is community structure changing (diversity, patterns of dominance, relative importance of functional groups)? To what extent are specific, observed changes in the elements described above due to human versus natural causes, or local versus regional causes?	Long-term data sets that encompass local and regional variability and trends in abundances, water quality, etc. Long-term data sets that encompass natural variability and trend. Future use/trend models.

While loss of the quantity and quality of most habitats in the bay has been substantial, the food web is another direct way environmental change influences ecosystems whether the change is natural or anthropogenic.

For San Diego Bay, losses of shallow subtidal, intertidal, and upland transition habitat quantity and quality have been severe. However, altered food chains and related aspects of environmental structure are another direct way that environmental change influences the ecosystem. This is crucial to management decisions because the relative importance of these influences to specific management questions is poorly known. Many of the changes seen in fish, bird, and mammal populations in the offshore waters of California appear to be caused by trophic interactions. The ecosystem changes in ways that affect the growth rate and abundance of the phytoplankton; usually a change in nutrient input causes this change in productivity. This, in turn, affects the abundance of the herbivorous zooplankton that feed upon the phytoplankton. The zooplankton are the food source for fish, birds, and mammals, either as adults or during their juvenile stages. There are strong correlations over time in the long-term trends in the abundance of the plankton and indices of physical structure of the environment (temperature, salinity, ocean currents). These changes in plankton abundance are clearly associated with climate change, and they have important effects upon fish, bird, and mammal populations (T. Hayward, Scripps Institute of Oceanography, *pers. comm.*).

It is important to identify long-term trends in the bay in order to support management decisions so that variability that is natural can be sorted out from variability that is related to human activity.

Table 2-52 shows that one of the most important means of supporting management decisions on the state of the bay health is by the study of long-term trends and what drives those trends. Long-term trends are even more important to identify in a system such as San Diego Bay, which has high natural inherent variability compared to other systems. It is possible that extreme or episodic events such as storms, El Niño, and La Niña may regulate many fundamental processes in the bay, but this cannot be determined with episodic or site-specific monitoring.

Bay managers have direct control only over trends that are local and attributable to human activity. However, even if disturbance in the bay is not the primary reason for a species' decline, it still must be managed as a declining resource if human influence is believed to be a contributing factor.

Once trends are established, the key to targeting monitoring efforts is determining whether changes in populations are due to natural variability or human influences; if the trends are anthropogenic, whether they are caused by local influences. These local influences may be corrected by San Diego Bay management or large-scale influences, may be beyond the scope, or only partly addressed by local management. Bay managers have direct control only over trends that are local and attributable to human activity. However, even if factors in the bay are not the primary reason for a species' decline, it still must be managed as a declining resource if human influence is believed to be a contributing factor.

3.0 State of the Bay—Human Use

This chapter describes how people use the bay. It offers a brief overview of its settlement history, current use patterns, future plans, and the economies that have developed on its waters and shores.

3.1 History of the Changing Human Use of San Diego Bay

A detailed summary of the major human events shaping the present condition of the bay can be found in Appendix G. For a specific water quality history, see Section 2.4.1: Historical Change in Water Quality Condition.

"Fish constitutes the principal food of the Indians who inhabit the shore of this port, and they consume much shellfish because of the greater ease they have in procuring them" (Pourade 1960). The earliest that humans are documented in San Diego County is 9,030 years ago (Warren 1967). Native Americans in settlements around San Diego established villages as well as fishing camps. They also hunted for game, collected shellfish, and gathered acorns, seeds, and nuts.

In 1542, Juan Cabrillo found the natural, narrow channel opening to an embayment where seven river systems and tides created a shore lined with deltas, mudflats, and salt marshes. Remaining for six days, the Spaniard reported a few native tribes who hunted and fished the sea with nets. He named the bay San Miguel. Sixty years later, a Spanish-Mexican merchant, Sebastian Vizcaino, followed Cabrillo's route, found the embayment and renamed it San Diego Bay. To obtain fresh water, wells were dug on North Island.

Establishment of the San Diego de Alcala Mission in 1769 brought a new era of occupation and use of the bay as an active harbor for the Spanish fleet. Early California ranchers traded cattle hides and tallow that were shipped from the bay. By 1830, there were sixteen American whaling vessels operating out of the bay in search of the California gray whale. Commercial whale oil production began in the state in 1870. Between 1871–1872 the whaling industry peaked when 55,000 gallons of oil and 200 tons of whale bone were shipped from Point Loma (Fairey *et al.* 1996).

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Over geologic time the waters of the San Diego River alternated between Mission (False) Bay and San Diego Bay. By 1850, the town's population according to the first census was 650. The initial government action implying that the San Diego River was in need of curbing was the U.S. Coast Survey; an 1851 report by A.D. Bache warned that the bay may be destroyed by the silting action of the river and the only remedy was to turn the river into False Bay again. Lt. George Horatio Derby, of the USACE was sent to San Diego in 1853 to build what became known as Derby's Dike (Papageorge 1971). Therefore, after settling for several hundred years on the delta of San Diego Bay, the river was permanently diverted into Mission Bay in 1853–1854 (see Map 3-1 for bay habitat circa 1859).

With the land boom of the 1880s, water quality began to decline as raw waste was dumped directly into the bay.

In the late 1880s, the community of San Diego was experiencing growing pains. Building of the Point Loma lighthouse and completion of the transcontinental railroad connection to San Diego in 1885 made the region more accessible, stimulating trade. San Diego also became a winter resort destination. In 1887, a new San Diego City sewage disposal system dumped raw waste directly into the bay. Cuyamaca dam was built with in 1888 a flume that diverted water into Chollas Creek. Also in that year the first dredging in Glorietta Bay occurred using a steam suction dredge. Coinciding with the construction of Hotel del Coronado, the City of Coronado added a sewage system dumping into the bay in 1890, as did National City in 1893.

Problems relating to a fast growing community continued to mount. In an effort to keep up with accumulations of garbage, disposal at sea near Point Loma using a garbage scow began. Dixon Crematory was built in 1897 near the foot of 8th Avenue to burn trash, and the scows were discontinued. By 1901, the human population numbered 30,000. Charting by the USCG still indicated relatively undisturbed tidal flats and salt marshes.

The natural sloping conditions of the south bay were ideal for constructing dikes to form evaporation ponds for salt production, beginning with the La Punta Salt Works in 1871. The ponds replaced natural areas of salt marsh and mudflats at the mouth of the Otay River. The solar evaporation ponds expanded through 1942.

There was an influx of Navy and civilian personnel to the San Diego area during both WWI and WWII as ship building and airline construction reached new heights.

In 1919, the San Diego Chamber of Commerce purchased tidelands (mudflats and salt marsh) at the foot of 32nd Street ("Dutch Flats") for the Navy to dump dredge spoils from extending deep-water areas. The bay was being reshaped to accommodate larger vessels and fill a demand for waterfront development. "Dutch Flats" was converted to a municipal airport in 1928. Shelter Island was created from dredge spoil on mudflats in 1934. In 1941, dredging deposits were used to fill in Spanish Bight on North Island, expanding the island by 620 acres (251 ha).

The cumulative effect of dredging and filling the bay has caused the general effect of deepening the harbor and reducing its area. Comparing the current footprint to the 1859 condition (Map 3-1), dredge and fill has claimed much of the marshes, tidal flats, and shallow water habitats. A more complete history of dredge and fill is described in Chapter 2.

By 1942, the local population was reaching 250,000, coinciding with a buildup of the Navy and defense industry, as ship building and aircraft construction reached new heights. The overloaded sewage system failed. Raw or minimally treated sewage was being dumped from fifteen outfalls into the bay.

By the post-Korean War period, the bay was swallowing 50,000,000 gallons of sewage and industrial waste per day and supporting a population of 400,000 people. There were five tuna canneries and a rendering plant discharging waste. Between 1951 and 1958, 7 feet (2 m) of sludge could be found at the City of San Diego sewage outfall.

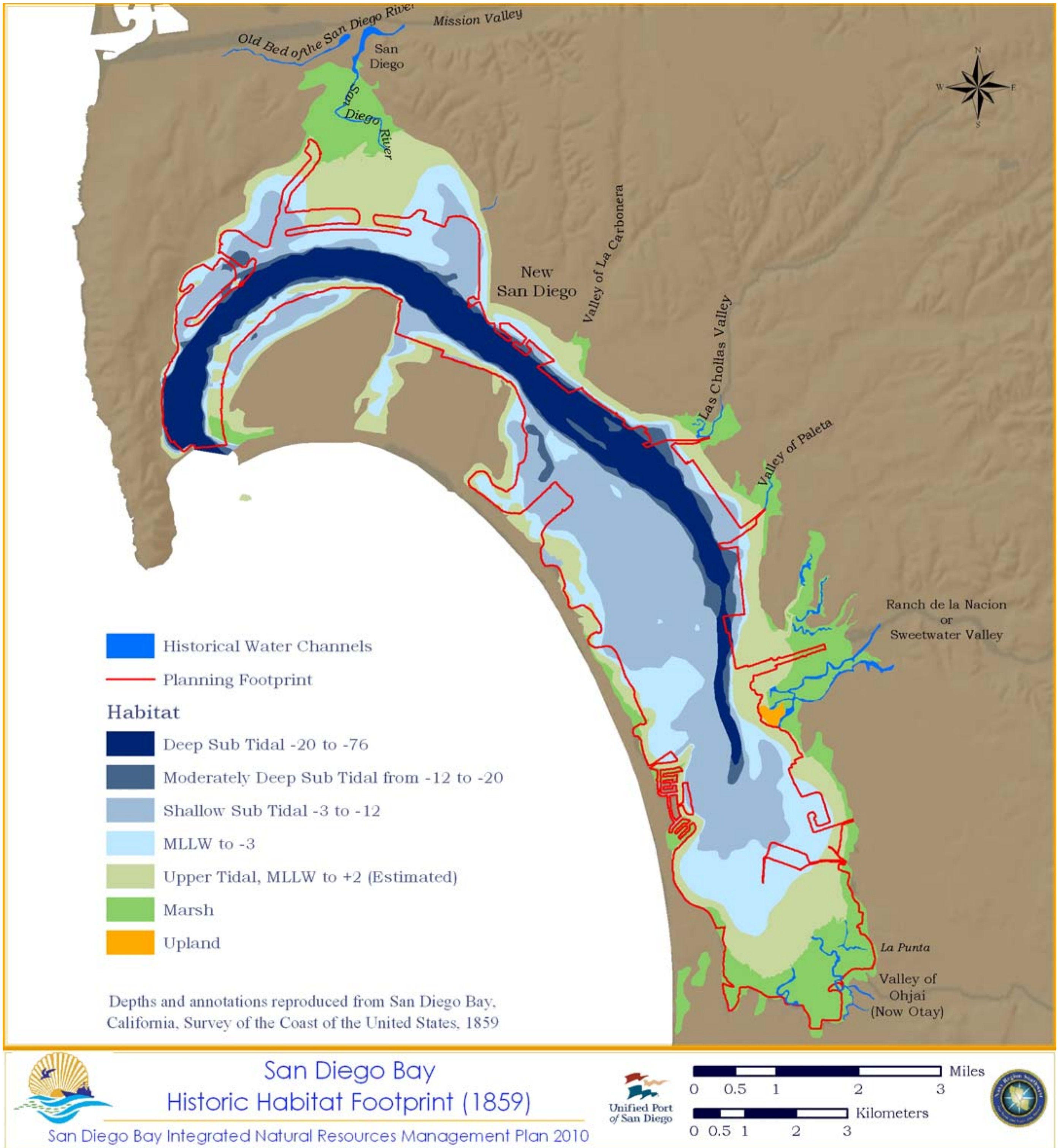
San Diegans can take great pride in initiating a bay cleanup that preceded both the state and federal CWAs, perhaps the first bayside community in the nation to do so.

San Diegans can take great pride in initiating a bay cleanup that preceded both the state and federal CWAs, perhaps the first bayside community in the nation to do so. In the 1960s, a new San Diego Metropolitan Sewage System with ocean outfalls went into operation and all domestic sewage was diverted to the new system.

Large-scale dredging and filling for National City and Chula Vista bayfronts and Harbor Island was initiated in the 1960s. Coronado Cays was constructed over a previous city burn dump site, adjacent to mudflats and salt marsh in 1968. The Port funded an access channel and L-shaped boat basin in the south bay. The SDG&E power generating plant also became operational in the south bay.

The 1970s and 1980s were a time of cleanup, and the human-induced decline of natural resources in San Diego Bay was reversed. Navy and industrial firms made headway in preventing and cleaning up oil spills. One cannery remained and it used a purification system.

Today, San Diego Bay is an agricultural trade center, a manufacturing trade center, a transportation hub, a base for sports fishing fleets, a base for Navy operations, a first port of call, and a center for tourism and recreation. And it supports abundant and diverse marine life.



Map 3-1. San Diego Bay historic habitat footprint (ca. 1859).

3.2 The Bay Region's Human Setting

Photo 3-1. City view, April 2007. Photo courtesy of Rob Wolf.

3.2.1 Population Trend

San Diego Bay itself is 14.7 miles (23 km) long and covers over 19 mi^2 (49 km^2) of water and land. The bay region includes the cities of San Diego (Photo 3-1), Coronado, National City, Chula Vista, and Imperial Beach. The San Diego Metropolitan Area ranks as the 7th largest city in the country and second in California. In 1990, the population census for these five cities was 1,353,013. By 2010, the estimated population was 1,724,163[1], an increase of 27% since 1990 with over half of that growth occurring from 2000 to 2010 (SANDAG 2010). This steady increase in population creates pressures for additional housing and jobs in an already densely populated region. Tourists swell the population year-round due to the numerous attractions of the area and great weather, with roughly 30 to 32 million annual visitors (San Diego Convention and Visitors Bureau [SDCVB] 2010).

3.2.2 Bay Water and Land Ownership

The footprint of this INRMP encompasses both uplands adjacent to the bay and all tidelands bayward of the historic (1850) mean high tide line. The latter is a mix of historic tidelands that still exist, formerly submerged areas that have been filled, and diked ponds.

Historic tideland areas are owned or controlled by the U.S. Government (Navy and USFWS NWR), the State of California, the Port, the County of San Diego, and the cities of San Diego and Coronado, as shown in Table 3-1 (SDUPD 2007). The closure and privatization of the Naval Training Center (NTC) property in 1999 is included in Table 3-1. Subsequently, a USFWS conservation easement on 25 acres of former NTC property that had been used as a least tern nesting site was removed, as part of an agreement between the Port and USFWS that resulted in establishment of the South San Diego Bay NWR.

1. Census data for 2010 currently unavailable. This estimate is dated January 1, 2010.

Table 3-1. San Diego Bay tidelands by ownership.[a] The Port's Master Plan deals primarily with land that the State Legislature has conveyed to the Port District to act as trustee and administration, and upon which the Port has regulatory duties and proprietary responsibilities.

Owner	LAND acres	%	WATER[b] acres	%	TOTAL acres	%
Federal	1,882	43	1,050	10	2,932	19.8
State of California[c]	12	0.3	6,490	61	6,502	43
Port of San Diego	2,491	56	2,992	29	5,483	37
County and City	34	0.7	0	0	34	0.2
Totals	4,419	100	10,532	100	14,951	100

a. Sources: Port 2007 Master Plan, including 1984 transfer of Port to state and 1999 transfer of NTC property to Port and City of San Diego; 1999 lease of 2,209 acres tidelands from SLC to USFWS for the South Bay National Wildlife Refuge; 2000 purchase by Coastal Conservancy of 91 acres in Otay River floodplain and transfer to USFWS; GIS coverages.

[b] Includes about 1,068 acres of salt ponds and flats.

[c] Includes SLC, CDPR, and CalTrans.

Ownership of the San Diego Bay shoreline is shown in Table 3-2. The Navy holds deeds to about 1/5 of the total tideland area and about 1/3 of the total shoreline. In 1962, the state legislature granted sovereign land in trust to the Port for the purpose of operating and maintaining Port facilities for statewide benefit. About 1/3 of the total tidelands and almost 2/3 of the bay's shoreline were granted to the Port by the state. Over half of the filled tidelands are under Port jurisdiction. The State Lands Commission (SLC) retained ownership of the majority of submerged lands under the bay, including the navigation channels.

Table 3-2. San Diego Bay shoreline by ownership.[a]

Owner	MILES	PERCENTAGES
Federal Military (deeded)	19.98	36.9
State of California Department Parks & Recreation	00.45	00.8
Port of San Diego (granted tidelands)	33.10	61.3
City of Coronado (granted tidelands)	00.48	00.9
Totals	54.01	100.0

a. Port of San Diego Master Plan 2010

Before the formation of the Port District, the SLC leased most of the salt pond area in the south bay to Western Salt Company. In 1984, the Port's 612 acre (248 ha) lease of water and salt ponds reverted to state control. In 1999, a future acquisition boundary was approved for the South San Diego Bay Unit of the NWR that encompassed 3,940 acres of land and water in the south bay. Following this action, the SLC approved a $20.5 million expenditure of Public Trust funds by the Port to acquire 722 acres of salt ponds owned by Western Salt Company. The lands were transferred from the Port to the SLC in accordance with state law, which requires lands acquired using public trust revenues to be retained by the trustee as an asset for the people of the state. In turn, the SLC leased these lands, as well as approximately 1,500 additional acres of state tidelands, to the USFWS for a period of 49 years, with an automatic extension to 66 years, to include in and be managed as a NWR. The Refuge Unit was officially established on June 16, 1999, the day the lease for the 2,209 acres of state tidelands was approved (USFWS 2006).

To complete the current boundary footprint of the NWR, in the year 2000, the USFWS acquired an additional 91 acres of vacant land located within the Otay River floodplain. This acquisition was the result of a donation from the Southwest Wetlands Interpretive Association, a non-profit organization dedicated to the preservation, restoration, and acquisition of wetlands. Southwest Wetlands Interpretive Association obtained the funds needed to acquire this property from the California Coastal Conservancy. Following acquisition, Southwest Wetlands Interpretive Association conveyed fee title of the property to the USFWS. With this acquisition, the total acreage within the approved acquisition boundary is 3,940 acres. Acres being managed as part of the NWR System was increased to 2,300 acres.

3.3 Current Patterns of Use

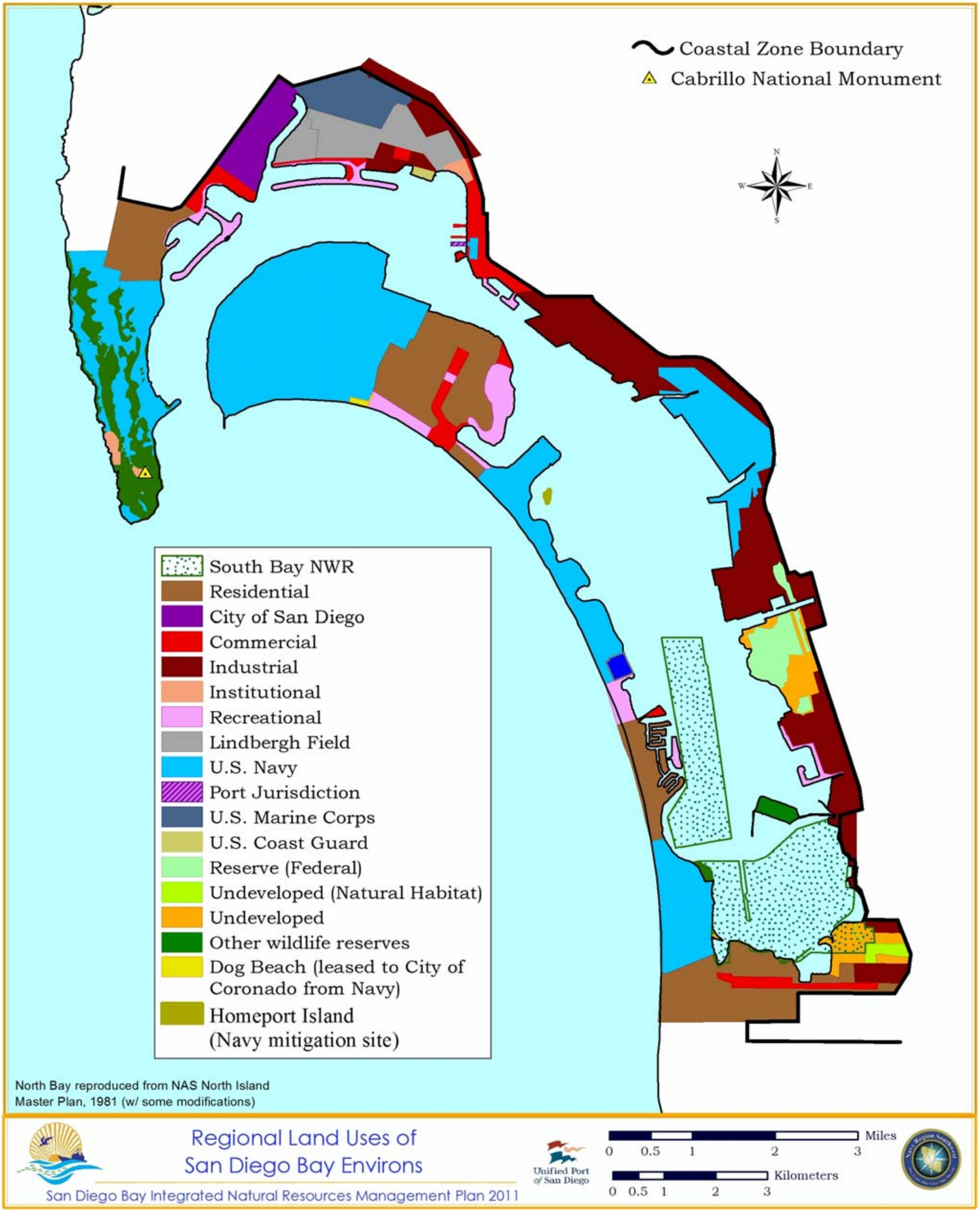
San Diego Bay is an urban port (Photo 3-2), with the exception of the south bay. Industrial uses along the bay and its environs include shipyards, boatyards, docks and wharves, shipping and trade companies, aerospace and airport industries, and manufacturing. Commercial businesses are represented by retail stores, hotels, conference centers, cruise ships, restaurants, marinas, office buildings, and salt ponds. Public uses include parks, beaches, bike trails, promenades, boat launch ramps, municipal buildings, and community centers. Only a few residential areas immediately abut the bay tidelands, with condominiums, apartment houses, and homes located not far from the shoreline.

Regional land uses are shown in Map 3-2. Planning jurisdictions for the cities, Port, and federal government in the San Diego Bay region are indicated in Map 3-3.

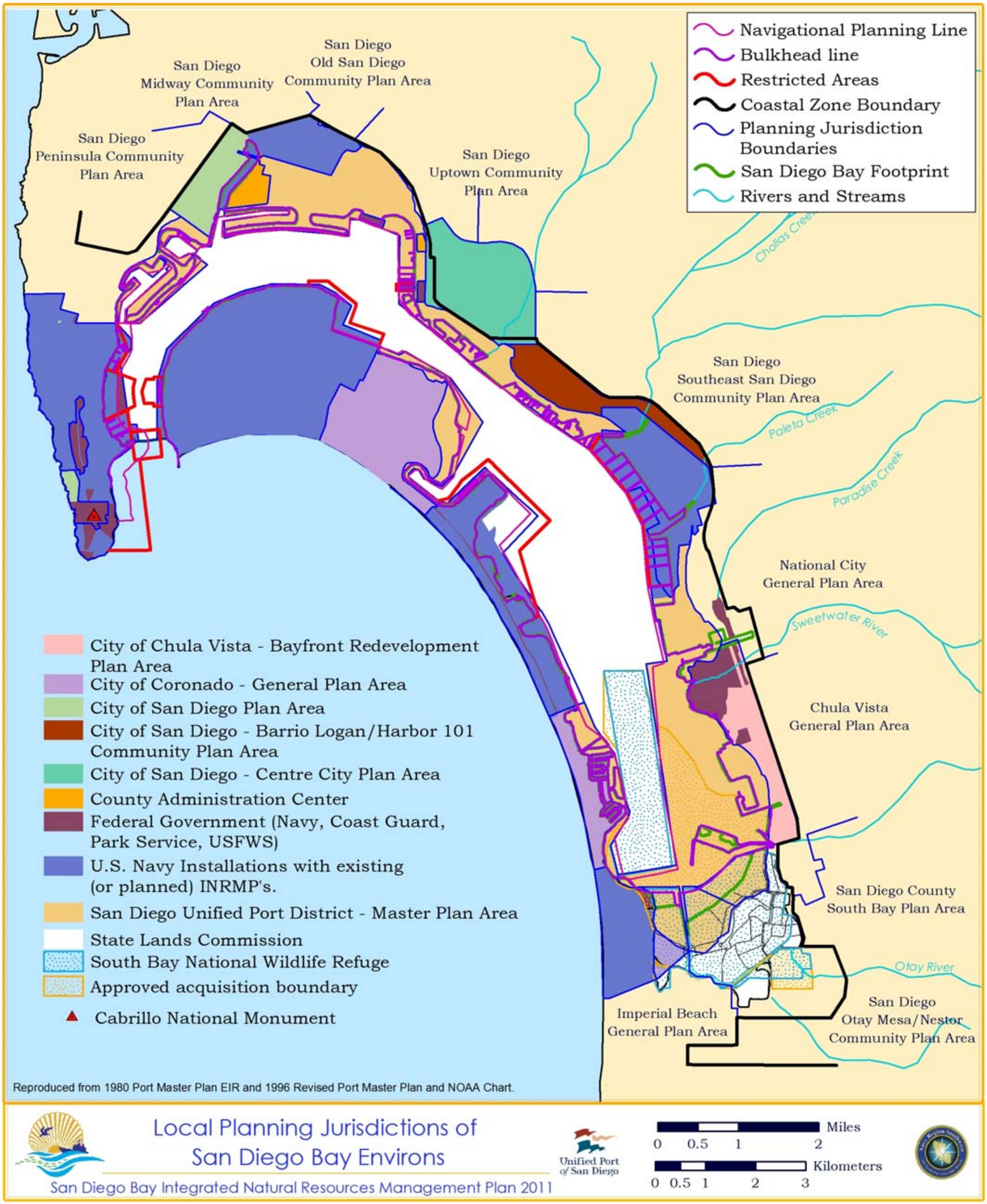
Photo 3-2. Urban San Diego Bay shoreline, 2007. Photo courtesy of Rob Wolf.

3.3.1 Navy Uses and Planning

Naval facilities in the bay area are comprised of industrial, commercial, and residential urban land uses in addition to open space (see Map 3-2). There are three primary property managers in the San Diego Bay Naval Complex; regional command is provided by the Commander, Naval Region Southwest.



Map 3-2. San Diego Bay regional land use.



Map 3-3. Local planning jurisdictions of San Diego Bay environs. Naval Air Station North Island has an Integrated Natural Resources Management Plan as part of Naval Base Coronado.

1. The NBC complex includes (only portions of NBC associated with San Diego Bay are listed):
   - NASNI
   - NAB (includes a 40 acre parcel leased by the Navy to the CDPR for public use, and 257 acres leased by CDPR to the Navy for military training)
   - NRRF
   - Imperial Beach Naval Outlying Landing Field (outside INRMP footprint)
2. The NBPL complex includes:
   - Space and Naval Warfare Systems Center (SSC)
   - Naval SUBASE
   - Fleet Anti-Submarine Warfare Base
   - Fleet Combat Training Center
   - Fleet and Industrial Supply Center (FISC)
   - Magnetic Silencing Facility
3. The NBSD complex includes:
   - Naval Station 32nd Street
   - Naval Medical Center in Balboa Park (outside INRMP footprint).
4. The Marine Corps Recruit Depot reports directly to Headquarters Marine Corps.

U.S. Navy INRMP

The U.S. Department of the Navy is required to implement and maintain a balanced program for the management of natural resources. For each Naval installation, an INRMP must be prepared based on criteria described within the Navy's Environmental Protection and Natural Resources Manual (OPNAVINST 5090.1C). Table 3-3 lists the current INRMPs and date of completion.

Integrated Natural Resource Management Plans are completed for each of the bay's Naval bases.

Table 3-3. Natural resource management plans and approval dates for San Diego Bay area.

Plan	Most Recent INRMP Approved
Marine Corps Recruit Depot	N/A[1]
Naval Base San Diego	2002
Naval Base Point Loma	2002
Naval Base Coronado	2002

1. No longer requires an INRMP and has been removed from the list (Sikes Act reporting data 2005).

Regional Shore Infrastructure Plans

Regional Shore Infrastructure Plans (RSIPs) have now replaced former installation-level master plans for facility needs and siting options. The Navy addresses facility structures, infrastructure, and landscaping in the RSIPs. The roles of the various Navy activities, their operational use of San Diego Bay, and related operational and maintenance requirements are shown in Table 3-4.

3.3.2 Port Master Planning

The Port Master Plan was adopted in 1980, and 33 amendments have been approved over the years (SDUPD 2010a). Amendments continue to be made to the original Plan's ten planning subareas: (1) Shelter Island, (2) Harbor Island/Lindbergh Field, (3) Center City/Embarcadero, (4) Tenth Avenue Marine Terminal, (5) National City Bayfront, (6) Coronado Bayfront, (7) Chula Vista Bayfront, (8) Silver Strand South, (9) South Bay Salt Lands, and (10) Imperial Beach oceanfront. It was last updated in 2010.

Table 3-4. U.S. Navy, U.S. Coast Guard, and U.S. Marine Corps uses of San Diego Bay by organization.

Organization and Mission	Operations and Activities	Operational Requirements Related to San Diego Bay
Naval Base Coronado		
NASNI: Arm, repair, provision, service, and support the U.S. Pacific Fleet and other operating forces.	■ Ordnance movement/transfer/supply (daily). ■ Nuclear carrier berthing (daily). ■ Pacific Naval Air Unit training & Helicopter Tactical Wing training. ■ Anti-Submarine Wing training. Weapons training. ■ Supply and support services.Repair and manufacturing services ■ Technical support services.	Shore access, anchorage, pier support, boat ramp, and maintenance. NASNI operations include 112,570 annual airfield operations (based on take-offs and landings in 2004), and training and recreational activities on the beach.
NAB: Provide on-base facilities and services in support of amphibious, unconventional, inshore; and riverine warfare; special warfare; and other approved training related to amphibious activities.	■ Physical conditioning.Obstacle course. ■ Amphibious assaults.Covert shore assaults. ■ Navigation and surf handling.Combat training. ■ Ship surveillance.Scuba diving.Swimmer delivery vehicles and special boats.Strategic sealift. ■ Container off-loading and transfer system. ■ Offshore bulk fuel system.Off-shore petroleum transfer. ■ Explosive ordnance disposal.Mine counter measures. ■ Conseil Internationale Du Sport Militaire.	Shore access, pier support, boat ramp, helicopter pad, anchorage, restricted waters for underwater and surface uses.
NRRF	■ Numerous military training activities mostly on foot in small squads. Area is fenced for security.	Shore including small boat access, physical security.
Naval Base Point Loma		
SSC: Research, Development, Testing, and Evaluation.	■ Research, Development, Testing and Evaluation. ■ Scuba/swimmers under piers (daily). ■ Whalers/inflatables in main shipping channel (daily). ■ Marine mammals (dolphins, porpoises, etc.) in submerged animal pens for underwater ordnance recovery and anti-swimmer security. ■ Underwater remotely operated vehicles, and various underwater equipment and tools. Cable-laying under SD Bay.	Shore access, boat ramp, maintenance of NRAD pier, water depth in main shipping channel. Pier maintenance.
Naval SUBASE: Provide logistic support to subsurface and surface units.	■ Camel Moves (daily). Life Guard Duties (daily). ■ Boom Handling (daily). Oil Recovery (as needed). ■ Harbor Transit (daily). Security Patrol (daily). ■ Diving, hull inspection/maintenance (daily). ■ Some recreational fishing from piers and ships by sailors.	Shore access, pier support and maintenance, boat ramp, primary road, electricity support, main shipping channel maintenance, restriction of recreational boating activity during special operations, dredging/filling, pile driving, pile replacement.
Fleet Anti-Submarine Warfare Center: Provide tactical and technical training to skilled anti-submarine warfare professionals capable of supporting requirements of higher authority.	■ Warfare training. ■ Security patrol.	Pier maintenance.
FISC: Provide Naval Forces quality supplies and services.	■ FISC includes two sites on SD Bay: FISC Broadway at 937 N. Harbor Drive, which includes a large berthing pier, and FISC Fuel Depot at 199 Rosecrans on Point Loma. ■ Ship Berthing (bimonthly). ■ Refueling: daily (2 ships/day). ■ Fuel Transfer (every other day from Fuel Depot to Miramar; bimonthly from Fuel Depot to NASNI).	Boat ramp, shore access, anchorage, piers support. Water depth at Point Loma Pier must be maintained at approximately 45 feet (15 m) for vessel refueling. Pile driving (pier repair), dredging/filling (pier maintenance). Berth at fuel depot requires a minimum 45 feet (15 m) depth for vessels. Pile driving and dredging/filling also occasionally occurs at the fuel depot for maintenance.
Magnetic Silencing Facility: Test and treat ships to minimize risk.	■ Testing and treating ships to reduce magnetic signatures & thereby minimize risk of setting off magnetic influence mines (periodic). ■ Deperming and degaussing (several times per year).	Facility has a 1,650 feet (503 m) radius electromagnetic interference zone around it that restricts development on adjacent SUBASE and FISC property.
Naval Base San Diego		
Naval Station, 32nd Street: Provide berthing dock for Naval ships.	■ Flight Ops—occasional (5/yr). ■ Diving—daily, hull inspection/maintenance; SEAL Ops. ■ Ammunition movement/transfer (1 or 2 every two weeks or so). ■ Oil spill response. ■ Small boat (rubber zodiacs and motor whale) activities (daily). ■ Helicopter flight operations on import ships, usually Amphibious Assault Ships (general purpose) (LHAs) or Amphibious Assault Ships (multi-purpose) LHDs (occasional, about 5 times a year). ■ Recreational fishing occurs occasionally off of the piers or ships by sailors. There is a Naval Station to NAB recreational swim held yearly.	Shore access, pier support, SD Channel maintenance, water depth 37 feet (11 m) from Coronado Bridge to Pier 14, pier maintenance, dredging/filling.
U.S. Marine Corps		
Marine Corps Recruit Depot: Provide training to recruits.	■ Recruit training. ■ Recreational fishing from the piers.	Boat ramp and marina (recreational), pier maintenance.
U.S. Coast Guard		
USCG: Provide services for southern California maritime law enforcement, search and rescue, oil spill and hazardous materials response, and some permitting.	■ Small facility on Point Loma immediately adjacent to SUBASE and the Naval Station degaussing facility, which is the mooring location for the USCG Cutter Tybee. ■ Facility (8 acre) at the south tip of Point Loma with lighthouse and housing for three senior officers. ■ Search and Rescue. Oil/hazardous materials response. ■ Law enforcement. Aircraft sorties (36 per month). ■ Patrol boat deployment (60 per month). ■ Permitting marine events and impacts to navigable waters.	Airfield access, shore access, helipad/drop-zone, pier support. Patrol boat deployment minimum water depth 20 feet (6 m).

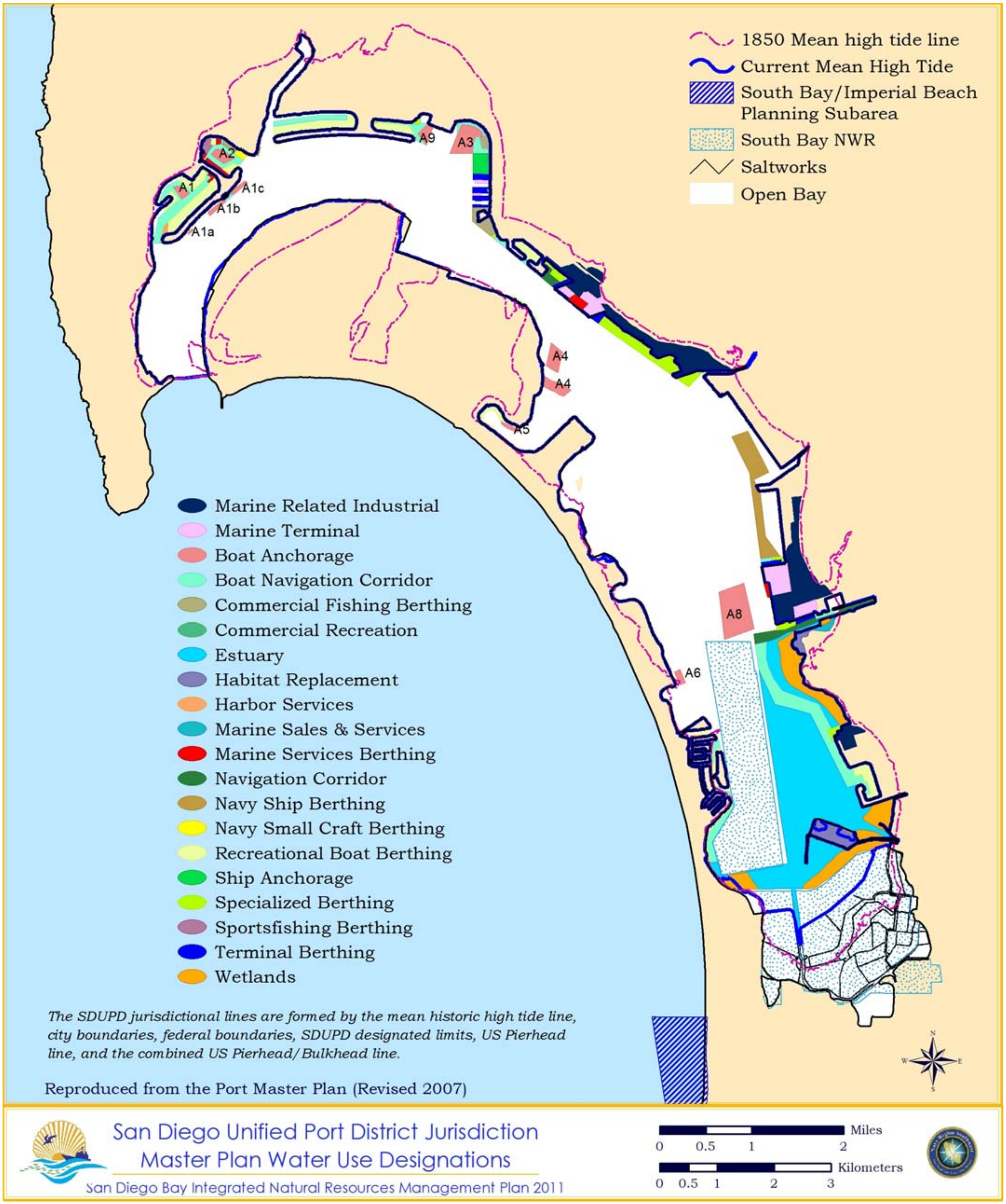
As part of the planning process, the CCC must certify the Port Master Plan to be consistent with the policies of the CCA. CCC certification authorizes the Port to directly grant coastal development permits. Since the last bay INRMP in 2000, 12 amendments have been approved (SDUPD 2010a). The Plan serves as guidance for policy decisions by the BPC. It is the Port's LCP. The Port Master Plan also serves as the basis for capital improvements programming and services for use by the staff, and as a source of information and opportunities by agencies, the public, and private investors (SDUPD 2007).

Water use designations within the Port's jurisdiction are shown in Map 3-4 with definitions of uses in Table 3-5. These categories determine which uses of the bay's water are allowable and not allowable. When the anchored vessel fleet increased to a size that caused many problems, the Port amended its 1980 Master Plan to repeal the identification of all of San Diego Bay as an anchorage ground and instead designated eight long-term mooring and anchorage areas for small craft. These areas are noted on the map, with derelict boats regularly being removed by the Port and placed in derelict craft storage, to be disposed of according to state law (SDUPD 2010a). Emory Cove anchorage was cleaned up in the early 1990s.

An estimated 885 boats with more than 1,220 people living aboard (approximately 1,000 live in marinas and 220 live in anchorages) can be found in the bay (SDUPD 2005). However, the tidelands trust does not allow liveaboards. Port-controlled tidelands are state public trust lands, lands that must serve statewide as opposed to local or public purposes. Generally, these are limited to water-dependent or water-related uses, and this excludes residential (SDUPD 2008).

Table 3-5. San Diego Bay Port Master Plan water use mapping definitions, as seen in Map 3-4.

Water Use	Mapping Definition
Boat Anchorage (A1–A8)	Small craft anchored vessels that are not connected to land by any docks.
Boat Navigation Corridor	Areas delineated by navigational channel markers or by conventional waterborne traffic movements. Channels that are too narrow and/or shallow to accommodate larger ships.
Commercial Fishing Berthing	Areas leased for the berthing of commercial fishing vessels.
Commercial Recreation	Areas leased for commercial recreation (restaurants, boat tours, etc.).
Estuary	The confluence of the Otay and Sweetwater Rivers with the bay; relatively warm, shallow, submerged areas where exchange occurs between salt and fresh water. The northerly extent of the estuary area had been altered by dredging that has reduced the exchange of waters.
Habitat Replacement	Conservation areas used to replace lost habitat.
Harbor Services	Harbor regulatory services and activities; including police, fire, and transient berthing facilities.
Main Ship Channel	Provides a depth between 35–42 feet (11–13 m) and widths varying from 600–2,000 feet (183–610 m) for the navigation of large oceangoing vessels.
Marine-Related Industry	Sites adjacent to water for industrial activity dependent for direct access or for linkages to waterborne products, processes, raw materials, or water.
Marine Terminal	Terminal requiring berthing space with water depth a minimum of 35 feet (11 m) at MLLW.
Marine Sales and Services	Areas adjacent to navigation corridors leased for marine sales and services.
Marine Services Berthing	Areas adjacent to navigation corridors leased for marine services.
Navy Ship Berthing	U.S. Naval Station (leased Port land).
Navy Small Craft Berthing	U.S. Navy Fleet School (leased Port land).
Open Bay	Portions that are free of development and where primary uses are recreational.
Recreational Boat Berthing	Areas leased for permanent and/or temporary berthing of private vessels.
Ship Anchorage	Areas for oceangoing ships.
Ship Navigation Corridor	Adequate draft for ship maneuverability, safe transit, and access to marine terminals, marine-related industrial areas and Navy bases (ship corridors must be maintained at adequate widths and depths to eliminate hazardous conditions in the harbor).
Specialized Berthing	Areas leased for marine-related industrial businesses (steel fabrication, ship building and repair, fuel receipt and storage, and marine-related food processing etc.).
Sport Fishing Berthing	Areas leased for private businesses chartering to the public.
Terminal Berthing	Berthing for commercial vessels loading and unloading cargo (general trade, petroleum products, etc.).
U.S. Navy Jurisdiction	Areas controlled by the U.S. Navy (some uses include training activities, ship berthing, open bay uses, etc.).
U.S. Navy Property	Uses vary by each individual piece of property (some uses include training with amphibious vehicles, ship berthing and repair, etc.).
Wetlands	Undeveloped areas having high biological productivity that are alternately covered with water and exposed to air.



Map 3-4. San Diego Bay Port jurisdiction Master Plan water use designations (also see Table 3-5).

3.3.3 Local Plans

Since the cities' boundaries overlap the Port's tideland ownership, the planning jurisdictions appear to overlap also in Map 3-3. While cities do not have any planning authority on Port lands, each city plans its land use by preparing and adopting a state-required general plan, as well as a LCP for property within the coastal zone. However, the BPC makes the final decisions on land use designations for Port tidelands within the Port's Master Plan.

The CCC provides state oversight to LCPs, as required by the CCA. Once these plans become certified by the CCC, the cities can issue development permits.

The CCP for the San Diego Bay SMNWR and South San Diego Bay Units satisfies a condition of Public Agency Lease between the California SLC and the USFWS, in which the USFWS is to provide a plan to the SLC for managing leased tidelands within the boundaries of the South San Diego Bay Units. The plan details management and development plans as well as provisions for public access. The plan does not constitute a commitment for staffing increases, operational and maintenance increases, or funding for future land acquisition. The CCP is required for all refuges.

3.3.4 Navigation

The waters in San Diego Bay are considered U.S. Navigable Waters; therefore, future proposals that would limit the public's right to free access of these waters would require federal and/or state rulemaking prior to implementation (USFWS 2007).

Navigation patterns in the bay are governed by the presence of artificially constructed, 10- to 60-feet (3- to 18-m) deep channels that allow passage of vessels of various sizes, as well as the presence of certain in-water restricted areas. These are shown in Map 3-5 (SDUPD 2007). Also, recreational uses depend upon the availability of marinas plus the patterns of wind and calm and how each sport uses these factors to advantage.

3.3.5 Aircraft Operation

The military maintains several helicopter and fixed wing air routes over San Diego Bay, which are used primarily, but not exclusively by military flights in and out of NASNI and Naval Outlying Landing Field Imperial Beach. The current instrument approach, Tactical Aircraft Control and Navigation used by fixed wing and rotary wing aircraft to Runway 29, NASNI, is from south to north, up the middle of the bay at an altitude of between 1,600 and 2,300 feet. Military aircraft also operate over the bay using visual flight rules approach and departure corridors, which extend the entire length of the bay. Within this "bay approach" corridor, military aircraft operate at altitudes of between 500 and 800 feet. Departures from Runway 36, NASNI, travel from north to south, down the middle of the bay at an altitude of about 500 feet. These flights leave the airspace above the bay either to the southeast at about the location of the South Bay Power Plant or to southwest over the NRRF. A visual flight rules helicopter route also extends northwest to southeast over Sweetwater Marsh, entering the airspace above the bay just south of the National City Marine Terminal (Rollins 1998).

The San Diego International Airport (Lindbergh Field) flightlines avoid San Diego Bay by regular departure paths taking off across Point Loma but avoiding residential areas, as far as possible, with air traffic directed to about 1.5 miles west of the shoreline before turning south. If crossing Point Loma, they must cross from Fort Rosecrans National Cemetery or south of there. Arrivals fly over Balboa Park and the downtown Highway 163-Interstate 5 interchange before landing.

3.3.6 Commercial/Recreational Fisheries

Several world renowned sport fishing fleets operate out of San Diego Bay attracting clients from southern California and visitors from out of state and abroad.

Revenue from the fishing-related industry associated with San Diego Bay is a vital component to bayfront business. Furthering the development of sport and commercial fisheries is one of the purposes mandated by the Port's enabling legislation (SDUPD 1980). A California commercial fishing revitalization plan was initiated in the spring of 2008 and was implemented through state grant funding to support and enhance the California based commercial fishing industry. In 2008, commercial fisheries earned $113 million in ex-vessel value, the price paid to fishermen. (SDUPD 2010b). San Diego area commercial fishers account for approximately 5% of California's direct annual revenue attributed to fish landings. Commercial passenger carrying vessel angling effort originating from the bay supports greater than 150,000 angler-days per year (number of anglers times the number of days they fished per year) from charter fishing operations alone (Sportfishing Search 2007). Considering additional angler effort aboard private vessels and from shore based platforms, yearly angling effort originating or taking place within San Diego Bay exceeds 300,000 angling days per year. Based on a 2008 report developed by the American Sportfishing Association, 1.7 million California anglers expend approximately 2.67 billion dollars in fishing related expenditures (Southwick Associates 2008).

Sport fishing in the bay is a minor component of effort compared to deep sea fishing in the ocean for yellowtail, yellowfin, albacore, and rockfish species. Several world renowned sport fishing fleets operate out of the bay, primarily from America's Cup Harbor (ACH), attracting regular clients from southern California, as well as visitors from out of state and abroad. In 1978, over 80 part-time and full-time charter vessels operated from ACH; in 2010, 66 boats operate from four separate landings within the bay, and additionally, independent operations conduct small, private, fishing charters. Each large "partyboat" averages 30 passengers per trip and smaller private "six-pak" charter boats are restricted to six passengers.

Landings of certain sport species (e.g. surfperch, halibut, croakers, sandbass) taken by private boaters and shore based fishermen are periodically monitored through boat and dock checks conducted by NMFS through the Marine Recreational Fishery Sportfishing Survey. Commercial charter boats are mandated by CDFG to log daily landings and catch locations. In 2006, commercial passenger fishing vessels reported nearly 550,000 fish landings for 133,000 anglers, nearly half of which were attributed to yellowtail, tuna, and other highly migratory species. No figures are collected by the state or federal agencies on shellfish harvest, although that has been reported in the bay. A 1992 sport lobster survey listed San Diego as the most popular area in southern California for catching lobster. Inside the bay, fishermen use hoop nets to catch lobster because scuba diving is prohibited (M. Fluharty, *pers. comm.*). In San Diego County recreational fishing for lobsters is a valued part of life in San Diego for many people (Hovel and Lowe 2007).

Sport fishing from personal boats and from piers occurs around the bay (Photo 3-3). Public fishing piers can be found at the Embarcadero, Pepper Park, Bayside Park, Shelter Island, and the Coronado Ferry landing. In a 1990 study by the County of San Diego, anglers were surveyed at four locations around the bay. The study found that 75% of their catch was represented by four species: Pacific mackerel, California lizardfish, barred sand bass, and spotted sand bass. The average fishing frequency of bay anglers in the survey was 6.4 times per month, with 6% fishing daily (San Diego County 1990).

Based on the potential health risk determined in a toxicological study of sport-caught fish, the San Diego County Health Officer posted health advisories starting in 1990. In 2005, new signs were posted by the Port, with the help of the counties, warning of the dangers of consuming fish and shellfish from San Diego Bay. The new signs were intended to warn people, especially children and pregnant women, to limit their fish consumption (EPA 2006). Sport fish may present a health hazard when eaten due to natural and industrial chemicals in their flesh, especially when they are consumed often over a long period of time. These advisories are not intended to discourage individuals from eating fish. The advisories should be followed to make eating sport fish safer.

Map 3-5. San Diego Bay water navigation systems and restricted areas.

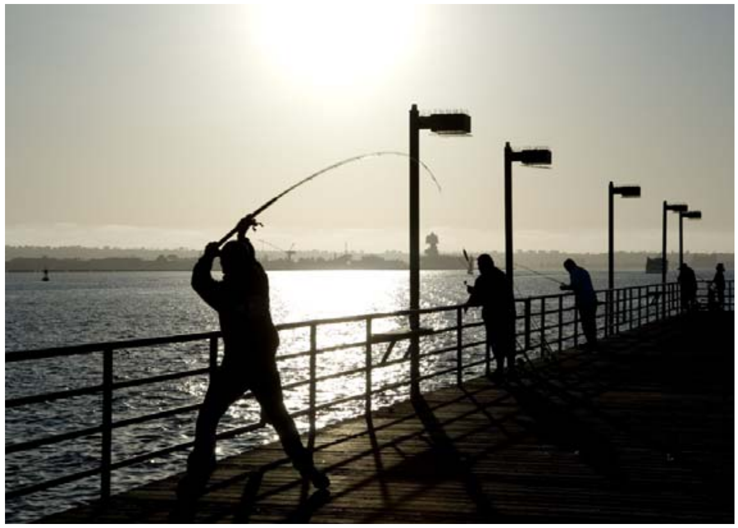


Photo 3-3. Public fishing, 2007. Photo courtesy of Rob Wolf.

Health advisories are not intended to discourage individuals from eating fish, an excellent source of low-fat protein. Eating sport-caught fish is safer when following advisories.

Health risks are dependent on the types and frequency of fish consumed (CDFG 2007a). Although the chemical levels found in sport fish are usually low, harmful levels do occur in some locations. According to the California Office of Environmental Health Hazard Assessment California EPA, no specific fish species within San Diego Bay are identified as health hazards (Office of Environmental Health Hazard Assessment 2008). Sport fishing continues in the bay, with the effect of warnings on the popularity of the sport not yet determined. Fishing in the bay is a combination of catch-and-release and subsistence fishing, thus health risks vary among ethnic and economic groups and probably affect those consuming the entire fish more so than those consuming only muscle tissue.

In the commercial fishery of the San Diego region, about 40 species of fish, crustaceans, and molluscs are allowed to be taken. Local commercial landings from California waters are mainly lobster, sea urchin, swordfish, sheephead, Thresher shark, spot prawns and various groundfish (CDFG 2010). Although bait fish (e.g. topsmelt, anchovy) are also caught in the bay and ghost shrimp are collected in the bay's mudflats, no reports of these commercial landings are required to be submitted to CDFG or NMFS.

The San Diego Oceans Foundation maintains and operates two grow-out facilities (pens) for white seabass in the bay, with the capacity to release nearly 90,000 white seabass annually back into the ocean (San Diego Oceans Foundation 2010). One pen is located at Grape Street and the other at Southwestern Yacht Club.

Commercial fishing boat sites in the bay are located at ACH, the seawall near Harbor Drive, and G Street Mole (Tuna Harbor) with 98 slips. Tuna Harbor symbolizes the bay's historic use as a home port of long-range tuna seiners. As tuna stocks decreased and the processing plants moved, this use of the bay dwindled. By 1980 San Diego's fleet of large tuna purse seiners operating in the Eastern Tropical Pacific numbered 10, of which about 30 were bait boats. Several events over the next few years exacerbated the problems of the tuna fishermen, including: the El Nino current of 1982-83 which caused the tuna to migrate into cooler waters in the Western Tropical Pacific, the movement of canneries overseas, and the seizure of U.S. tuna boats fishing illegally in the waters of Central America. By 1990 the number of purse seiners in San Diego had dropped to 30. Furthermore, in the same year, when the three major American tuna canners agreed to purchase only "dolphin-safe" tuna, the number of boats in San Diego's tuna fleet dropped from 30 to eight. Today, many San Diego tuna captains and fishermen fly to the international ports of Guam or American Samoa, where their boats are based, to continue fishing for tuna (Northwest Fisheries Science Center 2003).

The number of vessels licensed in San Diego County for commercial fishing (excluding research, party sport fishing, and tuna seiners) averaged 230 in the 1970s, and 197 in 1998 (SDUPD 1980; C. Jackson, *pers. comm.*). San Diego is principally involved in West Coast fisheries, including invertebrates, groundfish, coastal pelagics, and highly migratory species. In southern California, in the five years prior to 2000, 90 percent of the total landing value was contributed by squid, albacore/other tuna, sea urchin, coastal pelagics, shark/swordfish, lobster, and groundfish. The top three San Diego area fisheries in 2009, based on pounds landed and income generate, include Sea urchin, lobster, and swordfish. San Diego County, commercial lobster landings average approximately 225,000 pounds per year with a subsequent value of about $2.5 million dollars.

In 2000 at least six seafood processors were operating in San Diego. In the same year approximately 296 individuals were employed by these processors. The estimated total weight of their processed products in 2000 was 5,858,962 pounds, valuing $41,096,402. In 2000 the top three processed products in the community, in terms of pounds and revenue earned were kelp, salmon, and swordfish. San Diego is also home to an International Specialty Products company that manufactures alginates from California giant kelp; alginates are used in food, beverage, personal, and pharmaceutical applications. Additionally, numerous sportfishing companies offer processing and canning services, such as Fishermen's Landing, Sportsmen's Seafood, and Anthony's Seafood Group in affiliation with Point Loma Sportfishing.

3.3.7 Public Recreation, Tourism, and Environmental Education

According to the SDCVB, in 2009 an estimated 29.6 million people visited the region. San Diego Bay represents one of many established regional tourist destinations. In addition to over 250 acres of open space, the bay provides 27 miles of waterfront, 10 miles of pathways that front the bay, 22 marinas, three museums, a nature center, numerous restaurants and hotels, and a variety of unique shopping experiences.

Shoreline parks provide access to the bay and outdoor activities including swimming.

There are opportunities to participate in a variety of recreational activities, including boating, fishing, wildlife observation, biking, hiking, and some forms of organized sports. Sixteen public parks provide access for tourists and residents to the bay, along with opportunities for outdoor activities. Parks are located at Shelter Island, Harbor Island, Spanish Landing, Embarcadero Marina North and South, Coronado Tidelands, Chula Vista Bayfront, Chula Vista Bayside, Chula Vista Marina View Park, Cesar Chavez Park, Pepper Park, and Cancer Survivors Park. A few beaches are available for swimming in the bay: Coronado Park, Kellogg Beach, State Beach, Shelter Island and Bayside Park. Scuba diving in the bay is only allowed with special permit.

Tourism

Attendance at the San Diego Maritime Museum is at approximately 200,000 visitors annually as of 2007.

Tourists visit the bay and its waterfront areas for a variety of activities including boat tours, dining, sport fishing, shopping, summer concerts, biking, and sightseeing. Cruise ships disembark at the B Street Pier to allow passengers time to roam the area, which houses the San Diego Maritime Museum, including the Star of India (Photo 3-4). The museum has restored three ships at its docks, including the 1904 steam yacht Medea, which served in both World Wars, and attendance has swelled to 200,000 visitors annually (The Maritime Museum of San Diego 2007). The aircraft carrier USS Midway is located at the former Navy Pier, and is open for public tours (Photo 3-5). The Convention Center attracted about 300,000 delegates to its conventions and tradeshows in 1997; in 2010 this number is estimated to be 519,418 (SDCVB 2010).

Boating

The bay accommodates a wide range of year-round boating activities. It supports U.S. Navy ships, small boat activity, commercial ship traffic, and various forms of recreational boating. The Port has developed a Boater's Guide including a recreational map of anchorages, boat ramps, fishing piers, docks, military zones, etc. and telephone numbers of interest (Figure 3-1) for use by the public.

Photo 3-4. Star of India, tourist attraction of the San Diego Maritime Museum. Photo courtesy of Rob Wolf.

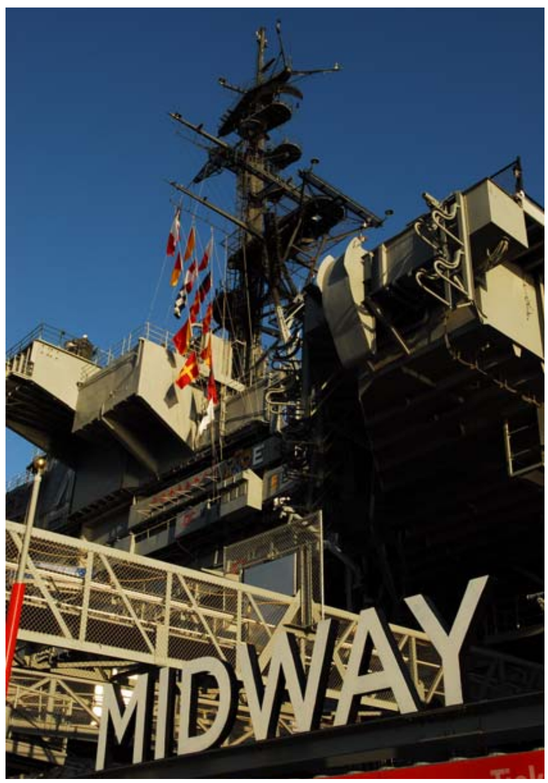


Photo 3-5. USS Midway, tourist attraction. Photo courtesy of Rob Wolf.

Figure 3-1. Example recreational map issued to tourists, taken from San Diego Bay Boater's Guide (San Diego Unified Port District 2006).

Studies conducted to characterize the boat traffic patterns in the bay demonstrate that most of the bay's boating activity takes place to the north of the Sweetwater Flood Control Channel (U.S. Navy 2000). This is due in large part to the shallow water depths in the south bay. In the south bay, artificial deep water channels have been constructed along the east and west sides of the bay to facilitate the passage of larger boats into and out of the Chula Vista Marina and the Coronado Cays. See Section 3.3.4. Navigation.

Most boat activity that occurs within south bay waters is associated with sightseeing, wildlife viewing, exercising, fishing, and general recreation. One company leads kayaking tours in the south bay that highlight views of sea turtles near the CVWR (Caladventures 2008). The shallow water depths, which range from one to 6 feet at low tide, limit the type of boats used in this area to motorized and non-motorized shallow draft vessels, such as rowboats, powerboats, canoes, kayaks, sail boards and personal water craft. Windsurfing and parasailing also occur. No boat inventories for this area are available to depict actual usage by season or day of the week.

The bay is renowned worldwide as a premier, year-round boating resource. It is an internationally-recognized venue for competitive yachting. Other recreational boat uses of San Diego Bay include sailing (Photo 3-6), motorboating, jetskiing, waterskiing, windsurfing, and kayaking.

Photo 3-6. Sailing San Diego Bay. Photo by Rob Wolf.

Boating facilities are depicted in Map 3-6. For the 21 public marinas, five private yacht clubs, four free boat launch ramps, seven full service boatyards, restaurant docks, and anchorages within the bay, a total of 8,281 boat slips are available, with nearly 90% occupancy (San Diego Waterfront 2008). Recreational boat berthing areas are found mainly at Shelter Island (Yacht Basin, 2,300 craft and ACH, 800 craft), Harbor Island, Embarcadero, Glorietta Bay, Coronado Cays (756 slips), and Chula Vista (552 slips) (SDUPD1997; USFWS 2006). In addition, National City Marina opened in August 2008 with 250 slips.

Boating speeds in the south bay are regulated; §4.30(c)3 of the Port Code states "It shall be unlawful for any vessel to be operated at a speed in excess of Five (5) miles per hour in South San Diego Bay as defined in §4.30(b)1 of this Code, except while transiting the Chula Vista Harbor Channel seaward of daymarks 11 and 12. Vessels must maintain a reasonable and prudent speed pursuant to §4.04 of this Code."

Bicycling and Walking

The Bayshore Bikeway is a 24-mile bicycle facility around San Diego Bay. It consists of a combination of bicycle paths and on-street lanes and routes providing convenient and scenic bicycle transportation around the bay. Future improvements include extending the bikeway north along the east side of San Diego Bay through Chula Vista and National city to 32nd street in San Diego (SANDAG 2010).

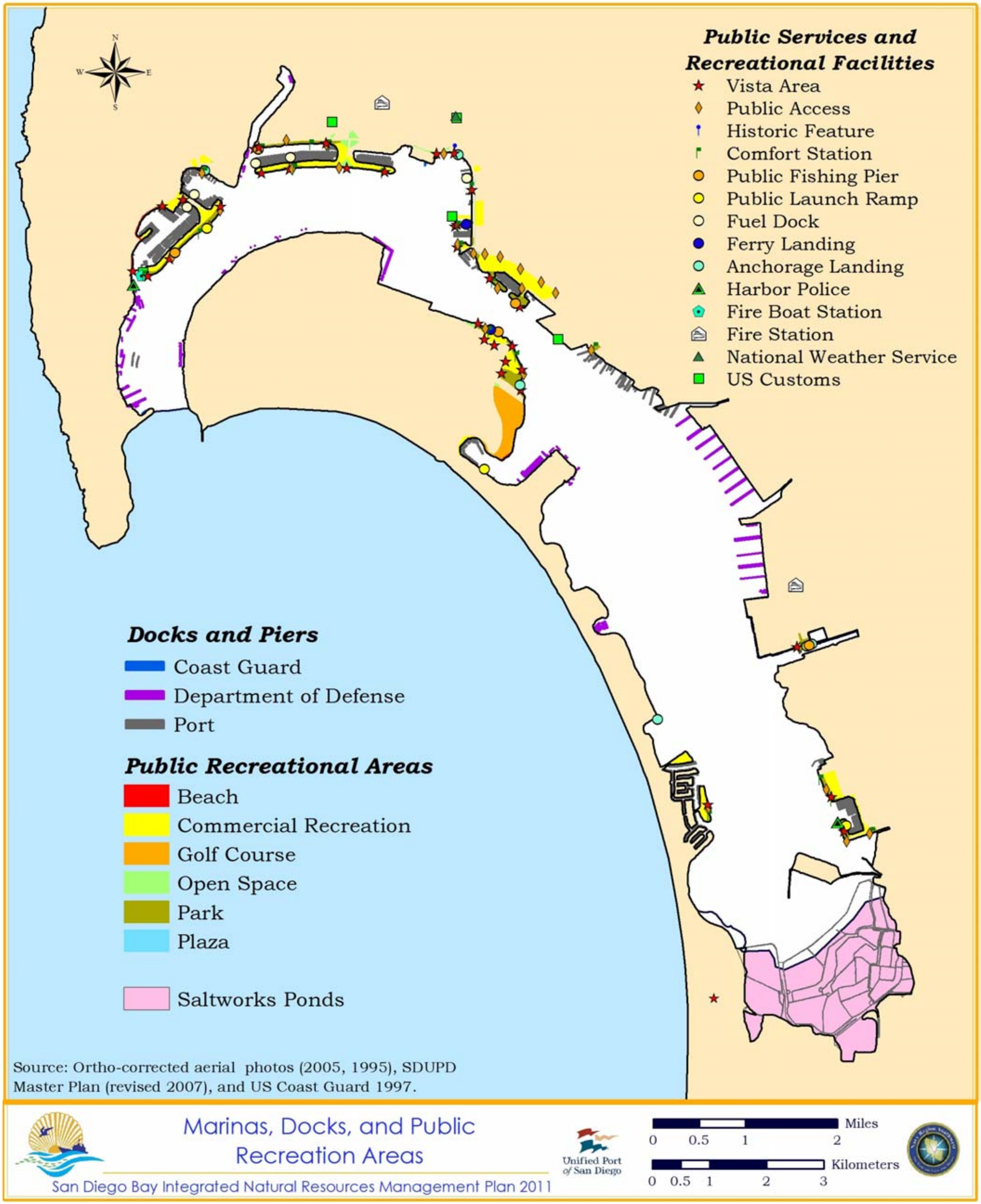
Another bike path, maintained by the City of San Diego, traverses north/south through the Otay River floodplain, primarily within the right-of-way of Saturn Boulevard. This bike path provides access from Main Street to Palm Avenue.

Walking trails are currently in place on the Sweetwater Marsh Unit of the NWR. The second phase of trail construction for the Otay Valley Regional Park was completed in 2010. The goal of the trails is to provide access along the entire length of the Otay Valley Regional Park, which, when all park lands have been acquired, will extend thirteen miles inland from the bay to the Upper and Lower Otay Lakes. The boundaries of the western most segment of the Otay Valley Regional Park overlap with the current boundary of the South San Diego Bay Unit of the NWR. The trails currently completed in this area, as described in the Otay Valley Regional Park Trail Guidelines (CSD 2003), extend a regional trail linkage under I-5 to connect with the existing bike path in Saturn Boulevard, ultimately providing a connection to the Bayshore Bikeway (CSD 2010).

The Bayside Birding and Walking Trail is planned to extend along the north side of the Bayshore Bikeway from 7th Street to 10th Street in Imperial Beach. The goal is to separate walkers and birders from cyclists so each group can enjoy use of the area without having to maneuver around each other. The trail is also designed to prevent unregulated pedestrian use in order to protect and reestablish salt marsh vegetation. It will be just under a half mile long and will include an interpretive overlook and pedestrian bridge. Construction is scheduled to begin in September 2011, with design beginning in October 2010 (USFWS 2010).

Events

Surrounding the bay are retail shops, restaurants, concert venues, museums, a convention center, and hotels. Special regional events on the bay include America's Cup races, Festival of Sail, Veteran's Day Parades, 4th of July and New Year's fireworks, Big Balloon Parade, symphony concerts, summer pops, and Navy Fleet Week. The Navy's Morale, Welfare and Recreation operates recreational facilities at Breakers Beach, Gator Beach, Smuggler's Cove on Point Loma, and Fiddler's Cove marina and recreational vehicle park. Navy Yacht Club San Diego is also supported by Morale, Welfare and Recreation. Navy events include: February - Annual Polar Bear Swim (Morale, Welfare and Recreation and Sea World) at Smuggler's Cove, May - Bay Bridge Run/Walk, September through October - Fleet Week with ship tours and fireworks.



Map 3-6. San Diego Bay marinas, docks, and public recreational areas.

Environmental Education Venues

Hundreds of thousands of visitors come to San Diego County as a whole each year to watch wildlife, primarily birds (USFWS 1998). The Chula Vista Nature Center had about 150,000 visitors in 2006. The San Diego Audubon Society sponsored the 14th San Diego Bird Festival at Marina Village in 2010. Twice-monthly bird walks take place at the NWR, and Audubon Society sponsors both a Bird Festival and a clean-up in winter prior to the seabird nesting season.

Opportunities for wildlife observation and photography on the Sweetwater Marsh Unit of the NWR are currently provided from Gunpowder Point and an elevated platform at the Chula Vista Nature Center. These areas provide views of the surrounding salt marsh. A bird blind provides observation opportunities of the various shorebirds and waterbirds on the mudflats bordering the southern edge of Gunpowder Point. Wildlife activity within Paradise Marsh and the F&G Street Marsh can be observed from the public right-of-way that abuts these areas (USFWS 2006).

Interpretive signage and public art contributed in various public locations around the bay are provided or sponsored by the Port, the NWR, and somewhat by the Navy (at Seaport Village, Silver Strand). The Port's Public Art program was the first "percent for art" program in San Diego County, created in 1996. Through this program, slightly less than one percent of the Port's operating budget is dedicated annually to the Public Art Fund. This 1.2 million dollar annual contribution is managed by the Port's Public Art Department to cover public art acquisitions and exhibitions for the Port's tidelands as well as personnel, operations and collections management (SDUPD 2010c). Photo 3-7 is an example of such art contribution in San Diego.

Photo 3-7. An example of a collaborative educational art gate funded by the Port Environmental Fund, Public Art Fund, Navy Natural Resources, and Port tenant Chesapeake Bay Fish Company.

3.3.8 Habitat Conservation and Mitigation

The Navy, Port, USFWS-Refuges, and National Park Service all contribute to designated habitat conservation areas in or near San Diego Bay. Examples are:

Habitat Replacement Zoning in Port Master Plan

In 2001, the Port approved an amendment to the Port Master Plan that redesignated the area located to the southwest of the F&G Street Marsh, a total of 15.4 acres, from Marine Related Industry to 10.9 acres of Commercial Recreation and 4.5 acres to Habitat Replacement Conservation. A Habitat Replacement Conservation designation is adjacent to the F&G Street Marsh to the southwest and provides a buffer between the Refuge land and the Commercial Recreation area further to the southwest (SDUPD 2001). As a condition of this Port Master Plan Amendment, the Port was required to enter into a cooperative agreement with an appropriate agency or organization, which would be designated to protect and/or enhance, where appropriate, the 210 acres of mudflats along the western edge of the Refuge (SDUPD 2001). A subsequent amendment to the Master Plan, approved by the Port and the City of Chula Vista in May 2010, increases the amount of land for conservation purposes throughout the south bay. As a result, the total area zoned for habitat replacement is 104 acres (SDUPD 2010a). The Port plans to request amendment approval from the CCC in 2011.

The Port Master Plan has two other categories that function as habitat conservation areas: there is an estuary designation that totals 1156 acres, and 498 acres are zoned as wetlands. All three conservation designations (habitat replacement, estuary and wetlands) occur in the southern portion of the bay: Chula Vista Bayfront, Silver Strand South, and South Bay Salt Lands (Planning Districts 7, 8, and 9, respectively). (SDUPD 2010a).

South San Diego Bay Restoration

Restoration of almost 300 acres of tidal flats, salt marsh, subtidal and native upland habitat will be restored in and around south San Diego Bay beginning September 2010. These areas include the western most salt ponds located adjacent to State Route 75, the CVWR, and the western edge of Emory Cove. Once construction is complete, the levees will be breached in order to re-introduce natural tidal flows and the ensuing natural recruitment of native species (USFWS 2010.)

Point Loma Ecological Conservation Area

A unique regional effort produced a joint Point Loma INRMP for the Point Loma Naval Complex, the Cabrillo National Monument, Fort Rosecrans National Cemetery, and the USCG, and Point Loma in 1994.

The U.S. Navy, Cabrillo National Monument, USCG, the City of San Diego, and the U.S. Department of Veterans Affairs collaborated and established the Point Loma Ecological Conservation Area, which covers 662 acres, in order to enable management of the natural resources on the entire peninsula.

Chula Vista Wildlife Reserve

The CVWR is an 80-acre habitat mitigation site that was built from dredged material obtained during the development of the Chula Vista Harbor in the 1980s. The Port retains management authority for this area and the Port Master Plan designates the site as a Habitat Replacement area. Public access to this area is prohibited.

D Street Fill

Six acres of the D Street Fill area south of the Sweetwater Flood Control Channel, is designated as Estuary in the Port Master Plan, which mitigates the loss of intertidal and shallow subtidal habitat resulting from the National City Marine Terminal Wharf Extension project.

The BPC designate in their Port Master Plan the southwestern half of the D Street Fill area for conservation in order to protect the California least tern. Changes of use must be approved by the Coastal Commission or its succeeding agency.

The entire D Street Fill area is also designated as critical habitat for the western snowy plover by the USFWS. Any changes to the land use must therefore also address this status.

Navy Eelgrass Mitigation Sites

An EIS on homeporting a nuclear carrier at North Island resulted in the construction of berthing for the CVN-I nuclear carrier in 1995 and resulted in the loss of 6.7 acres of eelgrass at the wharf site. An eight-acre eelgrass mitigation site was established to replace it. An upland area of 14 acres was excavated at Pier Bravo to compensate for a total loss of 13.4 acres of intertidal and subtidal habitat.

As a result of impacts related to repeated construction of an elevated causeway as a military training exercise, CWA §404 eelgrass impacts were mitigated at one of the Navy's established Navy Eelgrass Mitigation Sites (NEMS). In response to ongoing needs for eelgrass mitigation related to multiple other projects, the Navy had established several NEMS throughout San Diego Bay to compensate for current and to bank future losses to eelgrass habitat. Eelgrass that has been planted and not used to compensate for previous losses is banked for future use in accordance with the Southern California Eelgrass Mitigation Policy. Five eelgrass mitigation sites contributing to the bank have already been constructed and met the five-year performance standards required by NMFS. Formalization of this mitigation banking agreement between the U.S. Navy and NMFS is still pending in an Eelgrass Mitigation Bank Management Plan. This plan establishes a system of management, administration, and accounting for the CNRSW for future project-related impacts in order to facilitate military construction and maintenance project implementation in advance. It also covers impacts that may occur as a result of military operations and training exercises. The principal goal of the mitigation bank is to establish functional eelgrass habitat qualifying as special aquatic sites, as defined at 40 CFR 230.40-45, within San Diego Bay for mitigating impacts associated with projects and operational training exercises, and to establish credits from surplus habitats for future use. Other agencies, upon request to and receipt of approval from CNRSW, may utilize the Bank on a cost basis. The Bank is managed by a Mitigation Bank Technical Team, a multi-agency team providing technical expertise in and support for the implementation of this INRMP. The team includes the CNRSW as Chair, USACE, USFWS, NMFS, and CDFG. Other habitat types considered for banking purposes may be addressed through amendment of the banking agreement. However, for the mitigation of mudflats, only intertidal eelgrass credits may apply.

Homeport Island

With a shortage of Navy real estate to compensate for additional in-water impacts associated with a homeporting berth for a second nuclear carrier, the Navy opted to establish an island offshore of NAB Coronado (Photo 3-8). To comply with the 2000 Record of Decision for CVN II and USACE Permit No. 982004900-KMM, the Navy created 27 acres of intertidal/ subtidal habitat off the south shore of NAB Coronado using dredge material; established fish habitat enhancement structures within the site; created a four acre eelgrass mitigation bank south of NAB Coronado; added 1.5 acres of intertidal habitat by excavating existing uplands on the west shore of NASNI (near Pier Bravo). The CVN II project had required the dredging of over 500,000 cubic yards of material from an area of approximately 18 acres, as well as a 1.5 acre fill area to reconfigure the existing shoreline to accommodate the new berthing facility.

Homeport Island. Photo courtesy of Eileen Maher.

Photo 3-8. Homeport Island, offshore of NAB, as viewed on EarthGoogle.

Navy Seasonal Set-Aside Area for the California Least Tern

The construction of a helicopter maintenance and training facility, including a Light Airborne Multipurpose System, resulted in the loss of a nesting area and displacement of 13 tern nests. A total of 63.45 acres were affected by the project, including 36 acres to resurfacing the asphalt. As a result of Section 7 consultation, a 21.55-acre area of the existing nesting area called the MAT site was preserved, indefinitely, for nesting terns at NASNI. An additional 29.2 acres were prepared on an annual basis as alternate nest sites, including predator and vegetation control, in the event the MAT site was not successful. In addition to the sites at NASNI, the 1983 Biological Opinion (BO) set aside 75 acres at Delta Beach (North and South) to be fenced and managed as a California least tern nesting area offsite along the bayside beaches between NASNI and NAB Coronado. The designation of the Delta beaches as a “least tern preserve” was formalized in a 1984 MOU between the U.S. Navy and USFWS, that was drawn up to further implement 1983 BO 1-F-82-F-123. The MOU did not intend to inhibit the use of Delta beaches for military maneuvers, but it attempted to restrict these maneuvers to the north and east perimeters. Up until the time of this BO and MOU, Delta Beach North had been used both for Navy training and as a public boat launching facility. Public access was closed as a result of the fencing and a Coastal Consistency Determination was required to address this loss. The Coastal Consistency Determination that followed required the Navy to grade a road to Alpha Beach to facilitate public access there. In addition, a lease from the Navy to the State of California of 40 acres of NAB Coronado was promulgated to develop for park and recreation purposes.

3.3.9 Other Uses

Cargo and Cruise Ships

Two marine terminals, the Tenth Avenue Marine Terminal and the National City Marine Terminal, handle cargo from all around the world including refrigerated commodities, fertilizer, cement, breakbulk commodities, forest products, lumber, and automobiles. Industrial activity includes power generation, ship construction and repair, aerospace and airport industries. The B Street Cruise Ship Terminal located in downtown San Diego serves over 280 cruise ships per year.

Commercial Energy Production

The South Bay Power Plant, located to the northeast of the salt ponds, is a gas- and oil-fueled generating plant with four major steam cycle units. Bay water is used for the plant's circulating cooling water system. The plant takes in water from the bay through a channel constructed to the north of the CVWR and discharges the heated water just to the north of the salt works. The plant is slated for decommissioning at an unknown time.

The Port Master Plan (SDUPD 2010), describes the uses permitted within the tidelands under their jurisdiction. The marshlands located to the south of J Street are preserved as wetlands.

Salt Works

The South Bay Salt Works occupies approximately 1,068 acres at the south end of San Diego Bay. It is an active solar salt evaporation facility that is operated in accordance with a Special Use Permit issued by the USFWS to the Airport Authority. The current operation produces between 60,000 and 80,000 tons of salt per year. In addition to salt production, the Special Use Permit also allows brine shrimp to be harvested from Pond 23; however, no brine shrimp harvesting has occurred in the past several years.

Although the majority of the salt works, particularly the salt ponds, are located within the Refuge, some elements of the salt operation are located on lands that were excluded from the approved Refuge acquisition boundary. The excluded areas, which are owned by the Airport Authority, include Pond 40, a portion of Pond 42, and the land on which the salt processing plant and salt storage area are located. The Airport Authority also owns the processing equipment for the salt operation including the salt processing plant, conveyor, salt grinder, and other associated facilities. Western Salt Company currently has a month-to-month lease with the Airport Authority to continue to operate the salt works. The current operation also extends onto privately held lands, which are leased to the South Bay Salt Works by the private property owner. A Salt Works Site Assessment and Draft Vision plan discusses four alternatives for the long-term potential for public use of the site, two which propose closing the operation (Schmidt Design 2010). Further action on these alternatives is still pending. In addition, an application to designate various salt works buildings as sites of historical importance is also pending.

Special Study Areas

The South Bay Biological Study Area is owned by the U.S. Navy and managed by the City of San Diego as a wildlife preserve and nature interpretive area. A parking lot, a segment of the Bayshore Bikeway, and coastal salt marsh habitat are included within the Biological Study Area. In 2003, the County of San Diego completed repairs to the parking lot and bikeway and installed new interpretive elements, an overlook, and benches along the edge of the marsh.

Another area included within the NWR acquisition boundary, but not managed by the USFWS, is a 48-acre area of vacant land located at the southern end of the Otay River floodplain. This property is owned by the City of San Diego and is subject to the land use goals presented in the Otay Mesa Nestor Community Plan (CSD 1997). This city parcel, as well as those salt ponds located to the east of the Otay River (with the exception of Ponds 15, 28 and 29 and the northern portion of 14), were incorporated into the Otay Mesa Nestor Community Plan area. These salt ponds are designated in the plan as open space, while the area to the south, including the Otay River floodplain and the City owned parcels to the south of the Refuge, are designated as a Special Study Area. The Special Study Area overlay designation requires that all development proposals that are not consistent with the existing zoning on the property must include a Special Study that addresses biological resources, habitat value, and hydrology within the Special Study Area. This information would then be used as a basis for determining appropriate land uses.

Although the Otay Mesa Nestor Community Plan also serves as the LCP for this area, the State Coastal Commission has designated the salt ponds and Otay River floodplain as a deferred certification area. As a result, a Coastal Development Permit must be obtained directly from the CCC before any development can occur on the property.

YMCA Camp Surf

YMCA Camp Surf operates on the southwestern 45 acres of the SSTC-South on land leased from the U.S. Navy in a long-term agreement that expires in 2048. The YMCA teaches aquatic skills, arts and crafts, archery, other sports, and outdoor education to about 10,000 youth per year for over 30 years. Polynesian-style cabins and bath houses support overnight stays of about 400 campers at one time. The YMCA remains responsible for the planning and management of the site (Navy 2002).

State Park (California Department of Parks and Recreation)

Silver Strand State Beach features extensive beaches on both the Pacific Ocean and San Diego Bay. The park has 2 ½ miles of ocean beach and ½ mile on the bay. The entrance to the park is from Highway 75, which serves as a divider between the ocean side of the park and the bay (CDPR 2005). About 40 acres, located south of the enlisted housing and Navy training beaches, are leased to the CDPR from the Navy with a lease expiration date of 2022 (Navy 2002).

Silver Strand uses include camping, swimming, surfing, boating, water-skiing, volleyball, and picnicking. Anglers can fish for perch, corbina, grunion and yellow-fin croaker. Park facilities include four large parking lots, which can accommodate up to 1,000 vehicles. Restroom and cold showers are available on each side of the park. Beach restrooms are for Day-Use visitors. Per CCC regulations, vehicles that are not fully self-contained are turned away. Fire rings for cookouts are also available. There are approximately 130 campsites. Strolling along the beach, visitors can see moon-snails, conch shells, and an occasional sand dollar (CDPR 2005).

3.4 Future Plans for the Bay

3.4.1 Navy Future Plans

The Navy requires certain in-water construction or maintenance work to support its water dependent uses. Construction and maintenance projects proposed for the future include dredging, upgrading, repairing, and replacing piers. A summary of planned capital improvements for Naval facilities is presented in Table 3-6. These future plans are contingent upon environmental review, with avoidance and minimization of environmental impacts as part of this review process.

A minimum 37-feet (11-m) deep channel from the Coronado bridge to at least Pier 14 is essential for Naval Station operations. Piers 13 and 14 are relatively shallow, and tugs frequently stir up sediment plumes when berthing ships. The Naval Station recently developed an Environmental Assessment (EA) on use of new deep-draft, power-intensive vessels to the bay. The last major capital improvement project at Naval Station (“P326”) was to replace the Piers 10 and 11 with a new Pier 10. Also at Naval Station, Paleta Creek is planned for reconfiguration at its mouth for flood control purposes.

Similarly at NASNI, pier pilings replacement is planned on Piers B, and L/M/N/O/P (Carrier Quay wall) as necessary. NASNI uses untreated wood pilings, which require replacement every year or two. Plastic pilings on Pier B were installed. The new Stennis carrier is berthed just inside that pier.

All piling replacements are now done with plastic pilings. These and arsenic-zinc treated pier pilings are three times the cost of wood pilings, but last longer. Arsenic-zinc treated and other wood pilings need to be disposed of as hazardous waste, and wear out sooner.

Table 3-6. Future Navy plans for waterfront and Military Construction projects.

Base	Project# and Name	Fiscal Year
Waterfront		
NBSD	RM30-03/Repair Small Craft Docks-Chollas Creek	2006
NBSD	RM19-04/PR 8 Concrete Repairs	2006
NBSD	RM44-03 Concrete Repairs to Pier 6	2006
NBPL	ST6-04 Deck Repairs Pier 5000	2007
NBC	RM11-05 Repair Quaywall	2007
NBC	RM200-07 Concrete Pier Repairs, Piers 9, 10, 1012, 14 & 17 NAB	2008
Military Construction		
NBPL	P118 Pier 5002 Sub Fender Installation	2008
NBPL	P135 Magnetic Silencing Facility Modification	2008
NBPL	P793V Upgrade Magnetic Silencing Facility	2008
NBC	P704 Berth Lima Conversion	2009
NBSD	P327 Berthing Pier 12 Replacement and Dredging	2009
NBSD	P454 Upgrade Piers 12 & 13 to 4160 Volt	2010
NBSD	P440 Pier 8 Replacement	2011
NBSD	P443 Pier 6 Replacement	2012

3.4.2 Port Future Plans

The Port has many plans for the future of the bay. Projects include the development of Lane Field/B Street Cruise Terminal, renovation of the Old Police Headquarters, and construction the Shelter Island Marine Sales and Services Site. In addition, continuation of small projects. These include paving, drainages, site grading, environmental remediation, parking structures, roadway infrastructure, building demolitions, and area lighting. Major projects moving forward include the Chula Vista Bayfront Master plan, recently approved by the Port and the City of Chula Vista, including an amendment to the Port's Master Plan. The Chula Vista Bayfront Master plan increases access to the waterfront and enhanced public amenities. The Port plans to request CCC approval of the amendment in 2011 (SDUPD 2010d).

The Port published a compass strategic plan in 2006 defining goals and objectives for fiscal years 2007-2011.

In October 1998, the South Embarcadero subarea plan was completed and received approval by the Port's Board and the CCC. This plan was amended in February 2006 to further enhance public access to the embarcadero (SDUPD 2010e) The North Embarcadero Visionary Plan was certified by the BPC on April 25, 2000. At a meeting held October 11, 2005, the BPC and the Centre City Development Corporation's Board of Directors adopted a resolution to approve the recommended first phase of the project (SDUPD 2007). However, the CCC rejected the project's first phase in April 2010. The project proposed to redevelop 1.5 miles of waterfront along North Harbor Drive by adding public esplanades, landscaping, public art and gathering spaces. The project is currently being revised, with input from the public, in order to submit it again to the CCC for their approval (SDUPD 2010f).

The ACH Redevelopment Plan to enhance Shelter Island was certified on June 12, 2003 by the CCC.

A five-year (2009–2013) tidelands capital development plan by the Port includes seven new proposed projects that are deemed high priority and pertinent to this INRMP's footprint (Table 3-7).

Table 3-7. Proposed Capital Development Program projects for Port's tidelands, 2009-2013, pertinent to this INRMP.

Project Name	Description and Planned Years
Funding for Environmental Impact Report for wetlands mitigation in Chula Vista	Restoration of wetlands in Chula Vista will require an Environmental Impact Report. The area currently contains contaminated material left over from a previous business.
Cold ironing capability for 10th Avenue Marine Terminal, Cruise Ship Terminal and Broadway Pier	The California Air Resources Board will require that shore power (a.k.a. cold ironing) be available at these terminals by 2014. The goal is to allow ships at berth to be powered by electricity rather than diesel fuel, and thus improve air quality. The project will be a part of the Port's Clear Air Program. 1.5 million dollars has been allocated for the development of this capability.
Preliminary design for cruise ship terminal at B Street Pier	The goal is to improve cruise facilities at this pier in order to retain and attract cruise industry to San Diego. Each cruise ship visit brings about $2 million in economic impact to the regional economy.
Additional funding for South Campus Demolition Project (Chula Vista)	This project is an ongoing Capital Development Project on Port tidelands in Chula Vista. The goal is to remove remaining building foundations, slabs and underground utilities from 63 demolished industrial buildings. The project is a precursor for the Chula Vista Bayfront Master Plan.
Conference Center Site Demolition (Chula Vista)	The project will demolish three industrial buildings and the Chula Vista RV Park at Marina Parkway on Port tidelands in Chula Vista as well as remove pavement and utilities from surrounding streets. The project is a precursor for a proposed conference center and hotel on the Chula Vista waterfront.
Marine Terminal Enhancements	The project will make improvements to the 10th Avenue and National City Marine Terminals to meet the needs of growing cargo operations. It involves engineering, planning and preliminary design, demolition work, paving and improvement of storage areas.
Industrial Transition Zone	Money set aside for the project would be used to purchase land adjacent to the two marine terminals in order to create a transition zone around maritime-related businesses and industries along the waterfront in San Diego. The goal is to ensure compatible land uses around these businesses. The Port is currently working with the cities of San Diego and National City, who have jurisdiction over much of the transition zone, to consider the transition zone when updating municipal General Plans.

3.4.3 City Future Plans

Projects proposed by the five cities, which border the bay, are as follows:

City of San Diego: In conjunction with the Port, a Hilton Convention Center Hotel is scheduled to open in the fall of 2008. The proposed hotel is intended to satisfy the demand for hotel rooms to serve the San Diego Convention Center and hospitality needs of downtown San Diego. The project will transform the former Campbell Shipyard site into the hotel including meeting space, retail space, a health club, private rooms, a restaurant, a public park, and a water taxi dock to serve hotel guests as well (SDUPD 2007). Redevelopment of the Old Police Headquarters and Park is also planned to enhance the downtown Historic Harborfront Site in the South Embarcadero area of downtown San Diego. It will include entertainment venues, specialty retail, restaurants, museum space and other ancillary support uses (SDUPD 2006).

Chula Vista: The Chula Vista Bayfront Master Plan is a large waterfront planning effort with objectives to create an active commercial harbor with public space, redevelop underutilized and vacant areas in the city and on Port tidelands with uses, extend streets to the bay to ensure pedestrian, vehicle and bicycle links, provide a continuous shoreline walkway to connect Sweetwater, Harbor, and Otay districts and establish ecological buffers to protect adjacent environmentally sensitive resources. Also proposed are more than 200 acres of parks and other open space areas, marina improvements toward an active commercial harbor with retail restaurants and public space at the waters edge (SDUPD 2007). It was by the Port and the City of Chula Vista in May 2010, including an amendment to the Port's Master Plan. The Port plans to request CCC approval of the amendment in 2011 (SDUPD 2010d).

National City: National City is planning an aquatic center, which will become a tourist attraction to be run by the YMCA. The aquatic center adds recreational and educational opportunities to National City public amenities, such as water events, classroom facilities and other recreational uses. Improving public access for recreation has been of interest to National City.

Imperial Beach: The City of Imperial Beach plans to renovate and enhance public coastal accessways and view corridors for the western termini of Palm and Carnation Avenues, where these streets end and intersect with the beach. This will promote and enhance public safety, recreational opportunities, and accessibility to the public with an overall park-like setting at the end of each street (SDUPD 2007).

Coronado: Along Glorietta Bay, the City of Coronado is developing a new Civic Center and Promenade including a Community Center and City Hall, with a tree-lined promenade between the Coronado Yacht Club and NAB (City of Coronado 2007).

3.5 Economics of Use

The San Diego Bay serves as a vital economic resource for the San Diego region. Businesses are quite diverse representing military maritime activity, the cruise sector, aerospace and airport industries, manufacturing, tourism, service industries such as hotels, retail shops, and restaurants, and many other industries.

3.5.1 Navy Economic Contribution

As noted in Chapter 1, the DOD's annual financial benefit to San Diego is large and provides a stabilizing influence to the economy. The total impact of defense spending is estimated at $28.4 billion in 2010 (San Diego Military Advisory Council 2010; KPBS 2010). Based on data from the DOD as well as local military contractors, the military's contribution to the economy has been growing at a rate of roughly 8 percent a year at a time when a number of key civilian industries have been falling into stagnancy or decline. The bay is home port to over 75 ships that require servicing, supplying, and maintaining. The study estimates that the Pentagon will spend $17.3 billion in San Diego County this year on such things as military salaries, equipment repairs, construction and procurement. That makes San Diego the top recipient of military expenditures of any county in the country. According to the study, the military accounts for nearly 23 percent of the local work force, including more than 341,000 jobs (San Diego Military Advisory Council 2010; KPBS 2010).

The defense industry in and around San Diego Bay declined dramatically during the Navy downsizing of the late 1980s and early 1990s, affecting the area's economy. Between 1980 and 1990, the Navy sector showed a 10% decrease in employment in the region. In 2004, 5.1 billion in DOD contracts were awarded to San Diego County companies (Freedman and Ransdell 2005). Considering the current increase in construction at both Camp Pendleton, Naval Station San Diego, and the Navy's downtown Broadway complex, as well as the uptempo war setting, fiscal spending will persist.

3.5.2 Port of San Diego Economic Contribution

The Port's bayfront locations for real estate development and maritime trade generated $8.4 billion in 2005-2006 in total economic impact, up from $7.4 billion in 1996-1997 (SDUPD 1997, 2007). Tenants of the Port represent 600 businesses that employ more than 30,000 workers, or one in every 17 jobs in the region (SDUPD 2007).

Real estate income from the tenants produces funds for capital improvements, such as the Convention Center expansion in 1980. Marinas pay about 20% of their annual revenues to the Port, with other tenants paying either a flat fee or a combination of flat fees and sales revenues. As much as $20 million in annual revenues is generated by the cruise industry using the Port's terminal as a port-of-call.

For the calendar year ending December 2009, the Port announced near record cargo revenues. Maritime cargo revenues totaled $43.7 million for the 12-month period (SDUPD 2010a), just 5% below the highest recorded revenue reported over the same period in 2008. Shipments of steel windmill parts, lumber, auto imports and produce helped spur the increase. Total cargo tonnage for fiscal year 2008-9 was 32.8 million metric tons. Besides benefiting the Port to redirect revenues for betterment of the bay, the maritime business increase translates into significant high paying jobs, taxes, and economic benefits for the region (SDUPD 2007).

Overall, the port's maritime business generates about $600 million annually in economic impact to the San Diego region (SDUPD 2010a). The Port has been responsible for $1.5 billion in public improvements in its five member cities – Chula Vista, Coronado, Imperial Beach, National City and San Diego. With a $10.6 billion economic impact on the San Diego region, the Port oversees two maritime cargo terminals, a cruise ship terminal, 16 public parks, various wildlife reserves and environmental initiatives, a Harbor Police department and the leases of over 600 tenant businesses around San Diego Bay. The Port has operated without tax dollars since 1970.

3.5.3 Fisheries Economics

San Diego Bay is an active commercial harbor with two commercial wharves operated by the Port and numerous commercial fishing wharves as well (SDUPD 2007).

In 2009, CDFG reported an estimated 638,000 pounds of fish worth approximately $2.1 million were landed in the Port. The monetary benefit of fisheries to the greater San Diego Bay area far exceeds revenue from landings and commercial fishing charters considering the expenditures by operators, residents, and tourists on items such as fuel, food, lodging, mooring, and fishing tackle.

Commercial landings of ocean-caught fish and invertebrates in the San Diego region had a dockside value of $6 million in 2009, with $2.1 million landed in the bay (CDFG 2010). The overall economic value from fishing related industry is conservatively estimated to be $390 million for the San Diego region. Economic estimates were calculated using 10% of the California totals from recreational and commercial fishing (Woods Hole Oceanographic Institution 2003). Historical revenue generated from local canneries have since closed down and moved elsewhere due to increased competition from abroad, movement of the fleet to the western Pacific, and changes in oceanographic conditions (Leet *et al.* 1992; McWilliams and Goldman 1994). The increase in commercial passenger vessels servicing fishermen targeting offshore fish species has successfully captured revenue previously lost due to the decline of local commercial fishing industry.

Revenue from fishing-related industry associated with the bay is a vital component to bayfront business.

The value of sport fishing to the bay includes (1) the use of passenger vessels (e.g. charter and party boats) harbored but that provide fishing outside the bay; (2) the use of personal and rental boats for fishing within the bay; and (3) the use of shoreline facilities and sites for sport fishing and shellfish harvesting. The economic impact of recreational fishing is much greater than that of commercial industries because of what anglers spend on goods and services related to their fishing trips (McWilliams and Goldman 1994). These expenses include transportation to and from a fishing location; fishing equipment and clothing; food and lodging; and purchasing or renting boats, trailers, and campers. A 1985 study estimates that marine sportfishing contributes anywhere from $250 to $450 million annually to the San Diego community alone, with the state-wide contribution exceeding $2 billion annually (United Anglers of Southern California 2007).

3.5.4 Recreation and Tourism Economic Contribution

The bay's recreational values include both measurable and nonmeasurable benefits. The boating and yachting industry in the bay offers a tangible economic benefit, though not quantified in any local study. 7,048 boat slips are available in the bay, with an average 90% occupancy. In addition to marinas and yacht clubs, secondary businesses include boat sales, boat repair, fuel suppliers, food providers, and others. Economic multipliers expand the dollar value through boaters' use of restaurants, retail stores, and transportation to and from their boats. Other types of bay boating activities include jet skiing, kayaking, canoeing, and windsurfing.

Using public parks and beaches does not require the personal investment that boating does. Intangible benefits are provided by these sites to help improve the quality of life for residents and visitors alike. Valuing the benefits of wildlife and nongame fish to the recreational use of the bay is also not easily done in dollars. However, the Imperial Beach Bird Fest in 2007reportedly attracted about 300 observers. In 1998, an estimated 700 people spent an estimated $178,000 in the area (USFWS 1999). San Diego Bay bird festivals take place yearly now, usually in February, and offer numerous ways for the general public to learn about and enjoy natural resources while in the area.

One method that the cities use is the Uniform Tourist Tax (formerly Transient Occupancy Tax) collection, which is the tax amount collected from hotel operators as a percentage (8–10.5% currently) of their rental receipts. Table 3-8 represents five years of tourist tax collections from the bay region's five cities. As an indicator of hotel/motel use by tourists, the figures indicate a steady increase in use (assuming stable tax rate) for San Diego, Coronado and Chula Vista. Fluctuating usage characterizes National City, and Imperial Beach. The decrease in use for all five cities in 2009 is most likely a result of the recent economic downturn. San Diego provides, by far, the greatest number of occupied hotel rooms.

Table 3-8. Uniform tourist tax collections, Fiscal Years 2002–2006, for cities in the San Diego Bay region.[a]

Year	Chula Vista	Coronado	Imperial Beach	National City	San Diego
2005	2.203,085.00	8,231,498.00	279,826.00	891,386.00	121,023,478.00
2006	2.340,455.00	8,624,351.00	240,000.00	829,869.00	135,891,366.00
2007	2,492,190.00	8,910,953.00	292,411.00	837,944.00	150,417,640
2008	2,652,859.00	10,174,267.00	149,848.00	748,173.00	160,242,590
2009	2,318,198.00	8,460,505.00	175,791.00	576,349.00	136,320,441

a. Source: Research Department, SDCVB 2010.

For San Diego County, the impact of travel and tourism is dramatic. In 2003, 26.4 million visitors poured $5.3 billion into the local economy, making the visitor industry San Diego's third largest following manufacturing and the military (SDCVB 2010). With the expansion of San Diego's Convention Center, the addition of Petco Park, and a proposed central city library, tourism growth should continue.

3.6 Overview of Government Regulation of Bay Activities

3.6.1 Introduction

Bay activities are regulated by numerous environmental laws and agencies at various levels of government. The purpose of this section is to give an overview of the regulations that can pertain to all types of projects located within and adjacent to San Diego Bay.

For projects within the bay (in-water), Figure 3-2 depicts the key jurisdictions and the underlying laws pertaining to each since the location of projects can trigger different regulations. Location based on tide level, such as mean high water, is important in identifying which agencies become involved in project review. The tidal elevations are specific to the Broadway Pier in the bay and are interpretations of regulatory guidance. Tables 3-9 through 3-11 summarize the laws and responsibilities for each of the federal, state, and local agencies active in the bay.

For key jurisdictions of "in-water" bay projects and pertinent laws, see Figure 3-2.

3.6.2 Federal Agencies and Laws

Federal laws and regulations pertinent to the bay primarily target the protection of clean water, wetlands, endangered species, wildlife, and the coastal zone. The Navy sends annual progress reports to the EPA and the Office of the Federal Environmental Executive, describing Navy efforts to comply with EOs.

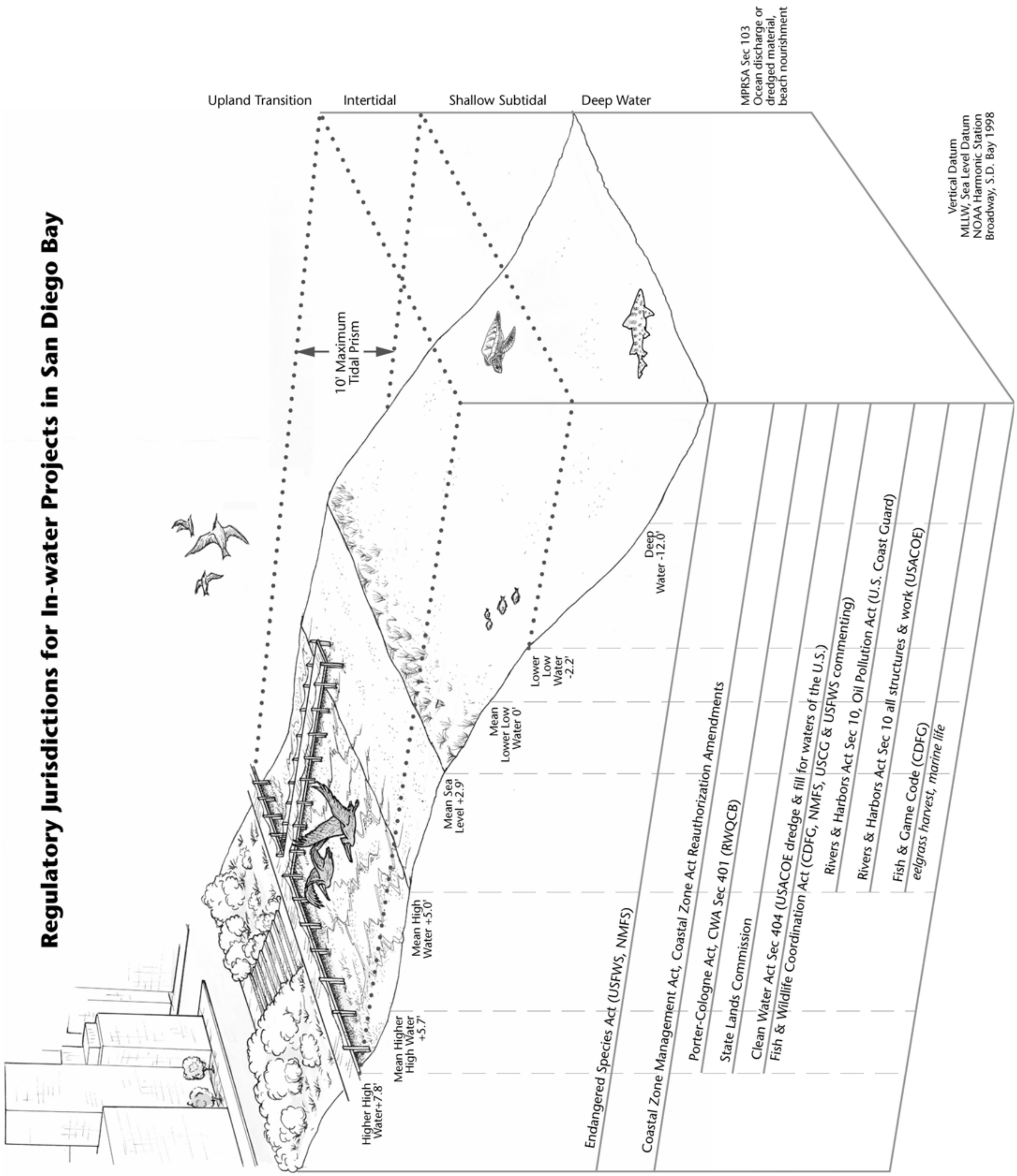


Figure 3-2. Regulatory Jurisdictions for In-water Projects in San Diego Bay (For Tidal Definitions, See Figure 2-3).

Table 3-9. Federal agencies with responsibilities for natural resources in San Diego Bay. [a]

Federal Agencies and Applicable Laws	Authority and Activities
U.S. Army Corps of Engineers	
■ CWA, §404 ■ Rivers and Harbors Act of 1899, Sect. 10 ■ Marine Protection, Research, and Sanctuaries Act of 1972, Sec. 103 ■ NEPA	■ Responsible for issuing §404 permits for dredged or fill material into waters of the U.S. (up to higher high water line in tidal waters) and into wetlands in compliance with EPA regulations. ■ Regulates construction, excavation, and deposition in navigable waters (up to mean high water in tidal waters). ■ Regulates dumping and transport for dumping of material into U.S. waters. ■ Commenting or lead agency authority for environmental review of proposed projects.
U.S. Environmental Protection Agency	
■ CWA, as amended ■ NEPA ■ Marine Protection, Research, and Sanctuaries Act of 1972	■ Develops §404 regulations and may veto USACE §404 permit. ■ Regulates waste disposal in coastal waters. ■ Administers (with NOAA) the Coastal Nonpoint Pollution Control Program. ■ Administers National Estuary Program. ■ Commenting authority on proposed projects. ■ Regulates waste disposal in coastal waters.
U.S. Fish and Wildlife Service	
■ Fish and Wildlife Coordination Act ■ Federal ESA ■ MBTA ■ National Wildlife Refuge System Administration Act ■ NEPA	■ Reviews and comments on federal actions that affect many habitat-related issues, including wetlands and waters considered under CWA §404 and Rivers and Harbors Act §10 permit applications. ■ Regulates, monitors, and implements programs for protecting the ecosystems upon which freshwater and estuarine fishes, wildlife, and habitat of listed species depend. Enforces international treaties and conventions related to species facing extinction. ■ Enforces prohibition against the taking of migratory birds, their eggs, or their nests. ■ Designates lands for the conservation of fish and wildlife as part of the National Wildlife Refuge System. ■ Commenting authority on proposed projects.
National Marine Fisheries Service	
■ Fish and Wildlife Coordination Act ■ Federal ESA ■ MSA ■ MMPA ■ NEPA	■ Reviews and comments on federal actions that affect marine fishery resources and many habitat-related issues, including CWA §404 and Rivers and Harbors Act §10 permit applications. ■ Jurisdiction over most threatened or endangered marine species, including the green sea turtle (outside of beach nesting sites). ■ Responsible for maintaining and conserving fisheries and rebuilding overfished stocks. Responsible for determining whether projects or activities adversely impact EFH zones (those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity). ■ Enforces protection provisions for marine mammals. ■ Commenting authority on proposed projects.
U.S. Coast Guard	
■ Ports and Waterways Safety Act ■ OPA of 1990 ■ Fish and Wildlife Coordination Act ■ Rivers and Harbors Act of 1899, §10 ■ CWA/Marine Protection, Research, and Sanctuaries Act	■ Manages maritime transportation and bridges over navigable waters. Permitting for marine events (e.g. America's Cup). Responsible for maritime safety/law enforcement, and environmental protection. Establishes safety standards and conducts inspections. ■ Ensures cleanup of marine oil spills and other pollutants. Responsible for oil spill responses based on Area Contingency Plan. Prepares most regulations needed for implementation of OPA. ■ Commenting authority on navigational issues, such as structures affecting navigation, USACE §404 dredge and fill permits, and new pilings. ■ Issues permits for bridges over navigable waters (up to mean high water line). ■ Enforces standards of oil and other hazardous waste discharge in marine waters.

a. Sources: Cylinder et al. 1995; California Resources Agency 1997.

Water Quality Regulation

Section 404 of the CWA regulates the discharge of dredged or fill material into designated "Waters of the United States."

The purpose of the CWA (33 USC §1251 et seq.) is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. To accomplish these goals, each state is required to establish WQS for its surface waters based on designated uses. Under CWA §303(d), each state is to submit to EPA a list of surface waters that are not meeting their WQS. For these "impaired" water bodies, each state is supposed to develop TMDLs, which are the amount of pollutants that can be assimilated by a body of water without exceeding the WQS. Based on the developed TMDLs, the states or EPA would limit any discharge of pollutants to a level sufficient to ensure compliance with state WQS. Direct discharges of pollutants to the waters of the United States are regulated by NPDES permits issued by EPA or under state NPDES programs approved by EPA. This includes discharges of storm water from municipal separate storm sewer systems, industrial areas, and construction sites. Non-point sources of pollution are to be managed through state or local controls. Indirect industrial discharges of effluent to publicly owned treatment works are subject to pretreatment standards promulgated by the EPA, state or local regulatory agencies.

The CWA prohibits spills, leaks or other discharges of pollutants into waters of the U.S. in quantities that may be harmful, which includes discharges of pollutants that:

- Violate applicable WQS; or

- Cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

The Oil Pollution Act (OPA) of 1990 amended the CWA to expand oil spill prevention activities, improve preparedness and response capabilities, and ensure that companies are responsible for damages from spills.

USACE

The federal CWA also requires a permit for the discharge of dredged or fill materials into "Navigable Waters of the United States," which includes "wetlands." Section 404 of the Act most commonly affects bay projects. The USACE is responsible for developing regulations for the §404 permit process and issuing permits, with the EPA maintaining power to veto the USACE's decisions. USACE's regulatory jurisdiction for tidal waters under §404 extends up to the high tide line (higher high water mark in San Diego Bay) (see Figure 3-2).

In this coastal zone, the USACE requires permits for certain structures, such as groins, breakwaters, riprap, jetties, and beach nourishment activities. Overlapping with the CWA below the mean high water line is authority under §10 of the Rivers and Harbors Act of 1899, which gives the USACE jurisdiction over projects involving construction, excavation, and deposition. Projects located in this lower zone also require permits, such as new marinas, piers, wharves, floats, intake and outfall pipes, pilings, bulkheads, and boat ramps, as well as dredge and fill. The USCG issues permits for bridges or other structures over navigable waters under §10 of the Rivers and Harbors Act. For both §404 and §10 permits, mitigation for impacts may be required.

Mitigation for impacts may be required for Sec. 404 and Sec. 10 permits. Conditions may be part of a permit but are not required.

Beyond the direct permitting authority of the USACE is the commenting authority available to other federal agencies through the §404 permit process. Commenting authority to the Corps on specific projects is provided by the USFWS and the NMFS, for example, because of requirements of the Fish and Wildlife Coordination Act. If the USACE supports their comments, then their proposals for project mitigation can become conditions of the permit even though these two agencies do not have direct regulatory authority under the CWA. Examples of their mitigation concerns are added measures to ensure eelgrass and mudflat habitat protection and restoration as a means to protect fish and wildlife populations.

The federal CWA amendments of 1987 established a framework for regulating storm water discharges from municipal, industrial, and construction activities under the NPDES Permitting Program. The primary goal of the permits is to stop polluted discharges from entering the storm water conveyance system and local receiving and coastal waters.

Endangered Species Act

For more on ESA, see Section 4.4.6: Special-Status Species Protection.

The provisions of the ESA are also discussed under Sensitive Species in Chapter 4, Section 4.4: Strategy by Species Group. Once a species becomes listed as endangered or threatened, regulations to protect the species from illegal "take" become applicable to any project that may affect an individually listed animal or its habitat. The USFWS oversees the ESA implementation for all species except most marine species, which are under NMFS jurisdiction. Since the bay presently supports eight federally listed species, these two agencies become involved in all projects potentially affecting any of these species.

The USFWS and the NMFS are involved in all projects that potentially affect the listed species in the bay.

Under §7 of the ESA, federal project proponents must consult with USFWS or NMFS if one or more listed species may be affected by an action. Consultation with USFWS or NMFS may range from informal discussions to formal consultation requiring a biological assessment by the project proponent. For nonfederal project applicants, the USACE takes the lead in this consultation if the issue is within their jurisdiction. Other federal agencies may appropriately be named the action agency that must conduct the consultation. With the issuance of a BO, "terms and conditions" are stated, which are measures to avoid or minimize the take of any listed species. When an "incidental take statement" is issued with the biological opinion, the federal project proponent may be excused from incidentally taking a listed species as part of the agency's otherwise lawful activity as long as the specified taking conditions are met. Section 10 of the Act also provides for a similar incidental take permit for private, state, and local government projects. To qualify, the project proponent must submit a habitat conservation plan and also seek to minimize and mitigate the impacts of the taking to the “maximum extent practicable” (Mueller 1994). This plan must then undergo an internal §7 review and are also subject to environmental review under the National Environmental Policy Act (NEPA).

Migratory Bird Protection

Migratory Bird Treaty Act

USFWS has sole authority to enforce federal migratory bird statutes regulating the take of federally protected species.

The Migratory Bird Treaty Act (MBTA) of 1918 (16 USC 703-711) is legislation that covers species protected under four international treaties. These treaties are agreements between the U.S., Canada, Mexico, Japan, and Russia and protect most species of birds. The MBTA prohibits the taking or pursuing of migratory birds, their eggs, feathers, or nests. Game birds are listed and protected except where specific seasons, bag limits, and other factors govern their hunting. Exceptions are also made for some nuisance pests, which have standing federal depredation orders.

The USFWS has sole authority for coordinating and supervising all federal migratory bird management activities, including enforcement of federal migratory bird statutes regulating the taking of protected species (game and nongame) by individuals and federal agencies. The MBTA provides the USFWS the opportunity to comment on projects potentially affecting bird species, and their habitats, that are not protected under the ESA. Violations of the MBTA can result in fines of up to $2,000 or two years imprisonment.

Migratory Bird Rule

In an effort to provide guidance for conflicts arising between military readiness activities and the MBTA, the USFWS issued the final rule on, “Migratory Bird Permits: Take of Migratory Birds by the Armed Forces” (50 CFR Part 21 in the February 28, 2007 Federal Register, pages 8931-8950), hereinafter: Migratory Bird Rule. The Migratory Bird Rule authorizes the military to “take” migratory birds during military readiness exercises under the MBTA without a permit, but if the military determines that the activity will significantly affect a population of migratory birds, they must work with the USFWS to implement conservation measures to minimize and/or offset the effects.

The authorization for take requires an understanding of the definition of the following highlighted terms:

- *Population* is a group of distinct, coexisting (conspecific) individuals of a single species, whose breeding site fidelity, migration routes, and wintering areas are temporally and spatially stable, sufficiently distinct geographically (at some time of the year), and adequately described so that the population can be effectively monitored to discern changes in its status.
- *Significant adverse effect* on a population means an effect that could, within a reasonable period of time, diminish the capacity of a population of migratory bird species to sustain itself at a biologically viable level. A population is “biologically viable” when its ability to maintain its genetic diversity, to reproduce, and to function effectively in it’s native ecosystem, are not significantly harmed.

Conservation measures undertaken under the Migratory Bird Rule require monitoring and record-keeping for five years from the date the Armed Forces commence their conservation action. During INRMP reviews, the Armed Forces must report to the USFWS migratory bird conservation measures implemented and the effectiveness of the conservation measures in avoiding, minimizing, or mitigating take of migratory birds.

Coastal Zone Laws

NOAA oversees the CZMA and the CZARA. The CCC has authority to implement their provisions.

Two additional federal laws operate in the coastal zone: the Coastal Zone Management Act (CZMA) of 1972, and the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990. While the NOAA oversees the Acts, the CCC has authority to implement their provisions. If activities on lands excluded by the Act (“lands held in trust by or which uses are subject solely to the discretion of the federal government”), such as U.S. Navy lands, "may affect" the coastal zone, then they must be reviewed for consistency with the California Coastal Management Plan (CCMP) based on §307 of the CZMA. Before the 1990 changes, the law read "directly affect" but now it reads only "affect." Federal rules for federal consistency can be found in 15 CFR §930.35–37. See further discussion on CZMA consistency under State Agencies and Laws below.

Magnuson-Stevens Fishery Conservation and Management Act

The MSA (PL 94-265 as amended through January 12, 2007) is the primary law governing marine fisheries management in U.S. federal waters. The Act was first enacted in 1976 and amended in 1996 and 2006. Most notably, the Magnuson-Stevens Act aided in the development of the domestic fishing industry by phasing out foreign fishing. To manage the fisheries and promote conservation, the Act created eight regional fishery management councils. The 1996 amendments focused rebuilding overfished fisheries, protecting EFH, and reducing bycatch. It requires federal agencies undertaking permitting or funding activities that may adversely affect EFH to consult with the NMFS. The MSA also requires Fishery Management Councils to amend all of their FMPs to describe and identify EFH for the fishery based on guidelines established by NMFS, to minimize to the extent practicable adverse effects on such habitat caused by fishing, and to identify other actions to encourage the conservation and enhancement of EFH.

The 2006 law added mandates on the use of annual catch limits and accountability measures to end overfishing, provides for widespread market-based fishery management through limited access programs, and calls for increased international cooperation.

National Invasive Species Act (P. No.104-332)

In 1996, the National Invasive Species Act (NISA) amended the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 to mandate ballast water exchange for vessels entering the Great Lakes and to implement voluntary ballast water exchange guidelines for all vessels with ballast on board that enter U.S. waters from outside the EEZ. Though the act did not make exchange mandatory, it did require all vessels to submit a report form to the USCG documenting The NISA authorized funding for research on aquatic nuisance species prevention and control. In addition, NISA required a ballast water management program to demonstrate technologies and practices to prevent aquatic non-indigenous species from being introduced into and spread through ballast water in U.S. waters. It modified both the composition and research priorities of the Aquatic Nuisance Species Task Force and requirements for the zebra mussel demonstration program.

Executive Order 13112 (64 Fed. Reg. 6183) Invasive Species

The order seeks to prevent the introduction of invasive species, provide for their control, and minimize their impacts through improved coordination of federal agency efforts under a National Invasive Species Management Plan to be developed by the newly created interagency National Invasive Species Council (NISC). The Council has three co-chairs: the Secretaries of Agriculture, Commerce, and the Interior. Members also include the Secretaries of State, Defense, Homeland Security, Treasury, Transportation, and Health and Human Services, as well as the administrators of EPA, the U.S. Agency for International Development, the U.S Trade Representative, and the National Aeronautics and Space Administration. Federal activities are now coordinated through NISC (established by the EO) and the Aquatic Nuisance Species Task Force (established by the NANCPA 1990 and NISA 1996).

3.6.3 State Agencies and Laws

California's natural resource laws provide another level of environmental protection. State agencies are responsible for implementing certain federal laws as well as state laws. For example, delegation has been given to the SWRCB by EPA to administer portions of the federal CWA and CZARA and also to the CCC to implement the federal CZMA and CZARA (as noted above). Table 3-10 lists the state agencies, laws, and authority that pertain to San Diego Bay. A description follows of major state regulations that project planners should be aware of.

Table 3-10. State agencies with responsibilities for natural resources in San Diego Bay.[a]

Authority	Activities
California Coastal Commission	
▪ CCA of 1976 ▪ Federal CZMA of 1972 ▪ Federal CZARA ▪ CEQA of 1970	▪ Administers state and federal coastal zone acts by developing policies for implementation by local government through LCPs and Port master plans, which must be approved by CCC to allow local permitting authority in coastal zone. ▪ Retains permanent permit jurisdiction for proposed projects within the immediate shoreline (tidelands, submerged lands, and public trust lands). ▪ Regulatory control over federal activities in the ocean, such as dredge disposal. ▪ Works with SWRCB to develop Coastal Nonpoint Pollution Control Program. ▪ Mandated to protect and enhance public access, recreation, wetlands, visual resources, agriculture, commercial and industrial activity, and environmentally sensitive habitats within the coastal zone through coastal development permits, local coastal programs, and federal consistency review. ▪ Commenting authority.
State Lands Commission	
▪ Public Trust Doctrine ▪ Public Resources Code ▪ CEQA	▪ Exclusive jurisdiction over all ungranted tide and submerged lands that are state owned. ▪ Assists with use-related issues on Port tidelands and reviews Port-related projects on state trust lands. ▪ May preclude the use of submerged lands and tidelands if inconsistent with public trust; requires Land Use Lease for encroachments, docks, crossings. ▪ Establishes the ordinary high water mark and ordinary low water mark. ▪ Manages the Ballast Water Management Program, boarding approximately 25% of all vessels that arrive to California to verify compliance with regulations, and to disseminate outreach materials to vessels and crews new to California. Reports to Legislature on commercial vessel fouling, proposing performance standards for ballast water discharges, and summarizing vessel ballast water activities and compliance ▪ Commenting authority.
California Department of Fish and Game	
▪ California Fish and Game Code ▪ Public Resources Code ▪ CESA ▪ California Oil Spill Prevention and Response Act of 1990 ▪ CEQA ▪ Fish and Wildlife Coordination Act	▪ Has jurisdiction over the conservation, protection, and management of fish, wildlife, plants, and habitat necessary for biologically sustainable populations of those species. ▪ Conducts biological studies on fish and wildlife. ▪ Regulates activities resulting in alteration of lakes and streams. ▪ Manages sport and commercial harvest of fish and wildlife and aquaculture. ▪ Investigates pollution and toxic spills, in cooperation with SWRCB and RWQCB. ▪ Enforces protection of state-listed sensitive animal and plant species. ▪ Responsible for oil spill prevention, response, cleanup, and natural resource damage assessment in state waters. ▪ Provides recommendations to other state agencies to prevent or mitigate adverse impacts on fish and wildlife; also has commenting authority on federal projects. ▪ Lead agency for AIS Management Plan, as well as a rapid response plan for invasions. Enforces regulations concerning the aquaculture industry; the importation and transport of live wild animals, aquatic plants and fish into the state; and the placement of any such animals in state waters. The agency is also responsible for conducting AIS surveys, and surveys to assess the degree of success of ballast water management activities (OSPR). Manages the California Aquatic Nonnative Organism Database.
State Water Resources Control Board	
▪ Federal CWA ▪ Porter-Cologne Water Quality Control Act ▪ California Water Code ▪ Federal CZARA ▪ CEQA	▪ Protects water quality and administers water rights. ▪ Designates beneficial uses and water quality objectives and protects beneficial uses statewide; adopts California Ocean Plan and an Enclosed Bays and Estuaries Plan. ▪ Develops statewide nonpoint source pollution control plan. ▪ Develops program to identify and clean up toxic hot spots in bays. ▪ Working with CCC and RWQCB to develop and implement Coastal Nonpoint Pollution Control Program. ▪ Works in advisory capacity to, other state agencies on hull fouling and ballast water. Invasives come under water board purview as part of enforcing the Clean Water Act (since a 2005 federal court ruling defining non-indigenous species as "pollutants" present in discharges from vessels, and finding that such discharges are not exempt from permitting requirements). Some regional boards have sought to place specific water bodies within their regions on the CWA's 303(d) list, as impaired by exotics. ▪ Commenting authority.
Regional Water Quality Control Board	
▪ Federal CWA, §§401, 402 ▪ Porter-Cologne Water Quality Control Act ▪ CEQA	▪ Daily regulation of point source discharges, stormwater discharges, underground storage tanks, and above ground petroleum tanks. ▪ Designation of beneficial uses and water quality objectives, and protection of beneficial uses for San Diego Region through adopted Basin Plan. ▪ Prepares public reports on condition of water bodies. ▪ Develops program to identify and clean up toxic hot spots in bays. ▪ Commenting authority.
State Coastal Conservancy	
▪ Division 21 of the Public Resources Code	▪ Develops projects and provides grant funds related to resources enhancement and restoration. ▪ Participates in control and eradication of aquatic invasives.
California Ocean Protection Council	
▪ Public Resources Code	▪ Makes policy and prioritizes the expenditure of funds for ocean protection purposes. Authorizes and prioritizes the state AIS plan. Ocean Protection Council's affairs are administered by the Coastal Conservancy with direction from an Executive Policy Officer housed at the Resources Agency.

Table 3-10. State agencies with responsibilities for natural resources in San Diego Bay.[a] (Continued)

Authority	Activities
California Department of Food and Agriculture	
▪ Public Resources Code	▪ Regulates aquatic weeds including quarantine, exterior pest exclusion (border stations, inspections), interior pest exclusion (pet/aquaria stores, aquatic plant dealers, and nurseries), and detection and control/eradication programs. In addition, the California Department of Food and Agriculture Plant Pest Diagnostic Center identifies plant species and assigns plant pest ratings. The California Department of Food and Agriculture maintains a rated list of noxious weed species.
California Department of Pesticide Regulation	
▪ Various pesticide regulations	▪ Regulates antifouling paints used on boats and ships.
California Department of Parks and Recreation	
▪ Public Resources Code ▪ CEQA	▪ Acquires and manages coastal lands for resource preservation and park and recreational uses; manages Silver Strand State Beach on the bay. ▪ Commenting authority.
California Department of Boating and Waterways	
▪ Public Resources Code ▪ CEQA	▪ Facilitates public access to California waterways, on-the-water safety, and keep waterways free of navigational problems. ▪ Enforces boating laws, and promotes boater education, improvements to boating facilities, and vessel sewage management. ▪ Conducts aquatic weed control program for water hyacinth (*Eichhornia crassipes*). ▪ Leads the California Clean Boating Network to increase and improve clean boating education efforts, including invasive species education.
University of California	
▪ University charters ▪ National Sea Grant College and Program Act	▪ Conducts research on invasive species issues. ▪ Runs U.C. Statewide Integrated Pest Management Program. ▪ Operates California SeaGrant Program to enhance the understanding, conservation, and sustainable use of the coastal and marine resources. Activities are funded principally by NOAA, with matching funds from individual states.

a. Sources: Cylinder et al. 1995; California Resources Agency 1997; http://ceres.ca.gov.

Coastal Land Use Regulations

Coastal land use is also controlled by the state. The CCA of 1976 implements California's Coastal Zone Management Program as required by the federal CZMA of 1972 (California Resources Agency 1997). It regulates public access, recreation, marine resources, land resources, and development within the coastal zone. Overseeing the Act's implementation is the CCC, which has permanent permit jurisdiction for proposed projects within the immediate shoreline (tidelands, submerged lands, and public trust lands). It also seeks to ensure that local governments within the coastal zone prepare an adequate LCP based on the CCMP. Once an LCP is certified by the CCC, the local government can issue its own development permits for most projects.

The CCA's provisions regulate San Diego Port's tidelands.

California ports must have Port master plans certified as being in conformance with the CCA in order to have their own development permit authority. The Act's provisions regulate all of the Port's tidelands: Chapter 8 (Ports) and Chapter 3 (Coastal Resources Planning and Management Policies) for wetlands, estuaries, and existing recreation areas. Based on Chapter 3 policies, certain development projects that are normally port-related can be appealed to the CCC while other projects are considered nonappealable. These appealable projects are identified in the Port Master Plan under each planning district. When the CCC certified the Port Master Plan in 1981, certain modifications were required as conditions of approval. One of the conditions added was that the Port "shall insure that there will be no net loss of habitat" for "rare and endangered" species on Port lands (SDUPD 1996).

Activities covered under CZMA include dredge disposal and dumping of military surplus.

The CCC has regulatory control over federal activities in the federal Outer Continental Shelf that affect the state's ocean and coastal resources. Dredge disposal and the dumping of military surplus are examples of such activities covered by this federal consistency requirement under CZMA.

For federal lands, all lands that are held in trust by or which uses are subject solely to the discretion of the federal government are excluded from California's coastal zone. Examples would include all property within NAB and North Island not directly on the bay or the ocean. The City of Coronado has asked for CCC review of Navy projects that could affect their city, such as traffic and noise, and the Navy has complied with this review. Most Navy projects are reviewed on a case-by-case basis with no specified criteria established to identify which types of Navy activities have no effect on the coastal zone and, therefore, do not require review for federal consistency.

A General Consistency Determination can be done with the Navy for a whole class of activities under a master review. In 1993, the CCC granted the Navy for the San Diego Bay area a General Consistency Determination for periodic replacement and repair of piers and shoreline structures (CCC 1993). The Navy had to clearly define the types of projects allowed and is required to notify the CCC of an activity being conducted pursuant to this Determination before the Navy awards the contract. The Consistency Determination expires in five years (last renewed August 11, 1998, CD-070-98). To adopt the decision, the CCC had to find that this proposed project "is consistent with the marine resource, habitat, access, recreational, and shoreline structure policies of the CCMP."

A Negative Determination, usually done on a case-by-case basis, avoids formal review. Projects can get this determination if:

1. the project clearly has no impact on the coastal zone; or
2. the project is clearly similar to another project that was previously determined by the CCC to have no impact.

Projects that could fall under the "no impact" category can often be determined using the "common sense" rule, which also means "if in doubt, ask." Some projects appear obviously exempt (e.g. modification to existing buildings). Certain routine projects, such as maintenance dredging, are not exempt because of the CCC's need to ensure that all relevant federal and state agency concerns (e.g. eelgrass, California least terns) are addressed, such as the disposal of dredge spoils (M. Delaplaine, *pers. comm.*).

Water Quality Regulation

Beneficial uses and water quality objectives for coastal waters of San Diego Bay are identified and established by the Comprehensive Water Quality Control Plan for the San Diego Region.

Water quality protection in the bay is under the responsibility of the SWRCB and the RWQCB San Diego. Authority comes from the state's Porter-Cologne Water Quality Control Act and the federal CWA §401. Issuing water quality certificates for discharges requiring USACE permits for fill and dredge discharges is a core responsibility of the RWQCB. With the SWRCB setting statewide water quality objectives, the RWQCB carries out specific aspects of surface and coastal water regulations. A Comprehensive Water Quality Control Plan for the San Diego Region, adopted by the nine-member RWQCB, identifies existing and potential beneficial uses and establishes water quality objectives for coastal waters such as San Diego Bay. If the SWRCB adopts a "Water Quality Control Plan for Enclosed Bays and Estuaries of California," its provisions will supersede those of the Regional Plan.

Implementation of the plans occurs through the issuance of permits for waste discharges under the NPDES by the RWQCB. Regulations initially focused on controlling "point source" (end-of-pipe) discharges, such as from sewage treatment, industrial, and power plant outfalls. Recently, point source discharges from commercial shipyards and boatyards in the bay have come under General NPDES permits. The Navy's General State Water Quality Certification was approved on November 2, 1998 (98C-127).

See Section Chapter 5.2.2: Storm water Management" for discussion of regulatory details.

As the result of amendments to the CWA (§402[p]) and to the Coastal Zone Act (CZARA §6217), storm drains are being treated as a point source of pollution and are required to come under NPDES permit. The Port, the county, and the cities are all under a General Municipal Stormwater Permit. In Phase II, CZARA is requiring that small construction sites (<5 acres/2 ha) also be included under a stormwater permit. Industrial stormwater permits are maintained by the Port for the airport and marine terminals. All U.S. Navy facilities are also subject to the statewide General Industrial Stormwater Permit.

Enforcement of NPDES permits by the RWQCB is done when monitoring or other source indicates a violation of permit conditions. Cease and Desist Orders and Cleanup and Abatement Orders can be issued along with stiff financial penalties can be issued for noncompliance.

State Tideland Authority

The Port operates on sovereign state land granted to it in trust by the Legislature for the purpose of operating and maintaining port facilities for statewide benefit. As such, the SLC is charged with overseeing the use of sovereign land and retains any authority not granted in trust. The SLC wants to ensure that projects on public trust lands are consistent with the terms of the legislative grant supporting maritime commerce, navigation, fisheries, and recreation.

Under CEQA review of Port projects, the SLC acts as a "responsible agency" and participates with many other state agencies in evaluating environmental impacts and establishing fish and wildlife mitigation requirements (California Resources Agency 1997). The SLC also provides technical assistance to the CCC on federal consistency reviews for projects on leased state tidelands. For encroachments, docks, or crossings on tidal and submerged lands under its jurisdiction, the SLC will require a Land Use Lease (California Office of Planning and Research 1980).

California Environmental Quality Act (California Public Resources Code §§ 21000 et seq.)

The CEQA requires public disclosure of all significant environmental effects of proposed discretionary projects. If a project would cause significant effects, final documents in the CEQA process show 1) what mitigation measures will be required to reduce particular effects to a less significant level, and 2) provide justifications for the approval of the project with particular significant effects left unmitigated (i.e. a finding of overriding consideration). CEQA also contains lists of project types exempt from this process. A "significant" impact is a "substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the project including land, air, water, minerals, flora, [and] fauna…." The documented adverse impacts associated with invasive species can fit this broad definition.

California Porter-Cologne Water Quality Control Act

Under California's Porter-Cologne Water Quality Control Act, "any person discharging waste, or proposing to discharge waste, within any region that could affect the quality of the waters of the state" must file a report of the discharge with the appropriate RWQCB. Pursuant to the act, the Regional Board then prescribes "waste discharge requirements" related to control of the discharge. The act defines "waste" broadly, and the term has been applied to a diverse array of materials. The San Francisco Bay RWQCB, for example, has determined that "ballast water and hull fouling discharges cause pollution as defined under the Porter-Cologne Water Quality Control Act."

The act (California Water Code, Division 7), lists a number of types of pollutants that are subject to regulation by the SWRCB. §13050, for example, specifically includes the regulation of "biological" pollutants by defining them as relevant characteristics of water quality subject to regulation by the Board: AIS are an example of this kind of pollutant if they are discharged to receiving waters. Several of the Regional Boards have taken legal policy and enforcement actions related to AIS (see also CWA, Appendix B, and SWRCB, California Agencies).

Fish and Game Code and Title 14 California Code of Regulations

The Fish and Game (F & G) Code consists of the laws passed by the state legislature that pertain to fish and wildlife resources. Under statutes in the Fish and Game Code, the California Fish and Game Commission has the responsibility for the adoption of regulations that provide details on how certain Fish and Game laws are to be implemented. These regulations are published in Title 14 of the California Code of Regulations. A summary is provided below of Fish and Game Code Sections that address invasive species issues or may relate to control actions.

F & G Code §§ 2080 – 2089 CDFG regulates the take of species listed under the CESA. In addition to the instructions in the Fish and Game Code, guidelines for this process are located in Title 14, Division 1, Subdivision 3, Chapter 6, Article 1 of the California Code of Regulations. These statutes and regulations should be consulted if AIS control measures have the potential to impact state-listed species.

F & G Code §§ 2118, 2270-2272: CDFG is responsible for enforcement of importation, transportation, and sheltering of restricted live wild animals; places importation restrictions on aquatic plants and animals; and prohibits nine species of Caulerpa.

F & G Code §§6400-6403: It is unlawful to place live fish, fresh or saltwater animals or aquatic plants in any waters of this state without a permit from .

F & G Code §§ 6430-6433: CDFG is responsible for prescribed studies for ballast water-related invasive species and has prepared a baseline report of species present in California entitled “A Survey of Non-Indigenous Aquatic Species in the Coastal and Estuarine Water of California.”

F & G Code §§15000 et seq.: CDFG is responsible for regulations pertaining to the aquaculture industry, including disease issues.

Marine Invasive Species Act (AB 433)

The Marine Invasive Species Act, passed in 2003, revises and recasts the state’s law (AB 703) pertaining to control of non-indigenous species and ballast water management. It imposes additional requirements upon vessel masters, owners, operators, and persons in charge of vessels to prevent the introduction of non-indigenous species into waters of the state or waters that may impact the waters of the state. The bill deletes exemptions for specified vessels from compliance with the act and revises the qualification for the vessels subject to the act.

Ballast water management is required of all vessels that intend to discharge ballast water in California waters, though the regulations differ depending on voyage origin. All qualifying vessels coming from ports within the Pacific Coast region must conduct near-coast exchange (in waters at least 50 nautical miles offshore, and 200 meters deep), or retain all ballast water and associated sediments.

All vessels must complete and submit a ballast water report form upon departure from each port of call in California. They must also comply with the good housekeeping practices, ranging from avoiding discharge near marine sanctuaries to rinsing anchors and removing fouling organisms from the hull. They must maintain a ballast water management plan prepared specifically for the vessel; keep a ballast water log outlining ballast water management activities for each ballast water tank on board the vessel, and make the separate ballast water log available for inspection; conduct training of vessel master, PIC, and crew regarding the application of ballast water and sediment management and treatment procedures; and pay a fee for each qualifying voyage at their first port of call in California.

To determine the effectiveness of the management provisions of the act, the legislation also requires CDFG to conduct a series of biological surveys to monitor new introductions to coastal and estuarine waters of the state. The 1999 law required a baseline survey of the state’s ports, harbors and bays. The 2003 statute expanded the baseline to include outer coast sites and then required continued monitoring of all sites to determine if the ballast control measures have been successful in reducing the number of new introductions.

California Ocean Protection Council Strategic Plan

The California Ocean Protection Council, formed to coordinate the activities of ocean related state agencies and improve state efforts to protect ocean resources, among other things (see State Agencies), adopted a five-year strategic plan in 2006. The plan supports the completion and implementation of both the state rapid response plan and AIS Management Plan, as well as the California Noxious and Invasive Weed Action Plan. An August 2010 assessment of the status of Ocean Protection Council actions highlights the organization’s funding to complete the AIS Management Plan and its ability to bring agencies together to work on invasive species issues.

3.6.4 Local Agencies and Laws

Local agencies consist of the land use, environmental, and public works departments and divisions within the Port, San Diego County, and the five cities surrounding the bay: Chula Vista, Coronado, Imperial City, National City, and San Diego. As with the state, local government is charged with implementing state and federal laws as well as local laws. Table 3-11 provides a general listing of the pertinent agencies, laws, and authorities of these various local agencies.

Table 3-11. Local agencies with responsibilities for natural resources in San Diego Bay.

Local Agencies and Applicable Laws	Authority and Activities
San Diego Unified Port District	
■ State Port District Act of 1962 ■ Port Master Plan ■ Port Ordinances/Code ■ CCA of 1976 ■ CEQA	■ Enables Port to operate and to promote the development of commerce, navigation, fisheries; and recreation within the Port. ■ Provides planning policies for the physical development of the Port's trust lands. ■ Regulates the conditions of use within Port's jurisdiction. ■ Authority to issue its own coastal development permits once Master Plan is certified by CCC. ■ Lead agency and commenting authority on projects and plans.
City and County Planning/Community Development Departments	
■ State Planning and Zoning Law ■ State Subdivision Map Act ■ Local general plan ■ Local Ordinances: zoning, grading, etc. ■ CCA of 1976 - LCP element of general plan ■ CEQA	■ Establishes state rules and guidelines for cities and counties. ■ Establishes state rules and procedures for local subdivision ordinances. ■ Provides policy direction for land use, conservation, transportation, housing, and safety. ■ Implements policies of the general plan. ■ Authority to issue own coastal development permits once LCP certified by CCC. ■ Lead agency and commenting authority on projects and plans.
City and County Public Works Departments	
■ State Safety and Public Works Statutes - Ordinances (flood control, stormwater, etc.)	■ Establishes state rules and guidelines for cities and counties. ■ Regulates use and procedures for maintaining public facilities.
San Diego County Department of Health Services, Environmental Health Division	
■ State Health and Safety Code - Local Ordinances	■ Establishes state rules and guidelines for cities and counties. ■ Regulates use and procedures for maintaining public health.

Local Land Use Plans

State planning and zoning law establishes the rules and guidelines for local government plans and their implementation (California Office of Planning and Research 1984). Each of the five cities and the county have adopted general plans to govern their current and anticipated land uses, along with required elements (e.g. Housing, Transportation, Conservation, and Open Space) and specific plans for subareas within their jurisdiction. These land use strategies have goals, objectives, and policies within their text and depicted in maps. Land use zones depict where different uses and densities are to be allowed, with zoning ordinances defining the allowable uses for each zone.

Local coastal plans provide more specific strategies for the portion of their jurisdictions lying within the state-defined coastal zone. All LCPs for bay jurisdictions have been approved by the CCC as being in conformity with the CCMP. The Coastal Zone for the bay region encompasses all land and water from the ocean to Interstate 5 on the east, and to Rosecrans Street to the north end of the bay. Much, but not all, of this land is within the Port jurisdiction. The county and the Port member cities have incorporated the certified Port Master Plan into their own LCPs. To implement the Master Plan, the Port has adopted Coastal Development Permit Regulations. Permit issuance by the BPC is based solely on the conformity of the proposed development with the certified Port Master Plan.

Local Water Quality Protection

To minimize runoff pollution from construction sites, some local agencies have adopted Grading Ordinances.

Implementation of federal and state water quality mandates occurs a great deal at the local government level. To comply with the RWQCB's NPDES permit, the Port is managing stormwater pollution through Port ordinances and the enforcement of its member cities' stormwater ordinances. Some local agencies have adopted Grading Ordinances to minimize runoff pollution from construction sites. All Port tidelands are regulated under RWQCB Order No. R9-2007-0001, NPDES Permit No. CAS0108758, (Municipal Permit). This permit was adopted in January of 2007 and replaces the previous permit Order No 2001-01. The Municipal Permit prohibits any activities that could degrade stormwater quality. The Port's Stormwater Ordinance

(Article 10 of the SDUPD Code 25 July 2000) is one of 12 elements of its Urban Runoff Action Plan for eliminating contaminated runoff into San Diego Bay (see Section 5.3 for more details on stormwater management).

In a parallel fashion, the Navy manages stormwater through its own NPDES permits and Chapter 8 of OPNAVINST 5090.1C (October 2007). The San Diego RWQCB issues NPDES permits to regulate industrial areas at the U.S. Navy facilities adjacent to San Diego Bay. In contrast to the Port, Navy stormwater discharges are regulated under Phase II of the CWA Stormwater Program. The Port's Phase I regulations apply to municipal separate storm sewer systems (MS4s) serving a population over 100,000, as well as storm water discharges associated with regulated industrial activities as defined in the storm water regulations, including construction activities disturbing 5 acres of land or more. The Phase II regulations apply to MS4s serving a population less than 100,000, that are located in an "urbanized area", and construction activities that disturb greater than or equal to one (1) acre of land, or as specified by an individual state. Federally operated storm sewer systems are defined as MS4s. Navy activities subject to storm water regulations must apply for NPDES permit coverage under either an individual permit or a general permit.

Applying for a local development permit within the county, cities, or Port jurisdictions triggers a multiagency project review to ensure compliance with the state and federal water quality regulations, as depicted in Figure 3-3. To help provide consistency among the local agencies' regulations, regional model water quality elements of plans are available with specific measures that can be taken by local jurisdictions to address the adverse impacts of land development to the region's surface and groundwaters.

The San Diego County Department of Environmental Health Ocean & Bay Recreational Water Program seeks to protect public health from the effects of polluted water and can close sites to fishing, swimming, or other uses when needed. It reports in the number of advisory beach closure days (in units of beach mile-days) for each coastal jurisdiction (see bay beach closure information in Section 5.3). A water contact Advisory/ Warning is issued when monitoring reveals ocean or bay water quality does not meet state standards due to high bacterial levels, or during the excavation of a coastal outlet (river or lagoon) when potentially contaminated water is released into the ocean. The Department of Environmental Health advises beach users to avoid contact with ocean and bay waters where advisory/ warning signs are posted. Signs are usually posted 50 yards (150 feet) either side of a sampling location where water quality does not meet state standards.

3.6.5 Project Mitigation Under NEPA and CEQA

Project mitigation may be required as a condition of approval for permits by regulatory agencies. It is also used as a means to address adverse environmental impacts through the federal (NEPA) or state (CEQA) review processes. NEPA and CEQA provide a useful planning tool to clearly evaluate the effects of decisions on the environment and to solve any potential problems as early in the process as possible. An overview of these acts and their roles with project mitigation follows. A typical project flow chart is shown in Figure 3-3.

NEPA and CEQA Processes

Both the federal and state Environmental Protection Acts provide similar processes to evaluate and solve the environmental impacts of proposed projects.

Both the NEPA and the CEQA were adopted in 1970 and possess many similarities. Activities directly undertaken by, financed by, or requiring approval of federal or state and local agencies, respectively, are subject to NEPA or CEQA environmental review processes, with only some specified exceptions. Several levels of review intensity are provided, and guidelines for implementation are adopted that are quite binding on the agencies. When a project has both federal and state/local activities that are subject to the Acts, a joint NEPA/CEQA process can be carried out. A comparison of the two processes is shown in Figure 3-4 (from Bass *et al.* 1999).

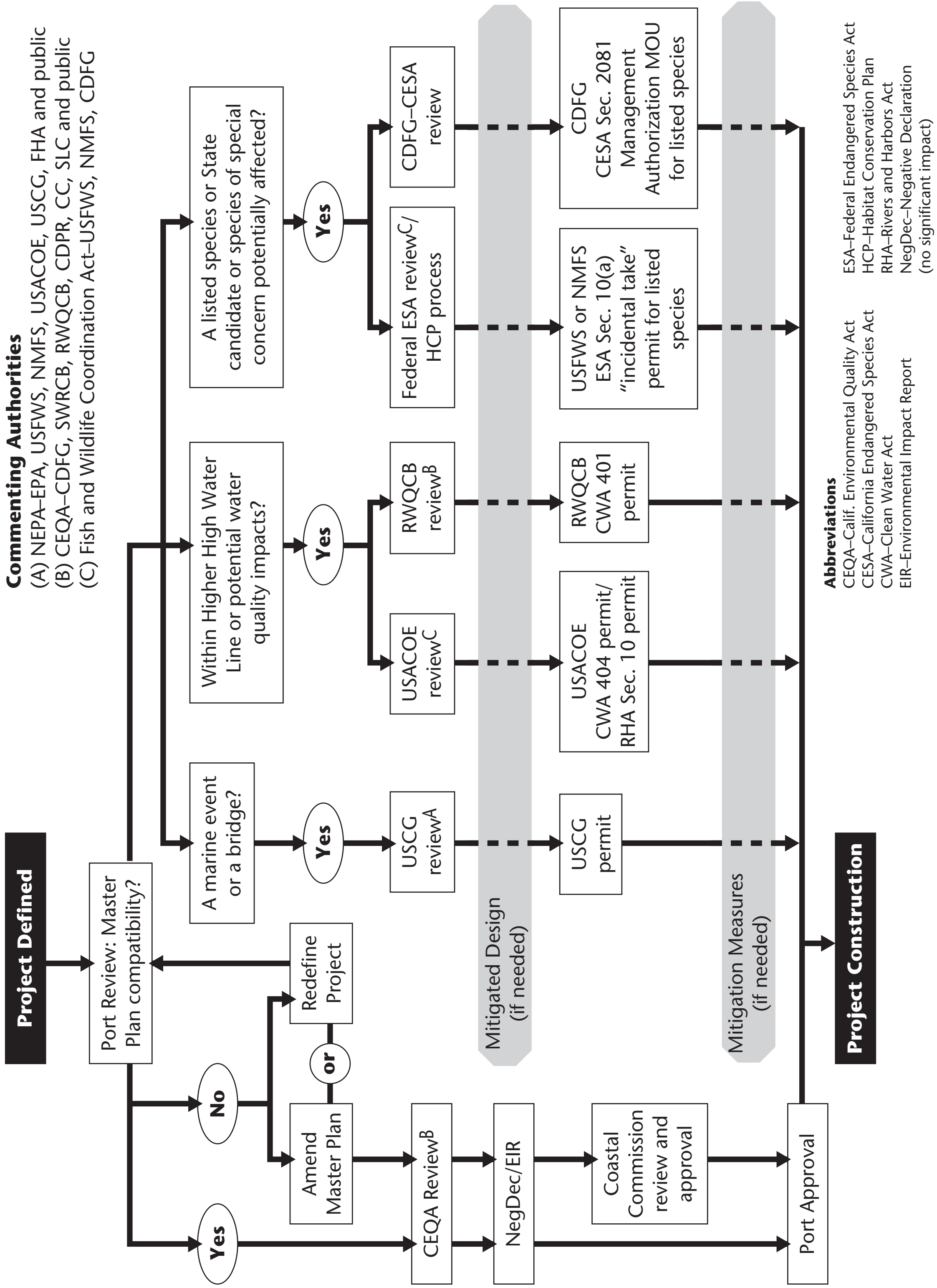


Figure 3-3. Typical project processing flow chart.

National Environmental Policy Act

The NEPA of 1969 (42 USC §4321 et.seq.) is the basic charter for environmental planning within the United States. It requires federal decision makers to inform themselves of the environmental consequences of the proposed actions that may significantly affect the environment and consider those consequences in determining courses of action.

The most important function of agency compliance with NEPA procedure is to ensure that the environmental consequences of the agency's action have been considered.

For Navy projects, the DoD has issued policy and procedures for its components. A supplement providing policy and assigning responsibilities was later adopted by the U.S. Department of the Navy (32 CFR Part 775). These Navy procedures meet the NEPA requirement that every federal agency adopt procedures to supplement CEQ regulations. Following the Navy directive, specific policy for compliance with procedural requirements is issued under a Navy Instruction (OPNAVINST 5090.1C, Ch.5). This latter document tasks each Naval installation with ensuring that Navy actions are in accordance with the letter and spirit of NEPA.

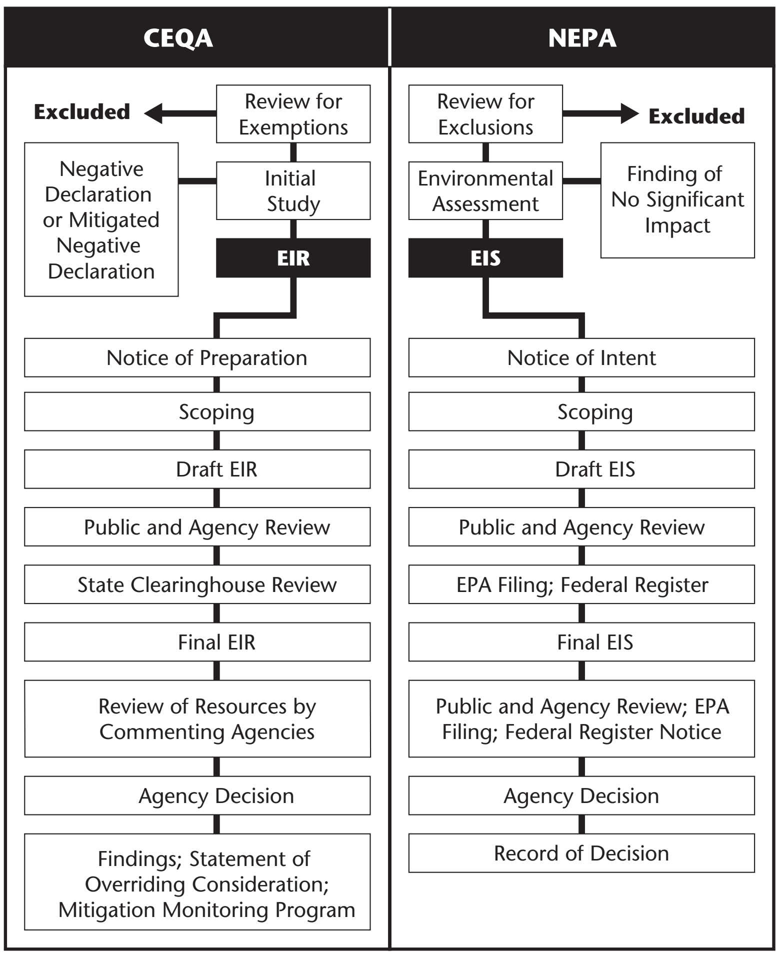


Figure 3-4. Comparison of CEQA and NEPA review processes (from Bass et al. 1999).

A project under NEPA must be evaluated on its potential to "significantly affect the quality of the human environment." The term "significantly" is determined by considering the context in which it will occur and the intensity of the action. "Human environment" is a comprehensive phrase that includes the natural and physical environments and the relationship of people with those environments.

A proposed federal agency action is first reviewed to see if it can qualify for a categorical exclusion (usually small, routine projects with no potential significant environmental effect; categories are identified in agency NEPA policies) or other exemption to the process. If not, then an EA is prepared by the Lead Agency, or an EIS if it is understood from the start that there will be significant impacts. If the EA concludes adverse environmental impacts will be insignificant, then the agency can file a Finding of No Significant Impact, followed by its chosen action. If the proposed project has the potential to "significantly affect the quality of the human environment," then the EIS process must be followed. Briefly, these steps are: Notice of Intent, Scoping Process, Draft EIS, agency/public Review and Comment, Final EIS, Record of Decision, and agency action.

The Lead Agency is the federal agency with primary responsibility for preparing an EIS. A Cooperating Agency is any federal agency other than the Lead Agency that has jurisdiction by law or special expertise with respect to the environmental impacts expected to result from a proposal. A Lead Agency must request participation of Cooperating Agencies early in the NEPA process, use their analyses as much as possible, and meet upon their request. A Cooperating Agency must participate in the process unless resource limitations must limit its involvement (Bass and Herson 1993).

California Environmental Quality Act

CEQA is administratively implemented by guidelines prepared by the state Office of Planning and Research and adopted by the Secretary of the Resources Agency. CEQA does not apply to federal agencies but does apply to the Port therefore the discussion of CEQA is included in this document. Extensive revisions to the CEQA Guidelines were approved in late 1998 by the state Office of Administrative Law to reflect new statutes and recent court decisions. All discretionary projects proposed to be carried out or approved by state or local agencies must comply with CEQA. Exemptions include ministerial projects, emergency repairs, and minor construction or reconstruction projects (Bass *et al.* 1999).

An Initial Study is prepared for a project by the lead agency to determine if the project may have a significant effect on the environment. At this point, the project sponsor can modify the project so that any adverse impacts are mitigated. If there is no significant environmental impact, the initial study should provide documentation for such a finding in a Negative Declaration. If significant impacts that cannot be mitigated exist, the lead agency must prepare an Environmental Impact Report (EIR). Briefly, the EIR process is the following: Notify responsible agencies and public, Issue and Scope Identification, Draft EIR, Notice of Completion of Draft EIR, Public Review Period, preparation of Response to Comments, Final EIR, adoption of Final EIR, and agency decision.

"Significant effect on the environment" is defined in CEQA to mean a substantial or potentially substantial, adverse change in any of the physical conditions within the area affected by the project, including land, air, water, minerals, flora, fauna, ambient noise, and objects of historic or aesthetic significance.

A CEQA Lead Agency is the public agency that has principal responsibility for carrying out or approving a project; a Responsible Agency is any other public agency with discretionary authority over a project; and a Trustee Agency is a state agency that has jurisdiction over natural resources held in trust for the people of the State of California (e.g. CDFG, SLC). The Lead Agency must coordinate and consult with the other agencies during the CEQA process.

Mitigation Measures

The environmental consequences section shall discuss means to mitigate adverse environmental impacts, if not fully covered in the proposed action or alternatives. CEQA requires that "each public agency shall mitigate or avoid the significant effects on the environment of projects it approves or carries out whenever it is feasible to do so." In addition, the probability of the mitigation measures being implemented must be discussed under CEQA.

However, a federal agency does not have to adopt mitigation measures included in an EIS unless agency-specific NEPA procedures require adoption of mitigation measures or the agency commits to implementing mitigation measures in the Record of Decision. Similarly, CEQA does not require decision-makers to deny a project with significant adverse environmental impacts. The decision-making body must make a finding that approval is granted because of "overriding" social and economic benefit.

4.0 Ecosystem Management Strategies

This chapter spells out management strategies for the bay's natural resource values viewed in a whole-ecosystem context. Values are collective benefits derived from the bay, such as wildlife habitat, species abundance and diversity, water purification, industry and military support, tourism, recreation, and aesthetic and spiritual rewards, as well as the intrinsic value of each resource itself. In this Ecosystem Management Plan, we intend to foster strategies that identify the physical, chemical, and biological roots of these values so that they may be conserved.

4.1 Ecosystem Approach

This INRMP seeks opportunities to better institutionalize the guiding principles of ecosystem management (see Section 1.3.2: Defining Ecosystem Management for this INRMP) for San Diego Bay.

- Maintain and improve the sustainability and native biodiversity of ecosystems.
- Administer with consideration of ecological units and time frames.
- Support sustainable human activities.
- Develop priorities and reconcile conflicts.
- Develop coordinated approaches to ecosystem health through partnerships.
- Rely on the best science and data available.
- Use benchmarks to monitor and evaluate outcomes.
- Apply adaptive management.

Specific Concerns

- Some important resources or resource dependencies may fall through the cracks of management if not considered at different scales and time frames within an ecosystem approach. In addition, the concept of sustainability allows a manager to look at longer time scales. Recently the Port's Environmental Fund and Committee have boosted the ability to get beyond project-by-project management. This has been supported by recent monitoring that takes a more comprehensive approach: Bight 1998, 2003, and 2008; regular fish surveys; eelgrass surveys; the first baywide avian species survey; and a statewide look at invasive species that included San Diego Bay. Still, joint baywide processes are in their infancy.

- Concern for biodiversity argues that different biological communities be well dispersed throughout the bay in a natural and proportional approach rather than concentrated in one subregion or another.
- The complexity of the bay as an ecosystem and the difficulty of dealing with this complexity argues for the use of management indicator species to provide a focus for decision-making, and these have not been identified by agreement among agencies.
- The tie between management indicator species, other monitoring, and INRMP goals and objectives needs to be strong.

Current Management

Current management of natural resources in San Diego Bay is project-, species-, or habitat-based. Research and monitoring efforts have also generally driven by project impacts under CEQA, CWA, ESA, and NEPA. Assessment from a broader, landscape or ecosystem perspective, in which interdependencies among habitats and populations are examined, is generally not done. A goal of ecosystem-based management is to maintain the whole as well as the parts by recognizing the connection among all the components.

Evaluation of Current Management

The premise of this INRMP is that management on a project-by-project basis is inadequate to conserve bay resources because the scale and time frame associated with projects is unlikely to consider all the resources and interdependencies that may be affected. At the same time, viewing issues on an ecosystem level may allow some important management concerns to fall through the cracks.

The 2001 INRMP proposed to monitor an integrated set of "ecological indicators" and certain target species to detect trends and provide management cues. At a minimum, the regular monitoring of plankton (phytoplankton productivity and zooplankton abundance and distribution), water temperature, salinity, habitat change, black brant, and juvenile halibut abundance was recommended. The Plan also provided criteria for selecting additional species and biophysical indicators. Most of the money currently expended on monitoring is tied to water and sediment quality compliance requirements rather than such indicators, annually constituting hundreds of thousands of dollars. Despite the designated beneficial uses of water that are natural resource related (commercial and sport fishing, preservation of designated biological habitats, estuarine and wildlife habitats, rare and endangered species, migration of aquatic organisms, and shellfish harvesting), no conceptual model linking the relatively abundant water or sediment quality data sets to species abundance and diversity is used across agencies.

Indicator species are used as a focus for ecologically based management decisions.

Resource managers need a focus for management decisions that are ecologically based and can provide insight into environmental conditions and the impacts of management decisions. Indicator species are used for this purpose. Selection criteria for an indicator species vary depending on the objective, but typically species selected as management indicators are (1) species representing important habitat types and are believed to be functionally equivalent to many other species with similar habitat/ecological needs, or (2) flagship or umbrella species that range widely (i.e. a migratory bird or fish) and managers assume that managing for their broad habitat and area needs will also provide for all other species in those habitats (Ruckelshaus and Hays 1998).

Selecting and tracking species that are of special interest or indicative of management trends or management indicator species is an accepted practice for monitoring management effectiveness; it is more robust in combination with other monitoring in order to provide multiple lines of evidence.

There has been criticism about the use of indicators when two species are ecologically similar. This has led to the discussion of monitoring and managing these species as one (Niemi and McDonald 2004; Power *et al.* 1996; Simberloff 1998). To respond to some of this uncertainty and also continue to recognize indicators as a necessary management tool (since it is impossible to track all plants and animals in a planning area), the National Forest Management Act directed the U.S. Forest Service to select and track species that are of special interest or indicative of management trends. These species are called Management Indicator Species. These species are selected on the basis of being likely candidates to provide information on the effects of management activities. The U.S. Forest Service is required to collect population data for all management indicator species (36 CFR 219.19[a][6]; see Sierra Club v. Martin (168 F.3d 1 [11th Cir. 1999]).

The criteria for selecting an indicator species could help focus further discussions in respect to San Diego Bay are as follows:

- Biological information in the scientific literature supports use of the species as an indicator;
- Species is sensitive to management activities in the local or regional vicinity;
- Species is considered a keystone species or habitat specialist;
- Species is a year-long resident of the vicinity (nonmigratory), or population trends of the species in the local or regional vicinity are closely tied to habitat conditions resulting from resource use locally;
- Species is indigenous or endemic;
- Species is found in similar habitats across most or all of the planning area;
- Species is appropriate for the primary ecological scale of interest (planning or geographic area);
- It is biologically and economically feasible to monitor populations and habitat at similar spatial scale;
- Populations are sufficient size or density to be reasonably detected and monitored
- Population trend information is already available or being collected; and
- Species is a migratory flagship or umbrella fish or bird that ranges widely and uses habitats San Diego Bay in sufficient numbers to monitor trend and can represent needs for all other species in those habitats.

Some final considerations in planning whether and how to use indicators are: to formally recognize the scientific debate during the planning process and in the planning documents; state clearly the logic and assumptions in selecting any indicator species; recognize the use of indicators as one of several planning tools at different scales; and recognize that using indicators will likely entail a long-term commitment of resources to monitor them over time.

Management Strategy—Ecosystem Approach

Objective: Protect bay natural resources and their function by planning and acting at ecologically meaningful, hierarchical scales and time frames.

I. Establish management objectives based on four hydrodynamic-based subregions of the bay (Map 4-1) as described by Largier (1996, 1997) (see Section 2.3.5: Hydrodynamic Regions of the Bay).

  1. North Bay, the **Marine Region.**
  2. North-Central Bay, the **Thermal Region.**
  3. South-Central Bay, the **Seasonally Hypersaline Region.**
  4. South Bay, the **Seasonally Estuarine Region.**

  A. Define the historical context of each region, as shown in Table 4-1.

  B. Describe the existing fish and wildlife values of each region. Consider the following:

  1. Marine Region. Abundance of schooling fish, a young-of-year topsmelt and surfperch nursery; use of intertidal primarily as high tide refugia rather than foraging. Abundance, distribution, and diversity of invertebrates and algae.
  2. Thermal Region. Large areas of former mudflat are missing. Young-of-year topsmelt and surfperch nursery. Abundance, distribution, and diversity of invertebrates and algae.
  3. Hypersaline Region. Abundant slough anchovy, topsmelt, spotted sand bass. Abundance, distribution, and diversity of invertebrates and algae.
  4. Estuarine Region. Abundance of shorebirds and waterbirds, nesting sea birds. Abundant slough anchovy, Pacific mackerel (seasonally), striped mullet, gobies. Abundance, distribution, and diversity of invertebrates and algae.

Map 4-1. Management units based on Largier (1996, 1997).

Table 4-1. Historic and current (2007) habitat acreages in four bay regions. Between 2000 and 2007, 20 acres of salt marsh were added in South Bay, and 15 acres of subtidal by filling in a deep water borrow pit. In South-Central Bay, 15 acres of moderately-deep water was filled to create about 15 acres of shallow subtidal and 4 acres of intertidal habitat. Blue font indicates changes since the last Integrated Natural Resources Management Plan (2000).

Habitat[a]		North Bay	North-Central	South-Central	South Bay	Totals
1859 Habitat	Intertidal	1,996	1,009	1,074	2,068	6,147
	Shallow	1,255	845	2,690	1,609	6,399
	Moderate Deep	218	209	424	104	955
	Deep	884	760	498	69	2,211
	Totals	4,353	2,823	4,686	3,850	15,712
Current Habitat	Intertidal	138	51	63	759	1,011
	Shallow	510	184	1,287	1,804	3,785
	Moderate Deep	483	323	1,196	199	2,201
	Deep	2,027	1,187	1,114	62	4,390
	Totals	3,158	1,745	3,670	2,819	11,392
Percent Loss/Gain(–/+)	Intertidal	–93%	–95%	–94%	–63%	–84%
	Shallow	–59%	–78%	–52%	+12%	–41%
	Moderate Deep	+122%	+55%	+282%	+91%	+230%
	Deep	+129%	+56%	+224%	+11%	+99%
	Totals	–28%	–38%	–22%	–27%	–28%

a. Intertidal excluding Salt Marsh (+2 to –2.2 feet in Figure 2-5, high tide line to –3 feet on 1859 coverage); Shallow Subtidal (–2.2 to –12 feet); Moderately Deep Subtidal (–12 to –20 feet); Deep Subtidal (>–20 feet).

II. Select indicator species for focusing bay management.

A. Consider the following as potential indicator species:

1. California halibut, a commercial species that uses the bay as a nursery and uses unvegetated shallows. Many young-of-year are found in mudflats.

2. Light-footed clapper rail for the lower marsh.

3. Young-of-year topsmelt, a resident species distributed throughout the bay.

4. Black brant for its close association with eelgrass.

5. Giant kelpfish or pipefish for close ties to eelgrass and resident status.

6. Western snowy plover for its use of high mudflat and upland transition.

7. California killifish, California halfbeak, or other fish that at some life stage requires movement between shallow and intertidal habitats.

8. Cover and abundance of eelgrass.

III. Require that cumulative effects analyses be conducted on both baywide and subregional scales, with consideration of the agreed-upon objectives and indicator species for each subregion.

A. Monitoring should also take place in nearby bays and estuaries to provide information on whether changes observed in San Diego Bay are the result of factors operating inside the bay or outside. If a decline is detected in all locations there is good reason to believe the factor is regional and not due to local causes within the bay.

IV. Adjust the selection of scales, objectives, and indicator species used for research and monitoring, and adjust them based on adaptive management principles.

V. Bay-Watershed Linked GIS Tool. Develop integrated data sets with climate change, hydrodynamic and oil spill response modeling, so that existing modeling technologies are more applicable for managers. A linked hydrodynamic-watershed model similar to that used in Puget Sound will help evaluate the fate and transport of storm water contaminants, sort out sediment toxicity clean-up responsibilities and priorities, influence TMDL decisions, support oil spill quick-response, and predict future watershed changes' effects on San Diego Bay. SPAWAR studies have found no difference between spring and summer copper, implying that sources were within the bay.

VI. Conduct a Biennial Conference on San Diego Bay Health, reporting on ecological Indicators, "State of the Bay" monitoring, and studies.

4.2 Mitigation and Enhancement

Since the 2001 INRMP, some habitat recovery has occurred due to mitigation and enhancement projects. The Navy created Homeport Island, and the Port created 15 acres of shallow subtidal habitat by filling in the Borrow Pit in South Bay. Trash collection at the end of creeks (such as Chollas, Paleta, Switzer) has improved conditions there.

Two out of 29 restoration or enhancement project concepts identified in the 2001 INRMP have been implemented and certain others are expected to be implemented through normal regulatory channels and mitigation for construction projects. A major restoration project began in September 2010 in south bay involving the western salt ponds, CVWR, and the western edge of Emory Cove. The implementing partners include the Port, NOAA, and the NWR. Other projects have been completed since the 2001 INRMP that were not identified in that document:

- National City Terminal wharf extension marsh. A salt marsh of cordgrass and annual pickleweed in south bay was expanded by about four acres in 2004 as mitigation for the National City wharf extension project, completed in 2003.
- USS Midway Marsh. The positioning of the decommissioned USS Midway at North Embarcadero as a San Diego Aircraft Carrier Museum required mitigation for 4.1 acres of open water habitat loss, when the USS Midway was parked along the downtown waterfront. The museum funded expansion of Lovett Marsh in National City which resulted in creation of nearly six acres of new salt marsh.

Many other projects are possible. These include:

- Alpha Beach/Crown Cove on Navy land (leased from state of California). Expand intertidal and subtidal eelgrass habitat from existing beach and open water. This will eventually cause the beach to widen and enhance the intertidal mudflat, using Homeport Island as a template for another project in Mission Bay.
- South Bay Power Plant site on Port lands. Enhancement potential could be integrated with plans for enhancing the CVWR's habitat functions and values. A significant population of green sea turtles could benefit from enhancement.
- Grand Caribe Isle South/Coronado Cays, 6 acres on Port lands. Excavate island to create intertidal habitat. The Port's BPC has agreed to set aside this area for mitigation purposes.
- CVWR on Port lands. The Reserve is currently undergoing restoration. This Reserve was created by constructing an access levee/road and a ring levee system in a subtidal area of south San Diego Bay. Dikes were designed to erode down over time. Enhancement potential should be integrated with any mitigation plans for the planned South Bay power plant shutdown. Create additional intertidal wetlands and improve wetland-upland transition. Establish tidal channels. Tern nesting could be expanded or improved by addition of a sand cap. Possible constraints are: there may be effects on the South Bay Power Plant intake/outflow channels (but the existing plant is scheduled to be torn down or re-engineered in the long run); possible alteration to water temperature patterns in south bay; and effects on green sea turtle, fisheries, and waterfowl.
- D Street Fill, approximately 100 acres of dredge spoil from Sweetwater Channel owned by USFWS and the Port. Portions are currently graded for least tern nesting. Excavate a tidal channel across fill, and create additional intertidal salt

marsh (~25 to 30 acres). Possible constraints are marsh enhancement must be balanced with the needs of the existing tern site and a spoil disposal method needs to be determined.

Specific Concerns

- The difficulty of crossing jurisdictional, ownership, and project boundaries does not allow mitigation planning to consider the functions most limiting to the San Diego Bay ecosystem as a whole. It is believed that more landscape-based, cross-jurisdictional planning could improve the sustainability of projects, and perhaps result in a better network of systems more productive and functional for all biological communities.
- Experimentation and innovation in design for ecologically sound mitigation projects are currently accomplished only within the confines of permit processing and the economics of project proponents. Broader support is needed to encourage innovation and improved techniques.
- There are currently no financial incentives to improve the habitat value of necessary armoring, to minimize its use, or to remove unnecessary armoring in favor of a natural shoreline. Additionally, technical expertise may be limiting the availability of designs to make riprap walls and other artificial structures more valuable as habitat and less damaging to intertidal habitats.
- Without provisions in current mitigation, enhancement, and other projects involving infrastructure to accommodate and provide buffers for expected sea level rise and possible warmer water temperatures, their long-term success will be jeopardized. Sea level rise will affect most of the existing habitat in the bay. For example, cordgrass at the lower end of the salt marsh will be drowned out, or eelgrass could be killed by lack of light penetration when water deepens or die back from warmer water temperatures.
- One of the promising locations for enhancement work is the South Bay NWR. Opportunities to conduct work in the Refuge are limited due to legal restrictions on the use of mitigation funds in a NWR.
- There is no mechanism for assigning restoration priorities based on vulnerability (risk) and irreplaceability of the habitats. For example, salt marsh is less vulnerable to loss now because it is mostly already lost, and what remains is mostly protected. Alternative approaches to enhancement have not been fully explored as a management opportunity; therefore, reduced and fragmented acreage remains a problem for dependent sensitive species and the ecosystem as a whole.

Current Management

Much of the creation, restoration, and enhancement of habitat that has occurred in San Diego Bay is the result of mitigation for impacts caused by development and other projects that either fall under the regulatory purview of the CWA or the ESA. Mitigation of direct, indirect, or cumulative impacts may also be conducted under NEPA, CEQA, CZMA, or CCA. See Section 3.6: Overview of Government Regulation of Bay Activities.

Projects that fall under the CWA or harbor species protected under the ESA result in creation, restoration, and enhancement of bay habitat.

Mitigation is the avoidance, minimization, rectification, and reduction or elimination of negative impacts or compensation by replacement or substitution (Office of Technology Assessment 1984). When an unavoidable impact requires compensation through creation, restoration, or enhancement of habitat, the mitigation site may be adjacent or nearby to the impacted habitat (onsite mitigation), or may be outside the habitat sustaining the impacts (offsite mitigation). The mitigation project may replace the resources that are lost with resources that are physically and biologically the same (in-kind mitigation) or different (out-of-kind mitigation) (Lewis 1989). Mitigation that requires replacing habitat may involve creation of new habitat or restoration and enhancement of existing habitat. Habitat creation is the conversion of one type of habitat into another type by human intervention (Lewis 1989) (e.g. excavating a wetland out of upland habitat).

In 2008, the EPA and the USACE modified the mitigation rules to set mitigation banking as the preferred alternative for impacts to wetlands and other natural resources from construction projects. The Port is in the process of creating a mitigation bank for Port tidelands property including the creation of an eelgrass mitigation bank. The Port's Mitigation bank, once approved, will be used to offset any impacts from construction or maintenance projects around the Bay.

Achieving compliance criteria is not the only value provided by mitigation projects.

A mitigation project is considered successful under the CWA or ESA when the project compliance criteria are achieved. However, a project that does not achieve its compliance criteria may provide other useful values, and a project that does achieve compliance criteria may not be considered "successful" in replacing the ecological function when compared to natural habitat.

Guidelines for mitigation under §404(b)(1) of the CWA are listed in EPA regulations (40 CFR 230–233) and the Memorandum of Agreement between the USACE and EPA on these guidelines. Of the Special Aquatic Sites identified to receive greater scrutiny under these guidelines—sanctuaries and refuges, wetlands, mudflats, vegetated shallows, riffle and pool complexes, and coral reefs—only wetlands (in the bay's case, the salt marsh) are specifically identified as requiring "a minimum of one-for-one replacement (i.e. no net loss of value) with an adequate margin of safety to reflect the expected degree of success associated with the mitigation plan."

A permit may be denied if "significant degradation" would result, or if an alternative exists that will meet the project purpose. The USACE will grant a permit unless it is determined to be contrary to public interest.

For intertidal habitat other than salt marsh, unvegetated shallows, and deep subtidal habitats in the USACE jurisdiction (below +7.8 feet [2.4 m]), compliance with 404(b)(1) Guidelines is essentially evaluated qualitatively and involves exercise of the judgment of the USACE in each permit application. The USACE is required to deny the permit if the findings show that the proposed discharge, even with mitigation, would result in "significant degradation," which includes consideration of effect of the fill on the water bottom, water flow and circulation, turbidity, the aquatic ecosystem and organisms, contamination of the water, and downstream resources (40 CFR 230.10[c]). The guidelines apply an additional burden of proof requirement covering special aquatic sites such as salt marsh, mudflats, and eelgrass beds—to demonstrate that no practicable alternatives exist that will meet the project purpose (40 CFR 230.10[a]).

Within the restrictions of EPA §404(b)(1) Guidelines, the USACE will grant a permit unless the permit is determined to be contrary to public interest. To determine effect on public interest, the USACE is required to balance the benefits expected against the foreseeable detriments of the proposed project. The factors considered in this review are conservation, economics, aesthetics, environmental quality, historic values, fish and wildlife values, flood control, land use, navigation, recreation, water supply and quality, energy needs, safety, food production, and the general public and private need and welfare (33 CFR 320.4).

Under authority of the CCA and the federal CZMA, the CCC has jurisdiction over permits for development in the coastal zone within wetlands, tidelands, submerged lands (below mean low tide), beaches, estuaries, riparian habitat, streams and public trust lands. The definition of wetlands used by the CCC differs from that of the USACE in that it includes nonvegetated areas such as mudflats and an additional 100 feet (30 m) wide terrestrial buffer measured from the upland edge of the wetland.

Mitigation is also required for impacts to threatened and endangered species protected under the federal and state ESAs. Excluding species that are associated with riparian habitat, there are three federally endangered species, two federally threatened species, and five state endangered species associated with San Diego Bay (see Table 2-48 for special status species and Appendix D for species and their habitats). The federal ESA requires that USFWS protect and restore threatened and endangered species and their critical habitat and that federal actions avoid impacts to these species. Under the parallel state ESA, the CDFG must be consulted on state projects that may impact endangered species.

It is important to document the evolution of mitigation policy in southern California. A brief history of mitigation in southern California is presented below in Table 4-2.

Table 4-2. Brief history of eelgrass mitigation in southern California.

The practice of mitigation for projects permitted under the CWA, ESA, and other environmental laws has evolved greatly over the more than 20 years since these laws were first enacted and enforced. During the late 1960s to early 1980s, a series of federal laws were passed that, together, form the core national policy for protecting natural resources. How this policy manifested itself in southern California and San Diego Bay is a story of, at first, resistance to change, then step-by-step acceptance and progressively honing the pragmatic details of making the policy work site by site, project by project.

An example is the evolution of mitigation practices for impacts to eelgrass habitat. At first, neither the regulator nor the project sponsor knew how to successfully establish eelgrass in a technical sense. There was no field experience on which to base methods. According to regulatory guidelines, the goal of compensatory mitigation was to prevent any net loss of function, area, or value. No one knew if compensation for impacts was even accomplishable, let alone enforceable. Methods were developed over time by both scientific experimentation and trial-and-error.

In addition, there was resistance to even attempting to compensate for eelgrass losses. Some project sponsors flatly refused to attempt eelgrass planting until they were threatened with legal action. The original criterion for “success” was simply getting the project sponsor to conduct eelgrass planting at all.

In the 1970s, the Navy was one of the first to mitigate for a bay fill with eelgrass planting. It failed based on today’s success criteria, but at the time there were no performance standards. With evolving technical expertise, it became clear that eelgrass could be established successfully in the field, and that a certain density of planting could be required within a specified time frame. Enforceable performance standards began to become a practicality.

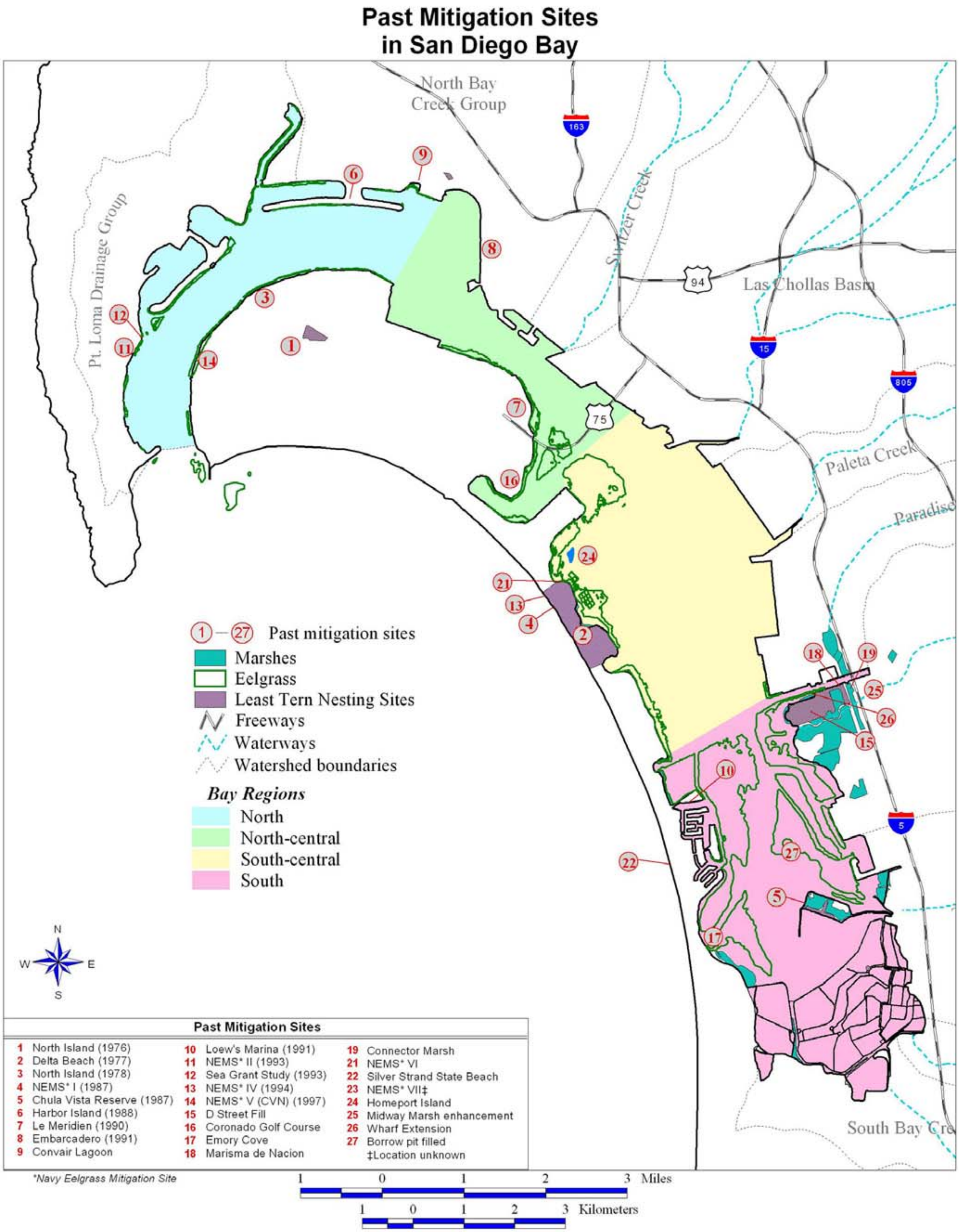
Gradually, as requirements and enforcement became more consistent and predictable, mitigation became accepted simply as a cost of doing business. This cost began to increase as the technically easy sites were taken, and project sponsors were forced into more challenging environments. Coincident with this cost increase, the number of permit applications decreased. Today, the requirement to compensate for eelgrass impacts requires more technical expertise, money and innovation than ever. The dramatic losses of eelgrass habitat that occurred prior to the CWA have abated.

The sum of this experience is found in the Southern California Eelgrass Mitigation Policy, first approved in 1991 by NMFS, USFWS, and CDFG, and last revised in 2005 (Rev. 11, 30 August 2005). The Policy is endorsed by USACE and the CCC. It has helped standardize the resource agencies’ response to projects such as dredging, pile-driving, in-water military training and operations, and research and development work.

Some past mitigation projects in San Diego Bay are shown in Map 4-2, which includes a brief description of each. Photo 4-1 shows an example of eelgrass in readiness for planting.

Projects that are “beyond mitigation and compliance” are those intended to: restore or enhance the condition of the Bay; are not required; and are generously funded through the Port’s Environmental Fund. The Environmental Committee and Fund was adopted in June 2006 by the BPC, Policy 730. Per the BPC direction, the Environmental Committee will assist the Port in evaluating and implementing programs to ensure the protection and improvement of the Bay.

Photo 4-1. Eelgrass ready for planting. Photo courtesy of Eileen Maher.



Map 4-2. Past mitigation sites in San Diego Bay.

Evaluation of Current Management

The previous INRMP recommended improving the effectiveness of mitigation in achieving the ecosystem objectives of the INRMP. There have been some successes regarding the recovery of certain severely depleted habitats for which little opportunity exists for enhancement in the usual project mitigation setting. Intertidal flats, upland transition, and cordgrass are such habitats. However, more consensus is needed on priorities and flexibility in crossing jurisdictional boundaries (both ownership and regulatory agency) in order to implement the beneficial use of dredge material, out-of-kind mitigation, or other means, to enhance severely depleted habitats. It is possible that in some cases, mitigation for a series of projects may be combined for the purpose of accomplishing a larger or more ecologically effective project without fines or penalties. This is a form of mitigation banking.

The following evaluation focuses on mitigation under the CWA and ESA. While the NEPA review process can also play a role in reducing environmental effects, many projects are small enough that a significant impact cannot be documented.
In addition, to be effective, a biologist must be involved at the site-selection and design phase, typically much earlier in the planning process than NEPA currently becomes engaged in some organizations.

Eelgrass

Mitigation policy and management for eelgrass has been very successful in increasing the amount of eelgrass habitat in San Diego Bay. During the last 10 years, most eelgrass transplant projects in San Diego Bay have met the permit success criteria of vegetative cover and density and have resulted in a net increase in eelgrass coverage. Although the success criteria are based on structural attributes only, a study conducted in Mission Bay suggests that full functional value is achieved in transplant sites within two to three years (R. Hoffman, *pers. comm.*; Hoffman 1990). Fish use was compared between a transplanted site and adjacent natural eelgrass beds, and within two to three years fish use of the transplanted eelgrass was equivalent to the natural eelgrass. Although benthic invertebrates and other resources were not specifically studied, it was assumed that they were present to support the fishes. In a study by Takahashi (1992) in the bay, the invertebrate fauna (Photo 4-2 for example) in transplanted eelgrass beds was found to become established within a short time. Additional studies could determine the success of eelgrass transplant projects in attaining full functional value for all resources including, for instance, development of detrital exchanges with other habitats. Detrital exchange is a primary way organic matter is made available to consumers–many animals feed on detritus.

Full functional value is achieved in eelgrass transplant sites within two to three years. Most eelgrass transplant projects have resulted in an increase of eelgrass coverage.

Photo 4-2. Eelgrass epibiota. Photo courtesy of Merkel & Associates.

Currently, at least some eelgrass is present in all locations of San Diego Bay that are suitable for its growth (R. Hoffman, *pers. comm.*). This means that there are currently few, if any, suitable sites for transplanting. Since there is currently no out-of-kind mitigation allowed for eelgrass impacts, projects must excavate uplands or fill deeper habitat to a suitable depth to support eelgrass transplants. For example, to mitigate recent Navy dredging that impacted eelgrass habitat, the dredge material was deposited in an area too deep to support eelgrass. Filling in this habitat solved the light penetration problem and the site became suitable for eelgrass growth.

Intertidal Flats

A mudflat mitigation project was completed off the NAB shoreline as mitigation and enhancement related to the second new nuclear carrier project. Generally, however, with nearly three-quarters of the shoreline length affected by stabilization structures and over-steepened or affected by too strong a current, and only 16% of the original tidal flat area remaining compared to historic acreages, little opportunity remains for enhancement of severely depleted intertidal flats through conventional mitigation policy implementation.

Salt Marsh

Some success has been demonstrated for salt marsh restoration, such as the Port's 2004 marsh restoration for the National City wharf expansion with cordgrass and annual pickleweed. This is a key improvement over previous efforts at salt marsh mitigation, which were believed to have replaced the structure and some, but not all, functions of these habitats. The most visible lack of function was the lack of use by marsh birds, especially for nesting by the light-footed clapper rail. This loss was documented both at the CVWR and at the Paradise Creek and Marisma de Nacion constructed marshes. The Connector Marsh mitigation project was an example of a project where mitigation criteria were changed, after litigation, to include functional requirements, as described above (See Table 4-7). The functions of the marsh system may have been missing due to problems with nitrogen levels, abundance of invertebrates, and the presence of invasive species (Zedler 1991).

Work in Mission Bay (Levin *et al.* 2000) examined four years of faunal recovery in a newly constructed marsh compared to a reference site. Fishes and invertebrate epifaunal components of the constructed marsh developed the most rapidly. Within six to nine months, densities of these groups had recovered to natural marsh levels. However, size structure and other properties remained different in the created and natural systems. Macrofauna developed more slowly. Density and species richness were similar between the constructed and natural marsh after two and one-half years, but species composition continued to differ after three and one-half years. Insect larvae colonized first, followed by oligochaetes. Natural spatial recovery in sediment particle size, soil organic matter, and elevation appeared to drive plant recovery and faunal recolonization patterns in the constructed marsh. Higher sea level associated with El Nino appeared to accelerate faunal development.

Levin (2000) made the following recommendations for salt marsh restoration based on this study:

1. Assess elevation carefully in design of restored marsh habitat. Lower elevations are wetter and promote more rapid development of macrofaunal assemblages.
2. Analyze pre-existing spatial variation in soil texture and organic matter content and, where possible, use historical marsh sediments. Finer-grained sediments with below-ground detritus promote marsh grass growth and a more abundant and diverse infauna. Sites that historically supported marsh habitat are more likely to exhibit these sediment properties and will experience enhanced restoration success.
3. Amendment of constructed marsh soils with Milorganite or a similar sewage-based product may promote development of plant and animal communities most similar to those in natural marshes.
4. Recognize rafting as a major marsh recolonization mechanism for fauna and create linkages (e.g. connecting channels) that promote transfer of plant and algal rafts from natural habitat.

5. Incorporate intertidal pools and other shallow-water habitat in the design of constructed marshes to provide nursery habitat for resident fishes.
6. Slow recovery rates and inter-annual variability suggest that long-term monitoring is required to accurately evaluate restoration success.

Fish Enhancement Structures

Long-term monitoring programs of finfish in southern California have found that in-bay and offshore artificial reefs can be productive at or above the levels of natural reefs (Pondella *et al.* 2002; Stephens and Pondella 2002). Reef systems have also been used to offset or mitigate for habitat loss in various estuarine systems worldwide (Davis 1985; Feigenbaum *et al.* 1989; Bortone *et al.* 1994; Kennish *et al.* 2002). Subtidal structures have been introduced into the bay to enhance fisheries at several locations: North Island, Shelter Island, a borrow pit in South Bay, south Embarcadero Fishing Pier, Coronado Marriott near shore, and Navy Homeport Island enhancement site. Pondella (2006) conducted a five-year study on a set of such structures at the Navy North Island enhancement site made of concrete or rock on fish utilization over time and comparing concrete versus rock types. He found that integrating enhancement reefs with eelgrass restoration in San Diego Bay at this site was an innovative design that benefited use by fishes at both the enhancement site and nearby eelgrass beds. These enhancement reefs can be built with either quarry rock or concrete rubble, and the distance between reef modules appeared to make a difference to their use by fish. His results demonstrated that, in addition to fostering a vibrant and complex fish community, the reefs increased localized fishery production in terms of both eelgrass restoration and production of target species of various species of sea bass.

Management Strategy—Mitigation and Enhancement

Objective: Improve the success of mitigation and enhancement projects based on regulatory (avoidance and minimization measures), functional, and ecosystem criteria.

I. Achieve no net loss of structure and function of natural intertidal and shallow subtidal habitats and a long-term net gain in acreage and function.
   A. Aggressive avoidance should remain the primary strategy to avoid loss of natural resource values in the bay.

II. Improve the effectiveness of mitigation and enhancement in achieving the ecosystem objectives of this INRMP.
   A. Seek an “optimum” landscape mix based on the best available knowledge of the following habitat attributes:
      - Most impacted (e.g. intertidal flats, salt marsh including, river mouths, shallow subtidal);
      - Most vital in terms of function. An important step in terms of knowing this is defining the functions natural resource managers are most interested in promoting. Some functions will simply not be as valuable as others, but knowing the functions that are of value will automatically help in identifying which areas are worth preserving;
      - Most limiting to protection of rare species (e.g. upland transition and intertidal sand flats, mudflats); and
      - Most at risk of loss (e.g. intertidal and upland transition).
   B. Establish a consensus among regulatory and resource agencies on target acreages in each of the above categories as a guide for mitigation planning. Revisit targets on a regular basis to evaluate their practicality as a management tool.
   C. At every reasonable opportunity, orient mitigation opportunities towards improving the value of severely depleted habitats for which little opportunity exists for enhancement in the usual project mitigation setting. Intertidal flats, upland transition, and cordgrass are such habitats. Such efforts should not result in a loss of fish or other pre-project habitat values.

D. Allow more flexibility in crossing jurisdictional boundaries (both ownership and regulatory agency) in order to implement on a case-by-case basis the beneficial use of dredge material, out-of-kind mitigation, or other means to enhance severely depleted habitats. Such efforts should not result in a loss of fish or other pre-project habitat values.

E. Develop agreements with resource agencies whereby mitigation for a series of projects may be combined for the purpose of accomplishing a larger or more ecologically effective project, without fines or penalties. This is a form of mitigation banking.

F. Maximize the habitat value and function of man-made structures in the bay through the permitting process.

1. Assess the relative habitat values of existing man-made structures in the bay. The value of the man made structures cannot be compared with any natural counterparts since hard structures are not natural to San Diego Bay. Their ecological value will entirely be based on what managers "want" out of them, and some are clearly support more abundant and diverse species than others.
2. Find means through the permit process or otherwise to encourage experimentation and installation of man-made habitats that function more like mudflats and tidepools. Mitigation performance standards should include both structural and functional criteria. Structural criteria describe the abundance, composition, and biomass of the ecosystem components (such as sediment, pore water, plant, invertebrate, and vertebrate properties). Functional criteria emphasize the processes that take place among the components, such as primary and secondary productivity, and use by species.
3. Conduct research to develop and validate practical, specific, quantitative measures for attributes of habitats that promote functions upon which plants, fish, and wildlife depend, such as:
   - Provision of food (trophic functions)
   - Provision of stopover or safe habitat for migratory species
   - Provision of nursery grounds for juvenile stages of fish, shellfish, and birds
   - Support of endangered or threatened species
   - Shoreline stabilization (reduced erosion)
   - Groundwater recharge
   - Trapping of particulates and pollutants from the watershed
   - Elemental recycling
   - Buffering of shoreline from destructive action of storm waves and currents
   - Export of energy and organisms to adjacent open water habitats
   - Bioturbation and irrigation of sediments (release or burial of pollutants)
   - Biodiversity maintenance
4. Consider the contents of Table 4-3 as a preliminary example of measures that should be researched to determine their level of importance, practicality, and cost-effectiveness for use as a performance standard.
5. Develop a mechanism to ensure the incorporation of attribute measures determined to be important into permit conditions for monitoring.

G. Use the Southern California Eelgrass Mitigation Standards as a model for developing and improving policy in intertidal and shallow unvegetated areas.

H. Explore the use of public-private partnerships to implement up-front mitigation, with sufficient time to demonstrate "success" prior to project approval.

Table 4-3. Attributes that should be researched to determine their level of importance, practicality, and cost-effectiveness for use as a performance measure .

Attribute	Subtidal Unvegetated	Subtidal Vegetated	Intertidal Mudflat	Intertidal Sandflat	Upland Transition	Salt Marsh	Shoreline Structures
Sediment Properties ■ particle size ■ organic matter content ■ salinity ■ incident light ■ Eh/pH (redox) ■ permeability and porosity ■ drainage patterns ■ sediment accumulation and erosion ■ pollutant concentrations	X	X	X	X	X	X	
Landscape Properties ■ patch area and configuration (dimensions) ■ elevation ■ boundary integrity ■ connectivity to other habitats including influence on adjacent habitats -for example, riprap has been shown to harbor fish that can completely alter the community composition of soft bottom habitats for hundreds of yards in every direction (B. Pister, *pers. comm.*)	X	X	X	X	X	X	
Vegetation Cover ■ algae and vascular plant density and biomass ■ primary production ■ density of critical function ■ density of endangered plants		X			X	X	X
Invertebrates ■ abundance/density/diversity of infauna ■ density of critical function taxa ■ diversity of infaunal/epifaunal lifestyles (e.g. dwelling modes such tube builders, burrowers, or attached) and feeding modes (suspension feeders, surface deposit feeders, herbivores/grazers, carnivores, scavengers ■ presence of larger infauna (ghost shrimp, clams, etc.) ■ bioturbation	X	X	X	X	X	X	X
Vertebrates ■ use by rays, California halibut, and other fishes (e.g. killifish) ■ use by birds (habitat, feeding, nesting) ■ diet analysis by stomach contents or isotopic analysis	X	X	X	X	X	X	X
Invasives ■ proportion (by abundance, biomass or % cover) ■ habitat alteration by invasives ■ invasive species role in food chains	X	X	X	X	X	X	X
Endangered or Threatened Species Use ■ density and diversity ■ spatial and temporal distribution ■ threats	X	X	X	X	X	X	X
Linkages With Adjacent Habitats ■ migratory birds ■ fishes ■ particulate and pollutant transport	X	X	X	X	X	X	X

I. Whenever possible, mitigation performance standards should use long-term, functionally based assessments, particularly for created habitats. Alternatively, mitigation performance evaluation should be integrated with regularly conducted "State of the Bay" assessments proposed by this INRMP. Long-term observations are necessary because of the extremes that occur in southern California (e.g. high variability in rainfall and stream flow) and to identify cause and effect.

J. Mitigation banking may be advantageous as an instrument on a restricted basis, such as for implementing out-of-kind mitigation for specific ecological objectives of this INRMP or other watershed-based or regional plan, within a basic no-net-loss framework. Since mitigation banking presupposes continued development impacts on protected habitats, including those recognized to be highly limiting and already heavily impacted in the bay, it should be accomplished as part of a public process that seeks to guide and balance the projection of any future losses and include this INRMP's goal and objectives. The EPA has draft banking mitigation language available.

III. Conduct baywide or coarser scale mitigation planning.

A. Identify and map all potential restoration and enhancement sites in the bay. Use Table 4-4 as a starting point.

Table 4-4. Candidate enhancement opportunity areas. Modified from Restoration & Enhancement Plan: To Benefit the Bay's Natural Resources (2008).

Area	Description and Possible Enhancement Opportunities/Constraints
1—D Street Fill, Chula Vista (potential Port Mitigation Site)	Area of approximately 100 acres (40 ha) of dredge spoil from Sweetwater Channel. Portions currently graded for least tern nesting and entire area is designated as critical habitat for the western snowy plover. National City wharf extension project was mitigated by creating wetlands from uplands and planted with cordgrass and eelgrass along northern margin of fill along Sweetwater Channel. *Enhancement Potential:* Excavate additional tidal channels and create additional intertidal (~25 to 30 acres/~10 to 12 ha). *Possible Constraints:* Must balance marsh enhancement with needs of existing tern site and western snowy plover critical habitat designation.
2—Gunpowder Point (USFWS-NWR)	A 36 acre (15 ha) "island" of coastal sage scrub and maritime succulent scrub surrounded by small areas of intertidal salt marsh and flats. *Enhancement Potential*: The San Diego Bay NWR CCP proposes a range of restoration subplans including creation of expanded tidal mudflats or salt marsh habitat, but most of enhancement potential is for upland transition habitat. *Possible Constraints:* Suitability of soils, proximity to D-Street Fill may result in problems associated with improved nesting for predators of the least tern and snowy plover.
3. F & G Street Marsh, connector marsh, and associated mudflats (USFWS-NWR)	Located in Chula Vista near BF Goodrich. Ephemeral tidal marsh at "F" Street and poorly flushed saltwater marsh on "G" Street, both serviced by a small, ineffective culvert. The Chula Vista Bayfront Master Plan development, as mitigation, will conduct some restoration work. *Enhancement Potential:* Excavate an additional channel, create refuge islands, create secondary tidal channels, and bayward expansion of the salt marsh. Expansion of J Street marsh into the upland transition zone. Needs improved flushing, possibly by new enlarged culvert and channel between culvert and Bay. Needs clearing of sediment, trash. Should close to recreational all-terrain vehicle traffic. *Possible Constraints:* Questions regarding current habitat conditions and possible impacts associated with enhancement projects. Suitability of soils.
4—J Street marsh, connector marsh, and associated mudflats	Intertidal mudflat and low-lying salt marsh and upland transition located adjacent to South Bay Power Plant on J Street. The Chula Vista Bayfront Master Plan development, as mitigation, will conduct some restoration work. *Enhancement Potential:* Expansion of the marsh into the upland transition zone.
5—CVWR	Reserve was created from dredge spoils from construction of the Chula Vista Marina. Created by constructing an access levee/road and a ring levee system in a subtidal area of south San Diego Bay. Dikes were designed to erode down over time. *Enhancement Potential:* Integrate with any mitigation plans for power plant. Create additional intertidal wetlands. Improve wetland-upland transition. Reserve could be expanded on the south, west, or north sides to create additional intertidal and salt marsh habitats. Reduce water-born debris. *Possible Constraints:* Effects on power plant intake/outflow channels (but the existing plant is scheduled to be torn down or re-engineered in the long run). Possible alteration to water temperature patterns in South Bay. Effects on green sea turtle, fisheries, and waterfowl values. Impact of construction activities on current habitat values.
6—South Bay Salt Ponds (USFWS-NWR)	Once the largest expanse of tidal salt marsh in south San Diego Bay, now the South San Diego Bay NWR. *Enhancement Potential:* The San Diego Bay NWR CCP proposes a range of restoration subplans including improving levees by replacing soil material and removing vegetation, enhancing the riparian habitat at the mouth of the Otay River, planting cordgrass, and expanding salt marsh. *Possible Constraints:* Impacts of enhancement projects on current habitat values for shorebirds and nesting seabirds.
7—Lower Otay River Watershed (USFWS-NWR)	An undeveloped upland site adjacent to tidal flow in Pond 20 that runs through the South San Diego Bay NWR. *Enhancement Potential: T*he San Diego Bay NWR CCP proposes a range of restoration subplans including realigning and broadening the Otay River to a more natural configuration through Pond 20 and other Refuge property. Excavate 8 acres fresh-brackish pond, establish 44 acres of tidal salt marsh and channels, and another 40 acres of willow-riparian woodland and mudflat riparian scrub. This could involve dredging or removing the train track berm. Control trash by upstream trash catchers.
8 - Ecological Buffer for Chula Vista Bayfront Master Plan	Ecological buffer between the Refuge and Sweetwater District Chula Vista Bayfront Master Plan will be 400 feet wide. 200 feet of the buffer is a no touch zone where all pedestrian traffic will be eliminated. *Enhancement Potential:* Planting buffer with native plants and expanding adjacent salt marsh into the ecological buffer.
9—Emory Cove and Reserve (potential Port Mitigation Site)	Located in South Bay on the western shore along Highway 75. It is an area of degraded wetlands and transitional uplands. *Enhancement Potential:* Marsh enhancement. Conversion of uplands to salt marsh habitat. Control trash. Remove invasive species.*Possible Constraints:* The Navy uses the channel for training.
10—Coastal Strand Dunes (U.S. Navy)	Navy property that runs along the western shore of Central Bay. *Enhancement Potential:* Remove invasive species, revegetate with natives, and restore dunes.
11—Grand Caribe Isle South/Coronado Cays (Port Mitigation Site)	Located in South Bay in the Coronado Cays. The BPC has set this site aside as mitigation for a future Port project. *Enhancement Potential:* Create intertidal habitat and salt marsh habitat. Create shallow subtidal habitat for eelgrass.
12—Crown Cove (U.S. Navy)	Crown Cove is Navy property in the South Bay along the western shoreline. *Enhancement Potential:* Removal of invasive species and debris. Construction of a boardwalk and launch dock to avoid disturbance of marsh habitat. Enhance existing salt marsh and dunes.
13 - Navy Radio Receiving Facility (U.S. Navy)	The NRRF is Navy property located in South Bay on the western shoreline. *Enhancement Potential:* Remove invasive plants. Restore dunes and vernal pools.
14—Paleta Creek Mouth (U.S. Navy/City of San Diego)	Located within the 32nd Street Naval Station. *Enhancement Potential:* Restoration of remnant salt marsh and shoreline. Work with landowner to shallow the banks as they lead into the Bay.
15—Chollas Creek Mouth (Port/U.S. Navy/City of San Diego)	Located between NASSCO and 32nd Street Naval Station. *Enhancement Potential:* Restoration of remnant salt marsh and shoreline. Work with landowner to shallow the banks as they lead into the bay.
16—Shoreline Point Loma Naval Station (U.S. Navy)	The shoreline between Navy's SUBASE and fuel pier in Point Loma is a disturbed dune habitat. *Enhancement Potential:* Protect foraging and loafing value for birds. Remove invasive plants. Recontour the cliff to historic configuration. Fill in and build up beach. Restore the uplands.
17—NASNI shoreline (U.S. Navy)	NASNI shoreline varies from beach to random rubble and rock revetment. *Enhancement Potential*. Enhance shoreline by removing structures, the boat ramp, and an old seaplane ramp.
18—NTC boat channel (U.S. Navy)	Channel is Navy property located north of the Airport. *Enhancement Potential*. Soften the shoreline and provide ecologically beneficial shoreline structures. Improve the wetland-upland transition. Consider vegetated swales for storm water runoff filtration.
19—Coronado Bayfront	Located along First Street between the Ferry Landing and the Aircraft Carrier Turning Basin. Shoreline now too narrow for effective shorebird use. *Enhancement Potential:* Enhance habitat value by creating artificial hard substrate. Broaden the shoreline and existing mudflat to improve intertidal habitat. Combine erosion control with ecologically beneficial shoreline treatment. *Possible Constraints:* Ensure eelgrass is protected with any change in shoreline structure.
20—Coronado Golf Course	The shoreline along the Coronado golf course adjacent to Glorietta Bay is a sandy beach with riprap stabilization. *Enhancement Potential*. Construct artificial hard substrate to enhance habitat value without affecting the adjacent navigation channel.
21—North Delta/NAB (U.S. Navy)	Navy property located south of the NAB in Coronado. Used for nesting by California least tern. *Enhancement Potential*. Reconstruct mudflat.
22—South Bay Power Plant includes Telegraph Creek, intake and discharge channels	Power plant discharge channel is home to a significant population of green sea turtles. Telegraph Creek is a concrete lined channel. *Enhancement Potential.* Integrate with plans for CVWR. Enhance and restore intertidal and shallow subtidal habitat in the intake and discharge channels for green sea turtle and other species. Remove concrete in Telegraph Creek and return site to a more natural configuration and create estuary habitat by planting marsh plants.
23—Sweetwater Flood Control Channel (Port/USACE)	Located on the border of National City and Chula Vista on the eastern shore of the Bay. *Enhancement Potential*. Remove the hard shoreline. Create salt marsh. Restore the natural connection and riparian upstream habitat. Remove invasive plants.
24 - BF Goodrich Marsh (USFWS-NWR)	BF Goodrich Marsh is located in Chula Vista near the F & G Street Marsh. *Enhancement Potential:* Restore remnant salt marsh. Remove debris and invasive species.
25—Convair Lagoon	Located north of the USCG Station along Harbor Drive. About 7 acres capped for PCB contamination and an L-shaped berm put in place. *Enhancement Potential:* Extend the fill to the east and west of the riprap berm around the cap to create additional shallow water area for eelgrass habitat. *Possible Constraints:* Ongoing contaminant concerns.
26—Mudflats off D Street Fill and SWNWR	Mudflats off of Sweetwater NWR is located south of the Sweetwater Channel. *Enhancement Potential:* Protect and enhance existing mudflats.

B. Identify target acreages for each of four bay regions for functional habitat enhancement on a landscape level.

C. Indicate the most appropriate restoration procedures for each site. Use scientific principles as a guide:

1. Large patch sizes support and maintain high biodiversity.

2. Good linkages with adjacent habitats and few barriers to water flow and animal movement support greater biodiversity. Small habitat remnants are likely to have lower resilience and less resistance to natural and man-made perturbations. Improve, expand, and link existing habitat remnants in preference to creating new habitat patches.

3. Specific communities will develop best if located near or adjacent to an existing community of the same type (so it can propagate and establish on its own).

4. In some cases, maximizing habitat "edges" will maximize a system's value, such as for marsh bird foraging. However, maximizing edges can have negative effects depending on disturbance regimes and the target management species.

D. Favor in-kind mitigation as a first choice unless the out-of-kind mitigation is for a more scarce habitat (Table 2-3) than the impacted site. Use the following priorities as a guideline for mitigation siting:

1. Link smaller, disconnected sites to larger ones.

2. Identify sites of high habitat value or that function as biodiversity reserves (e.g. intertidal salt marsh, mudflats, eelgrass beds) and expand these areas.

3. Expand area of smaller patches of high value or biodiversity, emphasizing the currently existing habitat.

4. Once expanded patches show promise for attracting and supporting sensitive species, create such habitat types at locations that formerly included them.

E. Leave as a last priority the creation of habitats at sites where they have never occurred historically.

F. Where no match is possible for in-kind mitigation, or where extensive modifications are likely to be unsuccessful, establish out-of-kind compensations within San Diego Bay that still contribute to the goal and objectives of this INRMP.

G. Integrate watershed and regional planning into bay ecosystem enhancement goals.

IV. Develop the inter-agency agreements and permit mechanisms necessary to achieve ecosystem-level strategies advocated by this INRMP.

V. Conduct more effective preplanning to avoid costly delays in project mitigation.

A. Major project proponents should hold quarterly meetings with regulators during which projects are presented at the 10% design phase.

B. Develop a project preplanning form to help communicate key parameters of a project, regulators' expectations, and compatibility of projects with the objectives of this INRMP.

VI. Support more effective regional mitigation standards and innovation and experimentation in mitigation technology, allowing for an adaptive management approach.

A. Determine how to identify and measure habitat values and functions (see also Chapter 2 and Chapter 6).

B. Research rare, endangered, and exotic species, particularly population dynamics; how they interact within their communities; minimum viable population size; and the habitat size necessary to support them (Williams and Zedler 1992).

C. Carry out ecological studies to determine what conditions limit ecosystem development so that appropriate performance standards can be met (Zedler 1996a).

D. Link research with mitigation monitoring to help explain habitat requirements, causes, and effects.

   1. Gain further understanding on what are the "natural" or expected levels of population fluctuations of eelgrass beds.

   2. Determine if there are some potential threats to eelgrass beds that can be managed for, such as invasive species.

   3. Gain knowledge on biological organization and physical estuarine processes, such as primary productivity, nutrient dynamics, and habitat specificity (e.g. the salinity tolerance of marsh plants or estuarine usage of fish and wildlife). Start by organizing and making available data that already exists.

   4. Facilitate small-scale experimentation with techniques to improve the success of mitigation, and disseminate this information to others.

   5. Verify physical modeling of bay circulation and tidal flushing.

4.2.1 Protected Sites

Specific Concerns

San Diego Bay has already lost about one-third of its original habitat area, much of it the intertidal and shallow subtidal regions that provide the bay's core wildlife values. The emphasis in this section is on applying existing statutes and regulations to help protect these sites of concern. Regulatory protections by agencies are addressed in Chapter 5.

Concerns specific to protected habitat sites in the bay include the following:

Regulatory protections are addressed in Chapter 5.

- Site protection is one step but does not necessarily imply sufficient management to address baywide or ecosystem level habitat degradation, management of conflict among special status and other species, or reduction of threats to natural resources values.
- Some bird populations are impaired by reduced amounts of intertidal habitats (salt marsh, mudflat, and areas with a mix of shallow zones) both in San Diego Bay and elsewhere along the Pacific Flyway.
- Minimum size, configuration, and management of protected sites is needed to sustain natural habitat values and functions.
- Management of these sites is often impeded by inadequate funding and staffing. Some sites are prone to illegal activities because of inadequate surveillance.
- Regulatory protection under the CWA does not necessarily guarantee that replacement mitigation sites achieve the value and function of natural ones in the time frame allotted for project monitoring (Zedler 1996a).

Current Management

Marine and coastal habitat areas in San Diego Bay that are designated for some level of protection from development are listed in Table 4-5, shown in Map 4-3 and are discussed below. Acreage figures are given for habitat types located within the sites. These federal, state, and local areas have varying degrees of management protection.

Table 4-5. Marine and coastal habitat areas in San Diego Bay that are designated for some level of protection from development.

Designated Areas[a.]	INRMP San Diego Bay Habitat Classification	Acres	Hectares
Habitat Protection Areas (in order of relative protection)			
South Bay Marine Biological Study Area (19.4 acres/7.9 ha)/County of San Diego, Parks and Recreation Department (U.S. Navy license)			
Also known as “South Bay Wildlife Preserve” or as “Educational Ecological Preserve.” Use limited to study of marine biology and open to students in County. Five Year Renewable License with the Navy since 1972.	Intertidal Flats	1.7	0.7
	Marsh	15.7	6.4
	Upland Transition	1.9	0.8
Emory Reserve (102.4 acres/41.4 ha)/San Diego Unified Port District			
	Intertidal Flats	74.5	30.2
	Marsh	8.5	3.4
	Upland Transition	4.0	1.6
	Shallow subtidal	15.4	6.2
Chula Vista Wildlife Reserve (61.8 acres/25.0 ha)/ Port of San Diego			
Designated in Master Plan as “Habitat Replacement”; uses limited to nature study, academic research and instruction, and similar resource uses. Boundary and use can be amended.	Intertidal Flats	10.2	4.1
	Marsh	33.0	13.3
	Upland Transition	18.6	7.5
Homeport Island	Shallow Subtidal	15	6.1
	Intertidal Flat	4	1.6
Midway Marsh	Salt Marsh	14	5.7
Wharf Extension Marsh	Salt Marsh	6	2.4
Silver Strand State Beach (40 acres/16 ha)/CDPR (U.S. Navy lease)			
Managed under 1984 general plan, uses include day use picnicking and a trail system on the bay portion. Navy lease expires in 2022. One parcel presently under negotiation with Navy for exchange purpose.	Intertidal Flats	0.6	.24
	Upland Transition	39.4	16.0
South San Diego Bay San Diego National Wildlife Refuge (2292 acres/927 ha)/USFWS and SLC (Includes Sweetwater and South San Diego Bay Units of the National Wildlife Refuge)			
Property and lease purchased in 1999 by the Port from Western Salt and donated to the USFWS for the Refuge. Primary intent is for wetland restoration, California least tern nesting site mitigation, and shorebird habitat protection.	Freshwater marsh	0.9	0.4
	Riparian	2.3	0.9
[This plant community summary excludes 95 acres of salt marsh restoration and enhancement at Pond 20 (E. Maher, pers. comm. 2007)]	Non-native Annuals (old ag fields)	97.7	39.6
	Upland/Transition	21.2	8.6
	Intertidal Flat (Mudflat)	259.7	105.1
	Salt Marsh	7.8	3.2
	Salt Pond	1037.3	420.0
	Levee	57.8	23.4
	Open water	807.3	326.8
	Eelgrass[b]	*412.5*	*167.0*
SUBTOTAL Habitat in Protected Sites (Refuge/Reserve/Study Area).		*2554.5*	*1034.2*
Port of San Diego Jurisdiction: Land and Water Use Designation with Some Level of Habitat Protection (in order of relative protection)			
“*Wetlands*” (305 acres) as defined by 2007 Port Master Plan			
To be preserved, protected, and where feasible, restored. Included is a Wildlife Preserve subarea contiguous to the north of the Navy-owned and designated South bay Wildlife Preserve (aka Marine Biological Study Area).	Shallow Subtidal	3.3	1.3
	Intertidal Flats	203.1	95.8
	Eelgrass[b]	*48.5*	*19.6*
	Marsh	31.1	12.5
	Upland transition	1.1	0.4
“*Habitat Replacement*” (945 acres) as defined by 2007 Port Master Plan (besides CVWR [see above], also a portion of D Street Fill).	Intertidal	1.4	0.6
	Upland Transition	18.0	7.3
Uses limited to nature study, academic research and instruction, and similar resource dependent activities.			
“*Open Bay*” (328.37 acres/132.9 ha)			
For the multiple uses of recreation and natural habitat.	Deep Subtidal	18.4	7.4
	Medium Subtidal	44.2	17.9
	Shallow Subtidal	157.8	63.9
	Intertidal Flats	104.6	42.3
	Eelgrass[b]	*50.7*	*20.5*
	Marsh	6.8	2.8
“*Estuary*” (1059 acres/ ha) as defined by 2007 Port Master Plan			
Uses limited to new or expanded boating facilities, intake and outfall lines, restoration work, nature study, aquaculture, and resource-dependent activities. Can be used for boating, fishing, and similar water sports as long as efforts are made to reduce potential environmental damage.	Deep Subtidal	20.0	8.1
	Medium Subtidal	78.3	31.7
	Shallow Subtidal	645.6	261.4
	Intertidal Flats	199.7	80.9
	Eelgrass[b]	346.3	140.2
	Marsh	2.8	1.1
	Upland Transition	0.2	0.08

Table 4-5. Marine and coastal habitat areas in San Diego Bay that are designated for some level of protection from development. (Continued).

Designated Areas[a.]	INRMP San Diego Bay Habitat Classification	Acres	Hectares
SUBTOTAL Habitat in SDUPD Zones			
Only these Water Use Zones	Deep Subtidal	20.0	8.1
Estuary	Medium Subtidal	78.3	31.7
Habitat Replacement (including CVWR) 55 acres	Shallow Subtidal	645.6	261.4
	Intertidal Flats	211.3	85.5
	Eelgrass[b]	*346.3*	*140.2*
	Marsh	35.8	14.5
	Upland Transition	36.6	14.9
SUBTOTAL		*966.0*	*391.1*
TOTAL for All Sites with Some Level of Habitat Protection			
All categories (without double-counting of CVWR)	Deep Subtidal	38.4	15.5
	Medium Subtidal	156.6	63.4
	Shallow Subtidal	837.1	338.9
	Intertidal Flats	859.5	348.0
	Eelgrass[b]	*858.0*	*347.4*
	Marsh	97.9	39.6
	Primary Saltpond	1037.3	420.0
	Upland Transition	104.4	42.3
	Riparian	2.3	0.9
TOTAL		*3,991.5*	*1,616.0*

a. The San Diego Bay NWR is administered by the USFWS and acreages are taken from its CCP (2006). The CVWR is administered by the Port and property acreage is an estimation from the 2007 Revised Port Master Plan. The South Bay Marine Biological Study Area is administered by the County of San Diego, leased from the U.S. Navy. Correct acreage as reproduced from a map provided by Realty Division, NAVFAC Southwest.

b. Eelgrass represents a subset of intertidal and shallow subtidal, therefore eelgrass acreages are counted into the total acreages.

The Port Jurisdiction Water Use Designations were reproduced from the 2007 Revised Port Master Plan and acreages are approximations. See San Diego Bay Port Jurisdiction Master Plan Water Designations Map 3-4 and San Diego Bay Habitat Map 2-11 for locations. All habitat acreages are approximations.

Note: 18.8 acres of "D" Street Fill currently not in INRMP footprint.

Table 4-5 describes types of federal, state, and local protections for various habitats within the bay.

A total of about 1,400 acres (567 ha) was added to the NWR system in 1999 to the existing Sweetwater Marsh unit (316 acres [128 ha]) established in 1988. The Port bought out the unexpired lease on 600 acres (243 ha) owned by the SLC and presently leased by Western Salt. The Port also contributed $900,000 for a management and restoration endowment for the new refuge. The Port's action was called "a stunning move forward in protection of the bay" by one local environmentalist (Klimko 1998). The South San Diego Bay NWR is now federally owned. Its designation protects the largest remaining tidal salt marsh in San Diego Bay.

Missions and policies for the NWR system as a whole were established with the National Wildlife Refuge System Administration Act of 1966 and by Congress in the National Wildlife Refuge Improvement Act of 1997. Under this Act, the USFWS prepared a CCP, which is mandated for all refuges lacking a plan. With funding provided by the Port, the USFWS prepared a CCP for the South San Diego Bay NWR in 2000. Both the Sweetwater Unit of the Refuge and the 1,400-acre (567 ha) addition of the South San Diego Bay Unit are covered in the CCP with specific restoration plans for each analyzed in an EIS. The allowable uses of the lawsuit-created Sweetwater Unit were spelled out in the USFWS BO of 1988 and more recently in this CCP. Nature interpretation and environmental education is actively pursued on the site through the Chula Vista Nature Center, operated by the City of Chula Vista. Public access is encouraged but restricted to approved trails during daylight hours. Volunteer groups help manage the property through cleanups, trail building, revegetation, installation of artificial nesting platforms, and more. No hunting is allowed.

The South Bay Marine Biological Study Area (also called "South Bay Wildlife Preserve" or "Ecological Preserve" on some maps and signs) is a 27 acre (10.9 ha) site in the southwest corner of the bay that is owned by the Navy and has been leased to the County of San Diego since May 1972 (recently changed to the City of San Diego). Since 1974, the Navy has issued five-year licenses for the purpose of "the establishment of an Educational Ecological Preserve which is open to the public," with use limited to the study of marine biology and open to the students of the Unified School Districts of San Diego

County. As conditions of the lease, the Navy requires compliance with the CWA's §404 conditions for wetlands. The site contains 26.35 acres (10.7 ha) of "federally protected wetlands" and the City cannot do any manipulation projects, including restoration, without a "Modification of License" from the Navy to ensure §404 permit compliance.

The CVWR is the most well-recognized site designated by the Port for protection.

Protected sites by the Port are described in the Port's Master Plan and accompanying Planning Area Maps (1980, as amended). The CVWR may be the most obvious protected site by its title, though designated "Habitat Replacement" in the Master Plan. It is a 55 acre (22 ha) artificial island created during 1977–1980 with dredged sediment from the Port's completion of the Chula Vista boat basin. In 1983 the constructed perimeter dikes were breached in two basins to allow tidal flow with the intent of creating a salt marsh. Use is limited to nature study, academic research, instruction, and similar resource-dependent activities. However, other water areas in the Port's jurisdiction are also designated for some level of protection from development, with "*Wetlands*" and "*Habitat Replacement*" the most restrictive categories and "*Open Bay*" and "*Estuary*" the most flexible. The Emory Reserve contains 8.5 acres (3.4 ha) of vacant uplands adjacent to Highway 75. Table 4-6 describes the intent of allowable uses within each planning designation.

The Navy lands also provide habitat protection, particularly for shorebirds and seabirds, through the following:

1. Security restrictions on public access;
2. Proactive management program for California least tern nesting colonies, as described in a MOU with USFWS (USFWS and Navy 1993);
3. Practices and projects defined in each facility's INRMP.

Habitat conservation is provided by the Navy through a combination of designations and management practices.

Silver Strand State Beach encompasses two parcels on the bay side of this coastal strand habitat. During World War II, the Navy dredged and filled most of this site, creating a larger parcel of above-water property out of the tidal flats. An area of relict coastal dune habitat can still be found along the eastern edge of Highway 75. A parcel of about 40 acres (16 ha) adjacent to the NAB is leased from the Navy to the CDPR for the State Beach, with a lease expiration date of 2022. Together with a southern state-owned parcel, the State Beach property includes 4,600 feet (1,402 m.) of bay frontage (CDPR 1984).

CDPR manages state-owned and Navy-leased parcels on the bay side of Silver Strand State Beach for certain habitat protection as well as for passive recreational use.

Management by CDPR is based on the 1984 general plan for this State Beach. The leased parcel is a passive recreation area with a formalized trail system to control foot and bike traffic. After discovering a population of the sensitive and endemic plant, Nuttall's lotus, plans for a campground were dropped. Interest in developing boat berthing and access was expressed in the plan, but the Navy has not clarified its approval of such use of the tidelands. The state-owned parcel is developed with day use and maintenance facilities. If other sensitive species are found, the park will restrict public access to the specific site (E. Navarro, CDPR, *pers. comm.*). A habitat restoration plan was implemented on the 40 acre (16 ha) parcel (M. Wells, CDPR, *pers. comm.*).

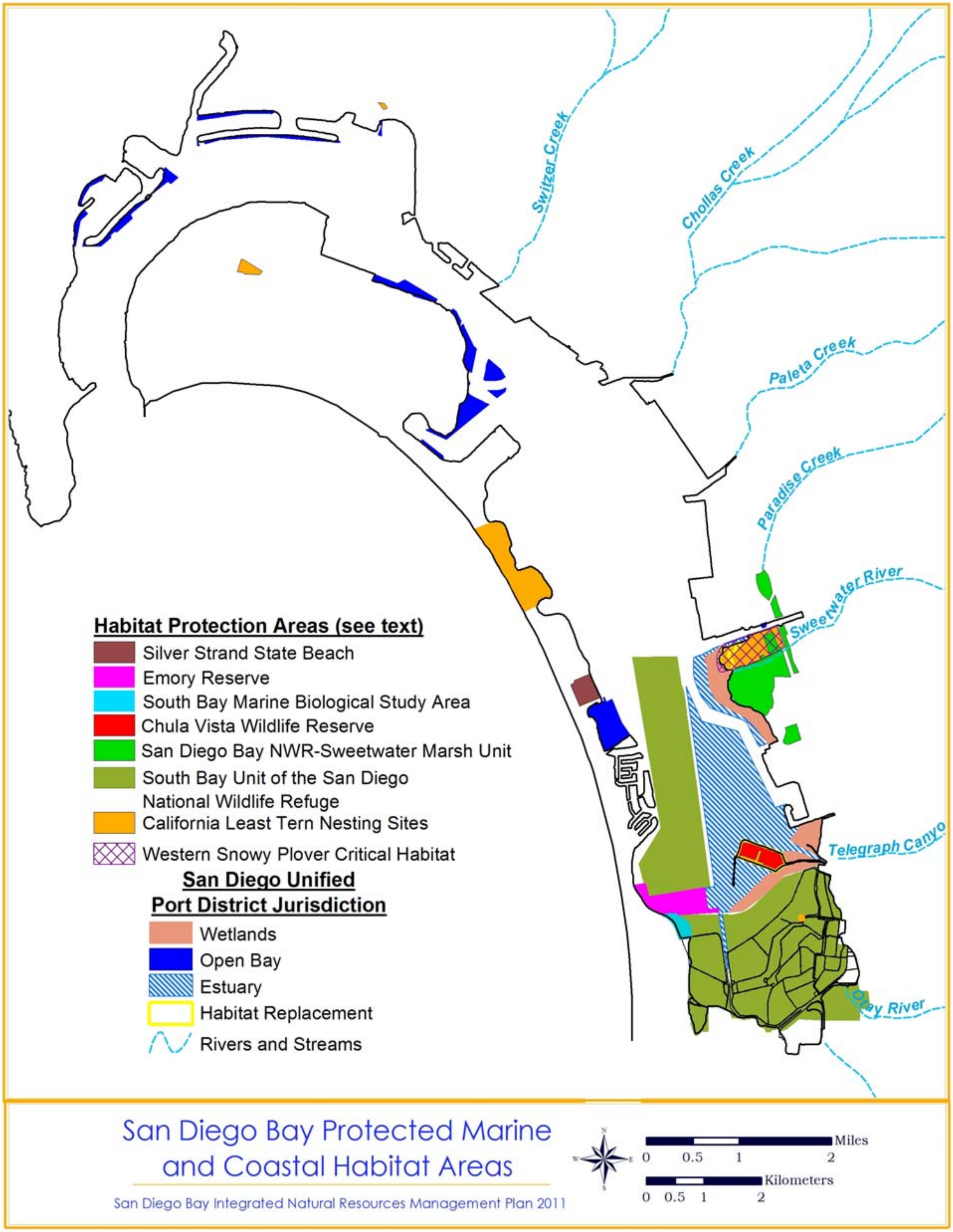
Evaluation of Current Management

Designated protected habitat amounts to 1,996 acres within the INRMP's footprint.

As shown in Map 4-3, the amount of designated protected habitat is 1,996 acres (808 ha) in addition to over 1,400 acres (590 ha) protected to some degree from development through Port use restrictions.

Baywide, biologists seek to:

1. Sustain the highest natural resources values possible in small parcels;
2. Sustain high natural resources values in artificial habitats such as shoreline structures;
3. Ensure connectivity among fragmented parcels (example: salt marshes are fragmented by hardscape, levees, and roads, cutting off connections to adjacent marsh habitats necessary for species migration and recolonization);
4. Resolve conflict between bay uses and natural resources;
5. Manage the competing uses of natural resources by different species groups including competing needs of special status species; and
6. Reduce threats such as invasive species, predation on special status species, and sea level rise.



Map 4-3. Protected marine and coastal habitat in San Diego Bay—2007.

While the Refuge offers protection from many human conflicts and was established "to protect and restore the small portion of the bay where native habitats remain," to benefit "federally listed and other trust species," the focus on federally listed and other USFWS trust species does not address some of these more baywide concerns.

Other designations, such as the South Bay Marine Biological Study Area and the CVWR, may be less permanent as tideland owners can change their intent for use of the sites or the size of the boundaries. The Port's Master Plan designations and allowable uses can be changed by amendments or through the Master Plan revision. This planning process, however, is open to public scrutiny and final approval by the CCC. In addition, the Port provides some beneficial habitat management: debris removal, wildlife monitoring, predator control, pollution controls, speed limit enforcement for boats in South Bay, environmental education, and an Environmental Fund for many natural resources-related projects (SDUPD 2007).

Not all designations offer permanent protection as owners can change their intent or the size of the boundaries. Protective management practices continue to benefit these sites.

Almost 25 years old, the Silver Strand State Beach General Plan is in the process of being amended. As of late 2007, meetings had been held with the City Council of Coronado and the Coronado Cays community to consider the concept of adding rental beach cottages in the parking lot area.

Management Strategy—Protected Sites

At least two options are available to add permanently protected sites in San Diego Bay if this is considered to be a priority: (1) creation of Marine Protected Areas (MPAs); or (2) additional protective management practices within existing protected sites.

In coastal marine waters, MPAs are designated for a variety of purposes and are represented by various state and federal names, such as marine refuges, reserves, sanctuaries, or ecological preserves. MPAs are commonly defined as "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (McArdle 1997). Table 4-6 lists the state MPA options that have not yet been used but could apply to sites within San Diego Bay. Quite a few of these options have been designated on the ocean side of Point Loma and La Jolla.

MPAs are intended to protect intertidal or subtidal habitats. Table 4-6 gives examples of some available State designations that are options for the bay.

Table 4-6. State Marine Protection Area options: intent, methods, examples.

Program or Designation	Intent	Method of Designation	Responsible Agencies/Regional Examples
Ecological Reserves (Fish and Game Code Sect. 1580 14 Cal.Adm.Code 630)	To protect threatened or endangered native plants, wildlife, or aquatic organisms or specialized habitat types, both terrestrial and aquatic, or large heterogeneous natural marine gene pools for the future use of mankind. Designated to be preserved in a natural condition or to be provided some level of protection for the benefit of the general public to observe native flora and fauna and for scientific study or research. In general, all living resources in a reserve are protected, unless specifically exempted.	CDFG, with approval of the Fish and Game Commission, may obtain, accept on behalf of the state, acquire, or control, by purchase, lease, easement, gift, rental, MOU, or otherwise for the purpose of establishing Ecological Reserves. Commission adopts general regulations for the occupation, utilization, operation, protection, enhancement, maintenance, and administration of the reserves, including any limits on resource takings, activities, and other uses. Shore angling generally allowed, but not boating or swimming without a permit.	California Fish and Game Commission, CDFG; local agency also San Dieguito Lagoon Ecological Reserve San Diego-La Jolla Ecological Reserve
Refuges (Clam, Fish, Game, Marine Life) (Fish and Game Code §10500–10514 *et al.*)	To protect specified invertebrates and plants for the purpose of propagating, feeding, and protecting wildlife. Categories include waterfowl, marine life, fish, and clam refuges. Designation may be for one or more categories and may include other specified limitations on activity.	Legislative action is needed to establish, except for clam refuges. Fish and Game Commission may accept donations, land, or wildlife, and may acquire by purchase, lease, rental or otherwise, and occupy, develop, maintain, use or administer land, or land and water, or land and water rights, suitable for refuges. SLC lease may be needed.	California Fish and Game Commission, CDFG San Diego Marine Life Refuge
Reserve (Fish and Game Code 200 *et al.*)	No legally mandated mission accompanies reserve designation. Each site has its own site-specific regulations.	Fish and Game Commission receives proposal and follows a multistep designation process. Then regulations are proposed, with public hearings, and a Final Statement is submitted to the Office of Admin. Law for approval. SLC lease may be needed for submerged lands.	California Fish and Game Commission; CDFG Point Loma Reserve
State Reserve, or State Underwater Park (Public Resources Code 5019.71; 5019.65.)	Reserve—Areas with outstanding natural or scenic characteristics of statewide significance established to preserve in a condition of undisturbed integrity. Underwater parks exist within or adjacent to existing units, leased from SLC.	Designated by CDPR Commission. CDPR works in cooperation with CDFG for regulations. Underwater park is not an official designation type with the State Park System.	CDPR/CDFG/or City (Underwater park) San Diego-La Jolla City (Underwater Park)
University of California Natural Reserve System	To preserve and manage the state's natural diversity to meet the university's teaching and research needs in disciplines that require field work. Each reserve functions as an outdoor classroom or laboratory.	UC Natural Reserves are designated by the Regents of the University of California.	UC Office of Pres., NRS Office, and UC campus Kendall-Frost Mission Bay Marsh UC Reserve

The success of MPAs in protecting marine resources is also varied. In a recent evaluation, identified benefits included an increase in marine populations when "no take" policies are enforced, maintenance of species and genetic diversity, and natural baselines to measure effects of resource use, such as fishing (McArdle 1997). Ineffectiveness was attributed to lack of clearly defined management objectives; inadequate enforcement; external factors; fragmented boundaries; and piecemeal, crisis-oriented designations. Interest in MPAs is growing rapidly as they are being viewed more often as a means of managing marine resources at an ecosystem level.

Objective: Ensure effective protection of a minimum quantity and quality of the remaining marine and coastal habitat in San Diego Bay, targeting a mix of habitat types that maximizes ecosystem function and carrying capacity.

I. Provide protection from development of additional areas of sensitive and high value habitat.

- *A.* Seek protective designation of habitat parcels with priority based on the most vital to ecosystem function. Since the bay ecosystem is not understood well enough such that a minimum acreage and configuration of habitats is known, use the following as a guideline in the meantime:
  - Most impacted habitat;
  - Most at risk of loss;
  - Most limiting to protection of rare species.
- *B.* Expand connections among marine, coastal, and upland natural habitat remnants, with careful consideration of the needs of and risks to endangered species remnant populations and habitats.
  - *1.* Pursue opportunities to provide linkages of smaller marsh, intertidal, and shallow unvegetated habitats, and improve value of connecting habitat.
  - *2.* Seek linkages of coastal habitats with adjacent ecosystems (uplands, riparian corridors, and nearshore waters).
    - *a.* Promote benefit to ecosystem values of San Diego Bay with on-going natural community planning programs, watershed management approaches and plans, and riparian park planning (e.g. Otay River).
  - *3.* Guard against potential increase in predator-prey conflicts and invasive species introductions that may arise on coastal habitat from improved access to riparian and upland habitat (see Section 4.4.6.2: California Least Tern and Section 4.4.1: Invasive Species).
- *C.* Investigate the usefulness of a state-designated MPA for marine habitat not protected under other designations.
  - *1.* Determine pros and cons of the various MPA options for presently under-protected sites, particularly intertidal habitat.
  - *2.* If the evaluation is positive, then pursue designation.

II. Support protective management of existing protected areas within San Diego Bay.

- *A.* Promote the development of effective, up-to-date, adaptive management plans that are consistent with this INRMP for:
  - *1.* SMNWR in combination with the South San Diego Bay NWR by USFWS.
  - *2.* South Bay Marine Biological Study Area by the County of San Diego Parks and Recreation Department.
  - *3.* CVWR by the Port.
  - *4.* Sites designated for habitat protection values (i.e. wetlands, estuary, open bay, and habitat replacement) by the Port in its Master Plan.
  - *5.* Silver Strand State Beach by the CDPR.
- *B.* Encourage management strategies that adequately conserve the functions of the existing habitat.
  - *1.* Promote cooperative agreements with resource protection agencies.

2. Include appropriate strategies from this INRMP.
3. Allow only those uses that are compatible with their habitat protection purpose.
4. Support a watershed planning approach whenever appropriate (see Section 5.3: Watershed Management Strategies).

C. Seek adequate funds for the planning and maintenance of the protected sites by the managing agencies.
1. Encourage local, state, and federal agencies to include adequate funding within their budgets for this purpose.
2. Provide adequate surveillance of sites to discourage illegal activities.
3. Support the establishment of Environmental Restoration Funds as a supplemental funding source for management of these protected sites.

4.3 Strategy for Habitat Management

4.3.1 Deep Subtidal

Specific Concerns

See also Section 2.5.1: Deep Subtidal (>-20 feet [-6 m] MLLW).

- Deep subtidal habitat has increased at the expense of shallower types, which are the most productive bay habitats both locally and regionally.
- Channels of adequate depth and width are needed to support the navigation and commerce functions of the bay; existing depths may not be adequate for future needs.
- Deep water use by foraging and rafting birds may be disturbed temporarily by turbidity plumes from construction and dredging projects, storms, and chronically by boat and ship traffic. Turbidity effects from vessel traffic on biological resources are unknown.
- Spatial and seasonal patterns of temperature, salinity, plankton, and invertebrates (water column and benthic) in deep water habitat have not been adequately described, yet they have significant implications for the bay's ecosystem.
- Deep water links regions of the bay together hydrologically, affecting the export of energy and organisms among habitats and out to sea. Deeper dredging and lengthening of deep channels affect bay circulation, velocity, tidal flushing, subsurface erosion, and sediment movement throughout the bay, but with unknown ecological implications or significance.
- Most of the deep benthic habitat has been disturbed by channel dredging and repeated maintenance dredging, with the presumed impact based on the untested assumption that recolonization by natives, not invasives, occurs fairly rapidly.
- Inputs may still be affecting ongoing contamination status of the deep water column and sediment, with unknown consequences for biota.
- Opportunities are needed in the bay to provide for more shallow habitat without impacting the navigation channel function of deep water habitat. Narrowing the width or constraining the realignment of navigation channels to provide more shallow subtidal habitat restoration opportunities may conflict with harbor safety.

Current Management

Dredge or fill impacts within deep subtidal habitat are usually considered temporary as benthic organisms recolonize the habitat within a short time.

Compared to historic (1859) conditions, deep water habitat in the bay has increased by 1,800 acres (728 ha), or 100%, opening up the harbor for navigation. The deeper and more extensive the dredging, the more harbor- and ocean-like the bay becomes, rather than providing the unique functions now concentrated in shallow areas along bay margins. Seasonal stormwater inflow (via storm drains and urban runoff to creeks) may now be the most important external source of nutrients to the deep water of the bay (WURMP 2003, 2007). The volume, seasonality, and composition of this water has changed due to urbanization of the upper watershed.

Effects to deep subtidal habitat are evaluated on a case by case basis. For example, the effects of dredging a deep habitat even deeper typically do not merit mitigation while using dredge material to raise the bay bottom for eelgrass planting can be applied as mitigation or enhancement. These impacts are usually considered temporary since benthic organisms will recolonize the habitat within what is believed to be a short time frame. This time frame and the nature of the recolonization (i.e. species composition and abundance) are being tested in the bay and elsewhere under a project paid for by the Ports of San Diego, Los Angeles, and Long Beach, as well as NMFS (Eileen Maher, Port, *pers. comm*). Guidelines for avoiding, minimizing, and mitigating these impacts are those of the overarching §404 of the CWA, with onsite and in-kind mitigation usually the preferred type. Actual requirements in San Diego Bay are decided on a case-by-case basis.

Evaluation of Current Management

The efforts of residents and regulatory protection have made San Diego Bay cleaner than it was 40 years ago.

Good water quality is a key attribute requiring consideration in this habitat. Toxic, point-source discharges have largely been abated with the exception of accidents, residual from past abuses, upland sources, and possible contaminants from ship and boat hulls. Efforts by San Diego residents in the 1950s and 1960s to divert sewage to ocean outfalls, and subsequent regulatory protection, have resulted in a much cleaner bay than that of 40 years ago. All point source discharges in the bay from municipal, industrial, and military sources currently have NPDES permits from the RWQCB that they must comply with. If not in compliance, they are issued a cease-and-desist order. Cleanup of nonpoint source (runoff) pollution to this habitat remains the primary and potentially more elusive target. Urban stormwater runoff is presently under NPDES permit for the bay's jurisdictions (WURMP 2007).

It is poorly known what effects the deepening and shrinkage of the bay from its historic proportions and changes in the dynamics of freshwater inflow have had on how the bay functions as a whole system. These may have changed tidal flushing, nutrient availability, and other processes that are tied to the interchange of energy and organisms among habitats, as well as the quality of habitat available.

While the deep water region is recognized as supporting the least abundance and diversity of organisms in the bay, it remains important in providing decomposition functions that make nutrients available to higher organisms. The role the deep water region plays in transporting planktonic larvae of both resident and migrating organisms is also important. However, this role is so poorly quantified that prioritizing management activities remains difficult.

Management Strategy—Deep Subtidal

Objective: Retain sufficient deep subtidal habitat to support safe navigation, good water quality, and physical and biological functioning in balance with the need for other habitat types in the bay.

I. Support continued management of the deep subtidal for navigation but identify channels that have been abandoned and can be used as enhancement sites by accepting clean dredge material.

  A. Maintain adequate width and depth of existing channels for safe navigation.

  B. Conduct dredge and fill operations in the deep subtidal as based on the use strategy detailed in Section 5.4.1: Remediation of Contaminated Sediments. Allow for limited extension (depth, width, length) of existing channels.

II. Avoid and minimize impacts to the water quality and physical and biological functions of deep subtidal habitat in conjunction with other bay habitats.

- *A.* Determine the ecological significance of changes to the bay's water quality, circulation patterns, sediment movement, and biota that could result from proposed projects (e.g. deepening or lengthening navigation channels) in the deep subtidal.
  - *1.* Use appropriate models, such as the TRIM hydrodynamic model developed at SPAWAR, to help answer management questions related to sediment transport in deep waters, such as the effects of deeper dredging on habitat functions of the more marginal bay habitats.
    - *a.* Verify the soundness of these models.
  - *2.* Support the implementation of sediment quality objectives and WQS specific to San Diego Bay that will provide a practical and realistic measure of the health of this habitat.
  - *3.* Promote better understanding of the biotic consequences of water and sediment contamination of the bay's deep water habitat.
  - *4.* Promote better understanding of the resuspension and distribution of bay sediment to support future sediment cleanup projects.
  - *5.* Identify the important biological functions of deep subtidal habitat through appropriate research, as described below.
- *B.* Promote avoidance and minimization measures for rafting and foraging birds due to expanding or deepening the deep subtidal.
  - *1.* Avoid and minimize impacts to birds rafting and foraging in the open water, navigation channel areas.
    - *a.* Manage when turbidity plumes from dredging and construction projects as much as possible.
    - *b.* Identify and implement methods to reduce disturbance by ships, boats, and recreational craft.
    - *c.* Avoid when possible dredging very close to salt marsh or mudflat habitat.
    - *d.* Consider keeping new navigation channels to the east side of the bay, where they are currently aligned.
  - *2.* Specify and apply existing criteria to evaluate effectiveness of mitigating and enhancing deep subtidal habitat.
- *C.* Explore alternative methods to recapture some of the abundant deep subtidal areas in order to develop more of the scarce shallow subtidal (<12 feet [3.7 m]) habitat.
  - *1.* Identify possible sites where realignment of existing navigation channels could provide sufficient slope and width for shallow subtidal habitat.

III. Pursue cost-effective, targeted monitoring and applied research that addresses management-related questions about the deep subtidal habitat.

- *A.* Evaluate the spatial and seasonal distribution and abundance of biota in the deep subtidal habitat zone, with priority on those biota for which inadequate information is available.
  - *1.* As a further focus, determine the rate, extent, and quality of recolonization of benthic deep subtidal habitat disturbed by maintenance or construction dredging projects, including the effect, if any, on the spread of invasive invertebrates.
  - *2.* Determine the linkages of ecosystem function between deep subtidal and the other bay habitats.
- *B.* Directly measure and observe long-term trends in key biological and water quality parameters of the deep subtidal zone, using scientifically valid methods that are low in expense, in order to foster their long-term implementation, yet high in providing insight.

1. Sustain and expand long term monitoring efforts to evaluate baseline conditions of key water quality parameters at established and representative sampling locations throughout the bay, building on the work of Bight 1998, 2003, and 2008, as well as the RHMP.
    a. Focus on shifts attributed to seasonal or regional water mass events and the range of diurnal and tidal parameter fluctuations to better understand known point source effects to overall bay water quality.
    b. Establish an adequate number of representative sampling stations in diverse locations throughout the bay. Sample intensely around project sites and during a range of seasonal, diurnal, and tidal cycles.
2. Focus on evaluating practical indicators to measure so that they may more likely be monitored on a long-term basis (e.g. chlorophyll *a*, zooplankton biomass, transparency, dissolved oxygen, temperature).
3. Obtain samples at the surface and at incremental depths to the bottom, including the benthic.
4. Seek cooperative assistance in implementing monitoring, such as from Navy or Port personnel, volunteers, or college students who can be trained and have boat access to the stations.
5. Compare results with those for equivalent parameters collected in the ocean and estuaries of the SCB and for the bay's RHMP.

4.3.2 Moderately Deep Subtidal

Specific Concerns

- Moderately deep subtidal habitat provides an opportunity for habitat enhancement with fewer navigational need conflicts. However, the opportunity for beneficial use of dredge material for such enhancement comes rarely and may require innovative implementation of CWA and other applicable guidelines without compromising their intent, including protection of water quality, fish habitat, and other functions and values.
- Moderately deep areas are candidates for expansion of deep navigational channels.

See also Section Chapter 2.5.2 Moderately Deep Subtidal.

Current Management

This habitat is managed similarly to deep water.

Evaluation of Current Management

While the same questions about current management remain for this habitat as for deep water, they are perhaps of more immediate importance in moderately deep habitat. This is because the habitat overall is more stable, having remained undisturbed by dredging for well over 50 years, and thus the benthic community and its functions may be better developed. These moderate depths can be made shallower and more productive by the use of dredged material. The shallower habitat would be expected to benefit from the establishment of algal communities on the benthos, unlike deeper habitat where insufficient light reaches the bottom to support these communities. As a result, they have a separate value from deep water areas by virtue of their long-term lack of disturbance from dredging, potentially more well-developed benthic community, and their enhancement potential.

There is a possibility that regular dredging could help manage invasive species if the species is locally isolated and not easily spread. However, dredging is costly, and exotic species tend to quickly colonize disturbed areas altered by such control activities. If a dredge does not completely remove all plant or invertebrate fragments, the area will quickly re-colonize, thereby negating the effect of the measure. This was evident at Mallards Landing on Lake Winnisquam in 2001 and at Jay's Marina on Lake Winnisquam, which was quickly colonized by milfoil after dredging for boat navigation in the 1980s (Smagula 2005). In contrast, dredging has been successfully employed on one occasion for eradication of an exotic aquatic plant infestation in New Hampshire. Milville Lake, Salem was dredged in the mid1980s to remove an infestation of exotic fanwort and the lake has not been re-infested since.

Management Strategy—Moderately Deep Subtidal

Objective: Conserve and enhance the attributes of moderately deep habitat that support diverse and abundant invertebrate forage for fishes and birds, as well as needed exchanges of energy, materials, and biota among habitats, in balance with the need for shallow and intertidal habitats.

I. Identify importance of rafting shorebirds (see Chapter 4.3.1 Deep Subtidal), fishes, and production of abundant and functionally diverse invertebrate forage for rays, California halibut, sand bass, and other predators.

- *A.* Discourage new navigation channels in this habitat in order to conserve opportunities for creation or enhancement of shallow and intertidal habitats.

II. Moderately deep subtidal habitat should be targeted for potential habitat enhancement by converting to shallower depths that are more productive.

- *A.* Conduct the preplanning necessary to take advantage of opportunities for filling moderately deep habitats to shallow or intertidal elevations.

III. Investigate and monitor attributes of moderately deep habitat as described for deep habitat, but with emphasis on the benthos which is expected to be better developed than in deeper habitat.

4.3.3 Unvegetated Shallow Subtidal

Specific Concerns

See also Section 2.5.3.1: Unvegetated Shallows (-2.2 to -12 feet [-0.7 to -3.7 m] MLLW).

- Only about 59% of historic (1859) shallow subtidal habitat, both vegetated and unvegetated, remains today in the bay. It is therefore considered a scarce habitat that requires conservation and enhancement.
- While less productive for fishes overall than vegetated sites, unvegetated shallows play an important ecological role in food web support and are critical to the needs of certain rays and flatfishes, including use as a nursery by the California halibut, a commercial species. Red algal mats add three-dimensional structure to this habitat in much of the bay especially in the summer, and its significance has not been evaluated quantitatively. Shallow subtidal habitat may be lost to projects such as expanding navigation channels, pier construction, or the building of boat ramps.
- Project construction in subtidal shallows can create temporary turbidity that impacts foraging for the endangered California least tern and other birds. Per the existing MOU between the Navy and USFWS, no construction in these habitats occurs during least tern nesting season.
- While recognizing that much of the bay functions as a nursery for various fishes, specific nursery locations within unvegetated shallow subtidal areas of the bay are not identified, so they cannot be managed to prevent conflict with users.

Current Management

Mitigation decisions for unvegetated shallow subtidal habitat are made on a case-by-case basis within the guidelines of §404 of the CWA.

This habitat is regulated due to its status as waters of the United States under §404 of the CWA, by §10 of the Rivers and Harbors Act, and as EFH under the MSA. The values of unvegetated shallow subtidal are described in the results of past fish surveys, as well as the baywide eelgrass surveys and in the recently completed baywide avian surveys. Within those guidelines mitigation decisions in the bay are made on a case-by-case basis.

Per the existing MOU between the Navy and USFWS, there is no construction allowed during the least tern nesting season and therefore no turbidity plumes or construction noise during the least tern nesting season.

Evaluation of Current Management

There are no local standards in place for offsetting losses of this habitat as there are for eelgrass. The lack of descriptive or quantitative information about the values at stake in unvegetated areas has probably hindered the development of such standards, especially since it has been considered “less productive” compared to neighboring eelgrass beds. As for ESA, this habitat (as well as the rest of the surface area of the bay) is used by the least tern and brown pelican for foraging. There is no critical habitat designation for any of the waters of the bay including this habitat.

Management Strategy—Unvegetated Shallows

Objective: Conserve and enhance the attributes of unvegetated shallow subtidal sites that sustain diverse and abundant algae, invertebrate community, fish and wildlife foraging, as well as an ecological role in detritus-based food web support.

I. Avoid and minimize losses of unvegetated shallows as a first priority, using clear guidelines for best practices.

II. Support effective mitigation for loss of unvegetated shallow subtidal habitat quantity and quality.

- *A.* Continue to implement Best Management Practices (BMPs) during construction and dredging projects to keep temporary turbidity increases to a minimum, to avoid and minimize impacts to foraging birds and fishes.
- *B.* Develop guidelines for avoidance, minimization and mitigation.
  - *1.* Since project impacts are relatively infrequent and small-scale in unvegetated shallows, implement mitigation requirements on a case-by-case basis using the following as a guide:
    - *a.* Provide clear guidelines for avoiding and minimizing impacts.
      - *1.* Alternative, innovative designs should be encouraged and considered early in the project planning stages that minimize impacts. Adjustments in project locations should also be considered to avoid or minimize impacts.
    - *b.* Mitigate unavoidable loss of habitat per regulation, recognizing and providing a means to define at least some differences in site value and restoration potential.
      - *1.* Differences in site value could be determined by:
        - *A.* Area affected
        - *B.* Patch size/fragmentation
        - *C.* Abundance/density of infauna
        - *D.* Diversity of infaunal lifestyles (dwelling modes and feeding modes). High density of one species or lifestyle (e.g. subsurface-deposit feeders) can indicate a fairly degraded system. Suspension feeders, burrowers, tube builders, etc. all coexisting denote a fairly healthy system.
        - *E.* Presence of larger infauna (ghost shrimp, clams etc.)
        - *F.* Site maturity (time since last disturbance)
        - *G.* Use as a nursery by halibut or other fishes
    - *c.* Consider recolonization rates for mitigation ratio discussions. Recolonization rates for invertebrates impacted in the unvegetated shallow subtidal have not been examined in San Diego Bay, but depend on several factors (degree of disturbance, proximity of propagules, individual species’ life span) and may vary from six months to three years (see Section 5.2.1: Dredge and Fill Projects).

d. Facilitate the local, beneficial use of dredge material for enhancement projects when the material has appropriate characteristics. When replacement shallow subtidal habitat sites are needed to mitigate for project-caused losses, convert from medium or deep subtidal habitats.

1. Mitigation requirements for effects on medium or deep subtidal should be minimized, in the context of an enhancement project, or waivered altogether, due to the net benefit to the bay and the objectives of this INRMP.

2. Armoring (adding rock or other hard substrate) of unvegetated shallows is a conversion from a habitat that is scarce compared to its historic area and proportions to one that is not indigenous to San Diego Bay. It should be treated as a partial fill.

C. Evaluate effectiveness of mitigation and enhancement efforts.

1. Use the same parameters described under *IIB1* to evaluate effectiveness compared to a control site. The monitoring of an adjacent or other acceptable control area (subject to the approval of the resource agencies) should also be conducted to account for any natural changes or fluctuations, and should be included as an element of the overall program.

2. Continue to make the following part of permitting requirements:

a. Specify and apply existing criteria in permit conditions to measure effectiveness of BMPs to turbidity control.

b. A monitoring schedule that indicates when each of the required monitoring elements will be completed should be provided to the resource agencies prior to or concurrent with the initiation of the mitigation.

c. Monitoring reports should be provided to the resource agencies within 30 days after the completion of each required monitoring period.

III. Pursue enhancement opportunities in unvegetated shallows, in support of target species identified to be markers of the health of this habitat, such as the California halibut (see Section 6.2.2: Long-term Monitoring for Bay Condition and Trend).

IV. Pursue cost-effective, targeted monitoring and applied research to address management-related questions about unvegetated shallow subtidal habitat.

A. Improve knowledge of the inhabitants of unvegetated shallow subtidal sites within the bay.

1. Identify fish nursery locations by species in unvegetated shallow subtidal throughout the bay at a scale typically useful for project planning (1 inch = 600 feet), so that these locations may be considered in avoiding user conflicts.

2. Describe the role of very small invertebrate species (interstitial infauna) living within the unvegetated shallow subtidal soft bottom community, as little is known about species composition, structure, or productivity.

B. Improve understanding of the range of attributes in shallow soft-bottom areas that add productivity and diversity to this habitat, such as:

1. the role and significance of red algae beds,

2. the reason for the predominance of sponges in areas of south bay,

3. the significance of changes in substrate to changes in the benthic community,

4. what it is about the habitat that makes it attractive as a nursery for certain species,

5. whether the length of time since last disturbance affects community composition or structure, and

6. the effects of natural versus human-induced fluctuations in turbidity, nutrients, temperature, deposition rates, and grain size profile.

C. Improve understanding of the dependencies of other habitats on shallow soft-bottom areas.

4.3.4 Vegetated Shallows

Specific Concerns

See also Section 2.4.3.2. Vegetated Shallows.

- Only about 59% of historic (1859) shallow subtidal habitat (both vegetated and unvegetated) remains today in the bay and it is therefore considered a scarce habitat that requires conservation and enhancement.
- The functional value of eelgrass and sea lettuce beds may vary by their size, fragmentation, and proximity to intertidal, marsh, or stream outflow areas. These values are not described or documented well enough that they can be used in mitigation planning.
- Shallow subtidal areas of the bay that have potential to harbor eelgrass generally already have it at some level, so there is a diminishing opportunity to locate new eelgrass planting sites as mitigation for projects, unless deeper areas are filled or upland areas are excavated.
- It is unknown why some eelgrass beds are more resilient than others to environmental or anthropogenic disturbance.
- Eelgrass communities are vulnerable to in-water project impacts and activities.
- Eelgrass adjacent to mudflat or salt marsh may provide a refuge for specialized fishes, such as killifish, that migrate from intertidal areas during low tides. This function needs documentation, and then conservation measures if appropriate.
- The relative importance of various wildlife uses of eelgrass beds needs to be better described and quantified if these uses are to be protected in mitigation policy. Examples are use as a nursery for development of fish larvae that drift in from open water, as refuge for young-of-year fish and invertebrates, for foraging by waterbirds, for use by special status species.

Current Management

Under the Fish and Wildlife Coordination Act, the NMFS, USFWS, and CDFG have commenting authority on §404 permits that may impact fish resources. NMFS is considered the lead authority of expertise in matters affecting eelgrass or fish resources of the bay.

The Southern California Eelgrass Mitigation Policy provides more specific guidance for vegetated shallow subtidal than is defined by EPA Guidelines.

This habitat has been broadly protected as a Special Aquatic Site under §404 of the CWA since its implementation in 1972. A regional policy, the Southern California Eelgrass Mitigation Policy, was agreed upon by the regulatory agencies in July 1991 (most recently revised 8/30/05), and is periodically updated. Prior to 1991 there was no standard policy for eelgrass mitigation. Transplanting of an equivalent area was generally required, but such transplants did not necessarily have to be successful (R. Hoffman, *pers. comm.*). The policy provides more specific guidance for the bay's submerged aquatic vegetation than defined by the EPA Guidelines. It can be viewed in its entirety at the website http://swr.ucsd.edu/hcd/eelpol.htm.

Harvesting donor plants for eelgrass transplanting must be approved by CDFG, and transplanting techniques must be current.

Under the policy, mitigation that occurs concurrently with the impact requires that 1.2 acres (.49 ha) be transplanted for each acre impacted. A ratio of greater than 1:1 (i.e. 1.2:1) is designed to offset productivity losses during the recovery phase within five years. A 1:1 ratio applies if eelgrass transplanting occurs at least three years ahead of the impact, if the impact is temporary, or if the maximum width of impact through the existing eelgrass bed is less than 10 feet (3 m). Eelgrass transplanting may occur adjacent to or nearby the impacted site but in the same bay region (north, north-central, south-central, or south) by altering deeper habitat, or by excavating uplands to a proper elevation. Donor material for transplanting is to be taken from the impact site and a minimum of two other distinct sites to ensure greater genetic diversity. Harvesting of donor plants must be approved by CDFG since that agency has authority over state waters. Transplanting techniques must be current with the best available technology at the time of the project. Approaches and techniques used to transplant eelgrass are found in Volume 3 of the South San Diego Bay Enhancement Plan (Macdonald *et al.* 1990) and the Proceedings of the California Eelgrass Symposium in 1988 (Merkel and Hoffman 1990).

Monitoring of the percent vegetation cover and density at the transplant site is required for a five-year period for most projects. A control eelgrass bed, generally adjacent to the transplant site, must be monitored to help account for any natural changes or fluctuations in the bed width or density that may occur. Success criteria are based on similar vegetative cover and density between the transplant site and the impact site, with specific coverages and densities required within certain time periods. If the transplant site fails to meet these criteria, then a Supplementary Transplant Area must be established. If the area of successful transplanting exceeds the mitigation requirements, the additional area can be used as credit in a kind of "mitigation bank" specific to that project proponent. Such credit is tracked under permit terms and conditions for an individual project sponsor rather than the traditional mitigation bank that is formalized at the national rather than local level. The Policy contains a punitive component, in which seven percent additional eelgrass area must be planted for every month of delay under the permit. Guidelines on mitigation for turbidity impacts are the same as for unvegetated shallows, above.

Evaluation of Current Management

The CWA and the Southern California Eelgrass Mitigation Policy have abate d the rate of habitat loss for vegetated shallows.

The Southern California Eelgrass Mitigation Policy and certain efforts at mitigation banking for eelgrass have helped to abate the rate of loss of shallow subtidal habitat has abated with vigilant implementation and enforcement of the CWA. Eelgrass beds of shallow subtidal habitat are the most recovered habitat in the bay, and eelgrass has currently established wherever it has potential to grow, based on existing bathymetric, substrate, and water conditions. During the last ten years, most eelgrass transplant projects in San Diego Bay have met the permit success criteria of vegetative cover and density resulting in a net increase in eelgrass coverage. Regular monitoring of eelgrass beds has allowed an assessment of acreage and density with some interpretation of natural variation versus human-induced impacts. It is assumed that since fish readily inhabit newly planted eelgrass beds, they retain functional value compared to impacted sites. Use by fish in mitigation sites compared to a control has been evaluated in Mission Bay (Hoffman 1990), but a comparison of natural versus transplanted beds for other functions in San Diego Bay has not been attempted.

Management Strategy—Vegetated Shallows

Objective: Conserve and enhance the attributes of vegetated shallow subtidal sites that sustain a diverse and abundant invertebrate community, fish and wildlife foraging, nursery function for numerous fishes, as well as an ecological role in detritus-based food web support.

I. Allow no net loss of shallow subtidal habitat in acreage or in existing net biological values. Seek long-term enhancement of eelgrass habitat.

- *A.* Continue enforcement of mitigation standards under the Southern California Eelgrass Mitigation Policy.
  - *1.* When replacement shallow subtidal habitat sites are needed to mitigate for project-caused losses, convert from medium or deep subtidal habitats in preference to other habitats.
  - *2.* Apply BMPs during construction and dredging projects to keep turbidity to a minimum to protect foraging birds and eelgrass beds from disturbance.
- *B.* Evaluate effectiveness of mitigation and enhancement efforts.
  - *1.* Specify and apply existing criteria to measure effectiveness of turbidity control BMPs.
- *C.* Disseminate learning on effective techniques in eelgrass mitigation in conference proceedings and elsewhere.
- *D.* Manage all subtidal areas with eelgrass as sensitive nursery and foraging areas for fish.
  - *1.* Determine if conflicts occur between surface use of vessels above eelgrass and use of the beds by waterbirds, foraging sea birds, the green sea turtle, and others.

II. Pursue cost-effective, targeted monitoring and applied research to address management-related questions about vegetated shallow subtidal habitat.

A. Seek better understanding of the ecological functioning of eelgrass beds in the bay.

1. Determine why some eelgrass beds are more resilient than others to environmental or anthropogenic disturbance.

2. Identify benefits of eelgrass beds in proximity to intertidal and marsh areas to improve mitigation planning and enhancement project design.

B. Improve understanding of the inhabitants of vegetated shallows within the bay.

1. Identify fish nursery locations by species throughout the bay at a scale useful for project planning (1 inch = 600 feet).

2. Identify bird use of eelgrass beds.

C. Determine the success of eelgrass transplant projects in attaining full functional value for all resources (e.g. detrital exchanges with other habitats; amount of organic material produced per unit area, per unit time; invertebrate use; fish use, bird use; etc.).

4.3.5 Intertidal Mudflats

Specific Concerns

See also Section 2.5.4.1: Intertidal Flats (+2.3 to 0 feet [+0.7 to 0 m] MLLW).

- Only 16% of the historic (1859) mudflat acreage of the bay remains, and the functional value of that remaining has been diminished.
- The potential for existence and enhancement of mudflats is limited because they cannot be sustained in the presence of any significant wave action. They must also have a source of fine-grained sediment, and they must occupy broad, flat expanses to be conducive to establishment of necessary anaerobic conditions and permanent invertebrate burrows.
- The physical processes needed to maintain functional intertidal mudflats are being or have been negatively affected by development.
- Continued channel dredging and shoreline armoring, as well as loss of influx from rivers and streams have changed circulation patterns in the bay, with possible loss of the potential to conduct intertidal enhancement in some locations.
- The relative importance of various wildlife uses of intertidal flats needs to be better described and quantified if these uses are to be avoided or minimized in mitigation strategy. Examples are use as a nursery for development of fish larvae that drift in from open water, as refuge for young-of-year flatfish and decapod invertebrates, for foraging by shorebirds and wading birds, for least tern foraging for smaller fishes consumable by chicks (M. Kenney, *pers. comm.*), for western snowy plover foraging, and Belding's savannah sparrow.
- Young-of-year California halibut appear to make substantial use of intertidal flats (Allen 1998a), and this species shows evidence of decline in abundance (Karpov 1981; Barsky 1990).
- Physical characteristics of subsets of intertidal habitat that provide important function for sensitive species are not described or quantified well enough to be identified in mitigation strategy, so they are not necessarily conserved. For example, birds use narrow versus broad intertidal differently, as well as coarse-grained versus fine-grained.
- Mudflats may depend on detrital food reaching them from other habitats, such as the salt marsh and eelgrass beds, and on microalgae living in the mud. Their proximity to these habitats may affect their value.
- Intertidal flats are vulnerable to oil spills, organic matter enrichment, and disturbance by personal watercraft.

- We do not know if the nutrient supply function of mudflats in the greatly reduced intertidal areas of the bay is limiting overall bay productivity.
- For shorebirds and some fishes, access to intertidal flats may limit their overall ability to use the bay.
- Unvegetated mudflat habitat is at risk of being lost through invasion by native salt marsh species as well as by the possible introduction of a more aggressive invasive cordgrass, as has happened in San Francisco Bay.
- Inadequate funding has been applied to restore this habitat type.
- In intertidal areas, birds are more abundant and diverse on sandy flats than on rocky substrates, yet such preferable habitats are among the most impacted in the bay and impacts have not been sufficiently avoided or minimized from development project.
- Presence of eelgrass in shallow subtidal habitat may preclude the enhancement of an adjacent mudflat under routine application of CWA guidelines.
- Riprap and other anthropogenic structures could harbor organisms that alter the communities of the nearby mudflats, in particular fish.

Current Management

Protection of bay mudflats comes from two federal sources. They are considered a special aquatic site under §404 of the CWA, and they may be occupied by the threatened western snowy plover protected under the ESA. The EPA Guidelines under the CWA for mudflats, in addition to the broader guidelines, apply a burden of proof requirement to demonstrate that no practicable alternatives exist that will meet a project's purpose. The NMFS and CDFG comment on activities in mudflats as they provide forage for fish, but USFWS remains the lead authority because of the importance of these areas to listed shorebirds. The CCC also regulates mudflats under their definition of a wetland, which includes a 100 feet (30.5 m) buffer on the upland edge (14 California Code of Regulations 13577).

Mudflats are considered a special aquatic site and may be occupied by the threatened western snowy plover. Protection is from two federal sources: the CWA and the ESA.

Evaluation of Current Management

Intertidal flats are severely reduced from their historic proportions in the bay and elsewhere in southern California from impacts that pre-dated the CWA. Many dependent shorebirds are declining along the Pacific Flyway. While the Salt Works has replaced some of the original ecological role of intertidal habitat, impacts continue. Routine application of CWA guidelines has not resulted in any improvement.

State and federal programs appear to allow great flexibility and latitude of interpretation and enforcement, with emphasis on site- and project-specific decisions, dependence on availability of sites and ability to identify alternatives, reliance on limited funding available for a specific project, and reliance on what is thought to be a reasonable permit requirement based on the size of the project. The project-by-project nature of the permit process and flexibility allowed seem to have led to a continued, gradual loss of intertidal habitat despite the laws, regulations, and policies in place. Until recently, with a mudflat creation projected proposed under the Navy's CVN II project, few resources have been committed to creating or restoring this habitat.

Management Strategy—Intertidal Mudflats

Objective: Achieve a long-term net gain in the area, function, value, and permanence of intertidal flats, and the physical conditions that support this habitat.

I. Conserve existing areas of intertidal flats within the bay and their use by dependent birds, fishes, and invertebrates, giving priority to medium and low intertidal elevations.

   A. Avoid future impacts by using alternative locations for Port and Navy projects.

B. Establish an efficient, orderly, and comprehensive baywide or regional strategy with respect to conserving intertidal habitats and shoreline management, similar to the Southern California Eelgrass Mitigation Policy, which will provide the needed consistent and predictable standards for project planners to first avoid, then minimize environmental impacts.

1. Develop an interagency mudflat/unvegetated shallow subtidal conservation agreement.

2. Provide clear guidelines, both including and going beyond existing guidelines (EPA §404[b][1] Guidelines for Specification of Disposal Sites for Dredged or Fill Material) for avoiding impacts, minimizing impacts, and mitigating unavoidable impacts to intertidal habitat, and recognizing and providing a means to identify differences in site value and restoration potential.

a. Encourage coordinated environmental impact review during the site selection and design stages, not after.

b. Minimize the creation of new shoreline stabilization structures and reconstruction of expendable, existing armoring (see also Section 4.3.7: Artificial Structures).

c. When new armoring or reconstruction of degraded armoring is unavoidable, incorporate maximum practical habitat value for native species, giving priority to "soft" solutions (see also Section 4.3.7: Artificial Structures).

d. Offset the impacts of new shoreline armoring.

e. Provide incentive for habitat enhancement of existing shoreline stabilization structures (see also Section 4.3.7: Artificial Structures) for intertidal habitat values.

3. Facilitate priority work on broad, gently sloping intertidal areas rather than small, narrow ones, in order to maximize the benefit derived from enhancement effort.

4. Investigate and then consider the relative importance of the following as appropriate as a basis for habitat valuation when planning or evaluating projects:

- Area affected
- Patch size
- Abundance/density of infauna
- Diversity of infaunal lifestyles (dwelling modes and feeding modes). High density of one species or lifestyle (e.g. subsurface-deposit feeders) can indicate a fairly degraded system. Suspension feeders, burrowers, tube builders, etc. coexisting denote a fairly healthy system.
- Presence of larger infauna (ghost shrimp, clams, etc.)
- Sediment stability with wave action, flooding, or migrating sand
- Drainage/flushing at low tide
- Use by foraging fishes/rays when the tide is in
- Use as a nursery by juvenile fishes and decapod invertebrates
- Habitation by invasive species (e.g. *Musculista senhousia*)
- Use by foraging shorebirds
- Time since last disturbance by dredging or other disturbance
- Natural vs armored condition of shoreline

5. Consider the following principles when determining restoration techniques:

- Enhance water circulation as affected by surrounding structures to ensure stability/persistence of intertidal sediments
- Grade to appropriate tide levels—unvegetated high intertidal supports relatively few organisms

- Improve drainage conditions
- Place structures subtidally to stabilize

C. Avoid potential impacts from dredging which could cause the erosion of intertidal habitats. If such dredging is unavoidable, provide adequate measures to benignly stabilize the potential erosion.

D. Avoid loss of mudflat enhancement opportunities due to projects in adjoining habitat types.

E. Pursue invasive species control measures to prevent invasion of mudflats by *Spartina densiflora* or other invasive species (See Section 4.4.1: Invasive Species).

F. Delineate the locations of all intertidal mudflats within the bay based on a commonly agreed-upon definition and at a project-planning scale (1 inch = 600 feet).

II. Increase the acreage quality and function of mudflats.

A. Conduct baywide and regional restoration planning for mudflats.

1. Thoroughly characterize existing mudflat remnants in the bay by microhabitat use for foraging fishes and shorebirds, fish nursery functions, sensitive species support, connectivity or isolation with other habitats, and patch size and shape. Identify the physical or chemical factors that affect habitat use, in support of more effectively targeting mitigation policy and enhancement strategies.

2. Set targets for use by western snowy plover, foraging California least tern, juvenile California halibut, and other declining birds or fishes, where baseline data are available to support the setting of targets.

3. Identify locations and prohibit development in inappropriate locations such as those with significant intertidal resources or fragile biophysical characteristics.

B. Identify specific locations for intertidal enhancement in the bay, such as abandoned navigational channels or areas of moderately deep subtidal.

1. Preserve existing native shoreline vegetation.

2. Consider expansion of the CVWR to create intertidal mudflats as described in Macdonald *et al.* (1990), by using prior CVWR construction techniques or by building an experimental breakwater to induce natural sedimentation.

3. Expand Emory Cove tidal flats, along with marsh enhancement and expansion, and creation of new eelgrass beds that connect with those off of the South Bay Wildlife Preserve and south Coronado Cays (Macdonald *et al.* 1990).

C. Facilitate the local, beneficial use of dredge material for enhancement projects when the material has appropriate characteristics and volume.

D. Enhance the interchange of nutrients, organisms, and organic matter between mudflats and other habitats in the project design.

E. Develop demonstration projects to convert medium subtidal into mudflat habitat.

1. Document the techniques that have worked elsewhere (e.g. mudflat terraces in Puget Sound) and apply as appropriate.

2. Assess the success of the projects in developing functional mudflat characteristics.

F. Apply successful techniques from demonstrations in additional enhancement projects at sites that are appropriate.

G. Foster innovation and experimentation with mudflat development and improving the habitat value of shoreline structures.

1. Conduct demonstration projects, such as small-scale enhancement of riprap-stabilized banks with mudflat “terraces” using riprap or other measures.

2. Experiment with breakwaters to reduce turbulence in areas where this limits mudflat development or quality.
3. Monitor and assess for appropriate techniques and for functional equivalency to natural mudflats.

4.3.6 Salt Marsh

Specific Concerns

See also Section 2.5.4.2: Salt Marsh (+7.8 to +2.3 feet [+2.4 to 0.7 m] MLLW).

- Only about 30% of the historic salt marsh habitat remains in San Diego Bay, and there are little means to get it back that are not excessively expensive.
- Existing, protected marsh at SMNWR may not be large enough to be self-sustaining or to support dependent species. The salt marsh habitats of the bay are fragmented by levees, roads, and other barriers, cutting off connection to both middle-intertidal and upland-transition habitats that are needed for species migration and recolonization.
- Light-footed clapper rail, Belding's Savannah sparrow, and salt marsh bird's beak are at risk of extinction because of losses and degradation to salt marshes of California.
- Constructed wetlands such as the CVWR, Connector Marsh, and Marisma de Nacion do not function in an equivalent manner to natural marsh in terms of clapper rail support, but do better in some other ways such as support of invertebrates and fishes. These salt marsh restoration projects have experienced long delays in achieving functional equivalency.
- There are several marsh areas that do not have the needed features to attract use by marsh-dependent birds, probably due to lack of channels and proper elevations, intrusion of inappropriate soils, inappropriate nutrient levels, or lack of natural fluctuations in salinity levels.
- While salt marsh alone supports less avian diversity than salt ponds or mudflats—the best of both is when they occur together in sufficient acreage at the right elevations. The beneficial, mutually enhancing juxtaposition of habitats is not recognized in mitigation policy.
- Salt marsh has been favored over unvegetated intertidal in mitigation policy as implemented in the bay, probably because salt marsh is considered a Special Aquatic Site (a wetland), for which no net loss provisions and higher mitigation ratios apply. While salt marsh is a productive habitat because of photosynthesis by marsh plants and algae, and because of access to nutrients from nitrogen fixation by bacteria or blue-green algae as well as flood tides, there is some evidence that nitrogen may be limiting to the system, at least in constructed marshes.
- The most important controlling factors for bay salt marshes are not monitored. These are uninterrupted tidal circulation that provides water, nutrients and oxygen to the marsh, and the infrequent, highly modified freshwater flow regimes of the associated drainages. Surrogates of functioning (plant cover, density, and composition) are monitored because they are related to use by certain targeted plants and birds.
- The yellowfin goby and sailfin molly are invasive fishes inhabiting Sweetwater Marsh that may have already affected community structure. There are also invasive plant introductions, especially at the higher end of the salt marsh.

Current Management

A standard of no net loss of value or function has been applied to San Diego Bay salt marsh, which is occupied by endangered and sensitive species.

Salt marsh is the only bay habitat defined as a wetland under the CWA. Since 1994, the standard for no net loss of value or function has been applied to the salt marsh, which means a minimum of one-to-one functional replacement. With only 30% of the historic salt marsh remaining in the bay, there is no latitude for additional loss.

Salt marsh of San Diego Bay is frequently occupied by endangered or other special status species. For instance, the Port added seed to the CVWR and D Street Fill to expand habitat for salt marsh bird's beak. In the mitigation standards developed for disturbance to salt marsh occupied by the federally endangered light-footed clapper rail, California least tern, and salt marsh bird's beak, an effort was made to use structural surrogates for the functional needs of the clapper rail, such as cordgrass of sufficient height to support use of the plant for nesting. Standards by which the overall performance of two constructed marshes could be evaluated were described in the BO associated with this project (USFWS 1988), which was designed to offset construction of the Sweetwater Channel, a freeway interchange, and the widening of Interstate 5. The standards are described in Table 4-7.

Table 4-7. Salt marsh mitigation standards.

Location	Standard
The home ranges	The constructed salt marshes need to be large enough to contain seven clapper rail home ranges (i.e. seven nonoverlapping areas, each 2 to 4 acres/0.8 to 1.6 ha in size). Each home range should be composed of low, middle, and high salt marsh; the low marsh should be at least 15% of the area and the high marsh should be at least 15% of the area.
The high marsh	In each home range, the high marsh should contain at least 75% of the native vascular plant species found in reference sites in the natural marsh. In each home range, the high marsh should have few invasive species—they should occupy less than 10% of the cover. There should be five patches of salt marsh bird's beak; each patch should be at least 10.7 ft^2 (1 m^2) in size and contain at least 20 plants; the patches should be at least 394 feet (120 m) apart. The salt marsh bird's beak patches described should be self-sustaining (i.e. stable or increasing in number and area) for three years.
The middle marsh	In each home range, the middle marsh should contain at least 75% of the native vascular plant species found in reference sites in the natural marsh. The middle marsh shall provide at least 70% cover and contain 75% of the native species typically found in this zone, in a comparable area at the Refuge.
The low marsh[a]	In each home range the low marsh should have at least 50% cover of cordgrass. Each home range should have at least one large patch of tall, dense cordgrass, i.e. a patch 969–1076 ft^2 (90–100 m^2) in size where the cordgrass is 24–31 inches (60–80 cm) tall and 90–100% in cover. The tall, dense cordgrass patch described needs to be resilient (i.e. maintain itself for three years and exhibit nitrogen fixation).

a. Alternative low marsh criteria were used in 1995 for assessing clapper rail habitat. Zedler's (1993) criteria considers the rail's need for a proportion of very tall stems to support its floating nests during high tides, and states that there should be at least one 1,076 ft^2 (100 m^2) patch that averages 100 stems/m^2 of which at least 90 stems are taller than 24 inches (60 cm) and 30 stems are taller than 35 inches (90 cm) when sampled with 10 circular quadrats 13.5 ft^2 (1.256 m^2) in size (Zedler 1993). At the 1995 annual meeting of the USFWS, California Department of Transportation, USACE, and PERL, it was decided that the mean height criterion for cordgrass, 24–31 inches (60–80 cm), was adequate.

Regular monitoring at Sweetwater conducted by the PERL at SDSU included water quality (dissolved oxygen, temperature, salinity profiles, nutrients in the water column); fish sampling; invasive fish traps; benthic invertebrates using core samples in channels; marsh vegetation species and cover; cordgrass heights and density; and soil salinity and soil nutrients.

The preferred alternative in the 2006 CCP for the Refuge includes plans for tidal wetland expansion from an existing 470 acres to 1,220 - 1,245 acres.

Evaluation of Current Management

Two marshes were constructed from previously deposited fill material: Connector Marsh, which was built as a hydrologic link between Sweetwater Marsh and Paradise Creek, and Marisma de Nacion, which was planted with cordgrass in 1991. To evaluate the success of the project, PERL compared nearby natural marsh functions to those of the constructed marsh. They found a range of success and failure in the constructed marsh (Zedler and Langis 1990; Boyer *et al.* 1996). The standard for abundance and diversity of fishes, as forage for the least tern, was satisfied within the first three years of the marsh (1989–1991). The standard for invertebrates was met in five years (1989–1993). The requirement for salt marsh bird's beak was met for the first time after six years, but the following year there were severe declines due to drought (an 85% reduction in area, and a drop in plant numbers from 14,000 to 1,200). The standard for use as high tide refuge by the light-footed clapper rail was met in the high and midmarsh after seven years, while use of the low marsh for nesting has yet to meet mitigation criteria.

In comparing natural to constructed marsh functions, most standards were met within seven years. However, use of low marsh for nesting has yet to meet mitigation criteria.

More recent efforts at salt marsh establishment have been more successful, with the recently-created marsh for the National City wharf extension featuring cord grass already over three feet tall. The Port also added seed to CVWR and D Street Fill to expand habitat for salt marsh bird's beak.

While the no-net-loss standard helps protect the remnants of salt marsh remaining in the bay, creating additional acreage may require innovative approaches to mitigation. The Refuge CCP proposal would at least triple the existing acreage of tidal wetlands, if implemented. Options for implementing salt marsh restoration in balance with bay-wide ecosystem needs are not in place at present.

Management Strategy—Salt Marsh

Objective: Ensure no net loss of existing structure and function of salt marsh habitat, and achieve a long-term net gain in its quantity, quality, and permanence.

I. Conserve salt marsh functions, such as primary productivity, nitrogen supply, detritus- and grazer-based food web support, endangered species support, and general fish and wildlife support.

- *A.* Participate in regional salt marsh restoration planning.
    - *1.* Thoroughly characterize existing salt marsh remnants in the bay by microhabitat use for foraging fishes and shorebirds, fish nursery functions, sensitive species support, connectivity or isolation with other habitats, and patch size and shape (See also *IIIA*).
    - *2.* Set targets for light-footed clapper rail support, Belding's savannah sparrow use, salt marsh bird's beak population stability, and young-of-year California halibut and other flatfish use, where baseline data are available to support the setting of targets.
    - *3.* If baseline data are not available, conduct appropriate studies.
- *B.* Avoid and minimize impacts to access to and from the marsh for species that migrate in and out tidally or during different life history stages.
- *C.* Provide public access controls especially near breeding colonies by posting, fencing, and patrols, to address walkers, dogs, lighting, noise, and trampling.
- *D.* Patrol marsh areas that are vulnerable to illegal activities. Organize general habitat cleanup of the marsh and other shoreline sites. Especially critical for cleanup is monofilament line, which can fatally entangle birds.
- *E.* Continue to control predation, the primary reason for reproductive failure of the least tern and western snowy plover.
    - *1.* Enhance the *island* nature of the CVWR to help control predators.
- *F.* Control evident shoreline erosion on Chula Vista east shore midbayfront marshes and the levees of south bay, using soft solutions (i.e. without armoring the intertidal zone).
- *G.* Investigate changes in marsh function and value due to presence of invasive fishes, invertebrates, and plants. Prioritize control efforts based on these results.

II. Expand and enhance existing habitat.

- *A.* When planning restoration, consider the marsh as part of a larger system of habitats that depend on each other.
- *B.* To maximize the potential for success, as a first priority, link smaller sites to larger parcels. Next priority is to expand smaller and then larger parcels. Last priority is to construct new marsh where none has been historically.
- *C.* Reevaluate recommendations of the South Bay Enhancement Plan (Macdonald *et al.* 1990).
    - *1.* Consider expansion of salt marsh on north side of Gunpowder Point at SMNWR.
    - *2.* Expand at E-Street marsh on south side of Gunpowder Point by excavating uplands and extending existing tidal channels into new areas.

3. Enhance J-Street Marsh by excavating a perimeter channel to separate the marsh from the SDG&E power plant; excavating a system of small, secondary tidal channels throughout the marsh and possibly partly across the tidal flats; and creating refuge islands for escape from high spring tides or major flooding episodes. Conduct load-bearing capacity strength tests on soils due to reportedly unusually soft and non-cohesive soils that may not stay in place.
4. Restrict vehicle access and boats anchored at the South Bay Marine Biology Study Area. Eliminate parking and other illegal activities. Eliminate garbage. Convert peripheral uplands to marsh. Excavate tidal channels into degraded marsh. Excavate secondary tidal channels to provide circulation.
5. Conduct marsh enhancement at Emory Cove in conjunction with expansion of marsh and tidal flats, and creation of new eelgrass beds that connect up with those off of the South Bay Marine Biology Study Area and south Coronado Cays.

D. Advocate project budgets that emphasize consideration of biological variables before engineering takes place, such as:
1. Whether planting is needed or recolonization will happen naturally.
2. Means to control invasive introductions.
3. Site selection to maximize connections, interchanges, animal movement among habitats.
4. Means to minimize delays in achieving functional equivalency.

III. Fill priority information gaps.

A. Characterize the linkages between the salt marsh and other habitats, and their relative importance for a broad range of species, food chain support, and water quality functions.

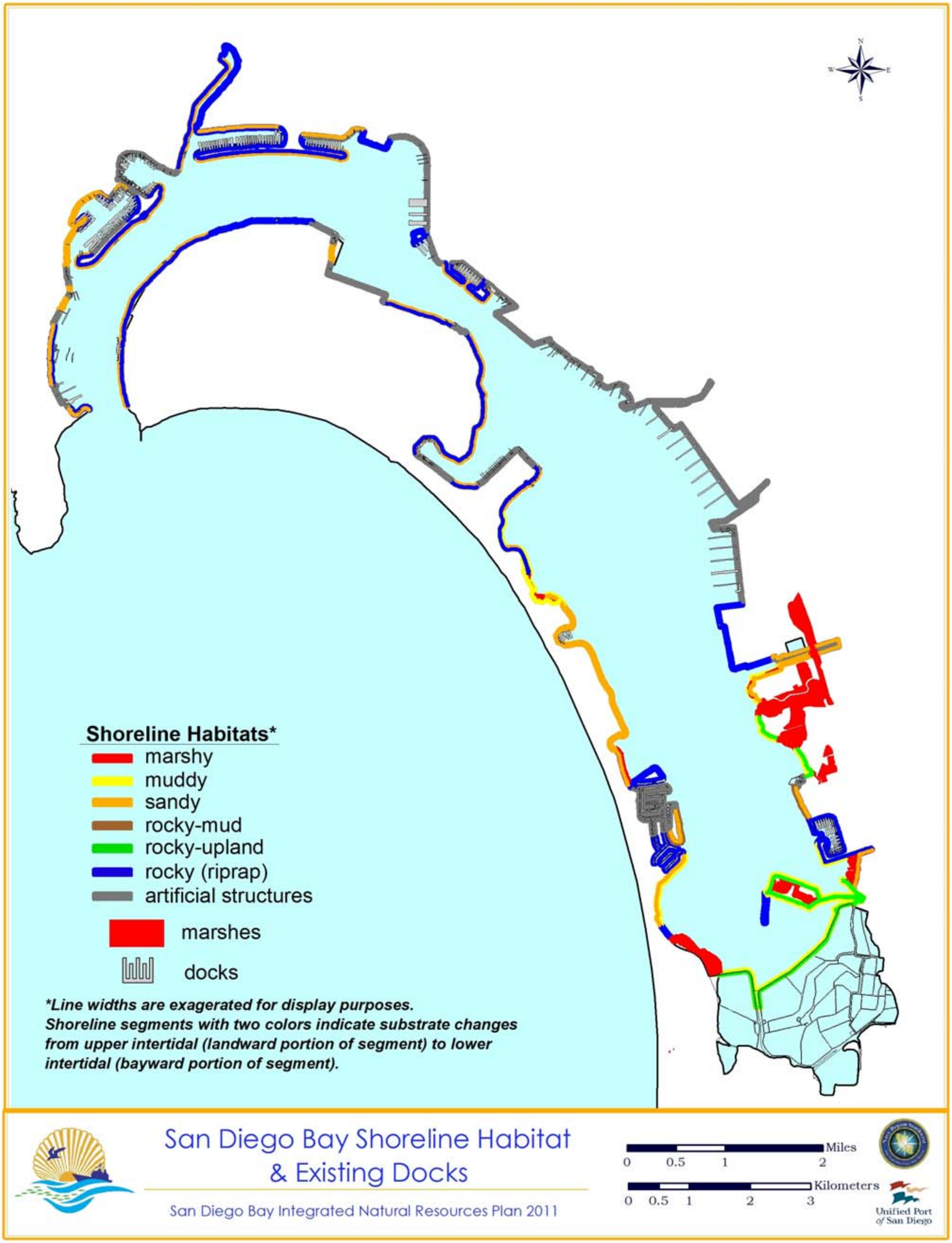
B. Investigate the hydrologic requirements of salt marsh plants and animals, including minimum water depth, hydroperiod, dissolved nutrients, flushing, the role of large but infrequent events such as El Niño, and the effects of long-term sea level rise.

C. Study the relationship of substrate to salt marsh plants and animals, and to chemical and biological functioning.

D. Characterize the existing remnant natural marshes by microhabitat subsets, patch size and shape, connectivity and isolation, and sensitive species support.

E. Make salt marsh restoration more predictable in terms of what is possible to achieve and how long is required to achieve it.
1. Investigate nitrogen deficiency in the marsh and effective augmentation methods and timing.
2. Investigate bioremediation measures for contaminated soils.
3. Investigate means to control invasive species introductions.
4. Investigate innovative ways to accelerate the restoration process, especially for listed species support, such as native plant propagation techniques, and use of soil amendments.

F. Continue to compare natural and constructed marshes: soil salinity; water quality (dissolved oxygen, temperature, water salinity profiles, nutrients in the water column); fish species composition and relative abundance; invasive fish presence and abundance; benthic invertebrate assemblage relative abundance and density; marsh vegetation species and cover; cordgrass heights and density; and soil nutrients. Investigate causal relationships.



Map 4-4. Shoreline habitats and existing structures of San Diego Bay as mapped in 1998.

4.3.7 Artificial Structures

Specific Concerns

This section uses the terms *soft* and *hard* shorelines. Soft shorelines are those comprised of natural or introduced materials similar to those indigenous to the bay, such as sand, mud, or vegetated marsh. Hard shorelines are made up of rock, concrete, wood, or other hard substrate introduced to the bay.

- Only 26% of the bay shoreline remains in a natural condition or is made of materials indigenous to the bay, yet it has been estimated that only 7% of the shoreline is naturally vulnerable to erosion (Smith 1976). The remainder has been armored by riprap, seawall, wharves, and piers. Over-steepened banks (associated with dredged channels) account for an additional need for stabilization structures.
- Fill and armoring of the bay's shoreline has either eliminated intertidal habitat or diminished the value of what remains. The conversion of soft substrate to hard substrate has created rocky intertidal habitat that was not historically found in the bay.
- Technical expertise may be limiting the availability of designs to make riprap walls and other artificial structures more valuable as habitat and less damaging to intertidal habitats.
- Due to the high real estate values around the bay and limited space, there are currently no financial incentives to minimize the use of necessary armoring, improve its habitat value, or to remove unnecessary armoring in favor of a natural shoreline.
- There is currently very limited consideration of soft rather than hard structural solutions, or incentive for innovative thinking about means to enhance habitat value of shoreline structures.
- Vibrations during pile-driving may affect schooling fish and, therefore least tern foraging.
- Intertidal habitat in the bay is valuable ecologically, is in short supply, and could be enhanced near shoreline structures. Structures can affect adjacent sandy beaches, which have very high value for birds, especially as high tide refugia.
- While rock or other hard substrate that is added to the bay's soft bottom is a net benefit to fish productivity, it is not known if some substrates are better than others, or if the addition results in any net gain to the ecosystem as a whole.
- There needs to be resolution of and a consistent approach to contrasting concerns about placement of riprap in intertidal areas as opposed to subtidal while still maintaining the shoreline fortification requirement. Whereas in subtidal, hard substrate is viewed as a benefit because of improved productivity of marine fish and invertebrates, in intertidal areas it could be viewed as a negative effect because of the loss of infaunal invertebrates consumed as forage by shorebirds.
- Agencies that regulate natural resources have expressed concern that the addition of too many piers, docks, and wharves may impair, through light reduction, algae growth which supports the invertebrate prey of birds and fishes.
- Rising sea levels and increasing storm intensity threaten San Diego Bay's existing infrastructure. This may result in a need to modify shorelines.

Background

The proper design of riprap structures and other coastal modifications is a popular research area in civil engineering, and is economically important to coastal communities (Herbich 2000; Pister 2007). Artificial structures such as riprap armoring likely represent one of the few marine habitats increasing in area throughout the west coast. In addition, environmental changes caused by climate change, such as rising sea levels and increasing storm intensity, threaten coastal urban settlements (Dean *et al.* 1987; McCarthy *et al.* 2001) such as San Diego Bay. This may result in a need to modify shorelines.

Shoreline stabilization structures (bulkheads, riprap, sea walls) form extensive artificial habitat in the northern and central portions of San Diego Bay and to a lesser extent in the southern bay. There are 45.4 miles (73.1 km) or 74% of the bay's shoreline that are stabilized with rock or concrete. This includes about 20 miles (32 km) of shoreline armored with seawall, considered to have low habitat value because of its lack of surface complexity.

Table 4-8 describes the bay surface area, as opposed to shoreline, affected by fixed over-water structures, by ecoregion and by manager. The boundaries of all piers and docks in San Diego Bay were digitized from a one-foot resolution 2003 aerial photo. The area of permanent over-water structures calculated from the photo is 142.4 acres. The acreage of docks managed by the Navy is 55.7 acres; 86.4 acres are managed by the Port and 0.3 acres are managed by the USCG. Table 4-9 breaks this down by habitat. Some structures have certain positive value because they are often used for roosting by waterbirds to conserve energy and avoid harsh weather. Floating docks in shallow water are used by roosting and foraging waterbirds (e.g. brown pelicans, cormorants, and gulls) because the sites are relatively undisturbed by human activity (Navy 1995; Tierra Data Inc. 2008). A series of studies in San Diego Bay found artificial structures to be important to least terns for roosting between feeding bouts (Baird 1997). Structures are also substrate for a diverse community of marine organisms that appear to attract schooling fish, foraging terns, and other waterbirds (Ogden 1994; Navy 1994; Tierra Data Inc. 2008). All of the man-made structures can support a wealth of invertebrates and seaweeds, including many of the non-native species that inhabit the bay. However, there are differences expected in both the assemblages of plants, seaweeds, invertebrates, fishes and birds, and the abundance of these. The species supported by artificial structures are not the same as those that were lost and that were potentially more dependent upon bay or estuary-like conditions rather than ocean-like conditions, or are more opportunistic in their habitat preference. The unquantified habitat value of the armored shoreline is expected to vary by material, construction, and elevation in relation to sandy or muddy substrate, and by maintenance procedure (see Photo 4-3).

Table 4-8. Dock and pier acreage separated by eco-region and manager.

Eco-region / Manager	Acres
North Bay	51.9
Navy	16.2
Port	35.4
Coast Guard	0.3
North Central	25.7
Navy	4.4
Port	21.2
South Central	50.3
Navy	35.0
Port	15.2
South Bay	14.5
Port	14.5

Table 4-9. Quantity and type of bay habitat surface covered by docks, piers, wharves, and docked ships and boats at maximum use.[a]

Habitat Type	Recreational (acres/ha)	Commercial (acres/ha)	Industrial (acres/ha)	Navy (acres/ha)
Deep subtidal	9/4	2/0.8	42/17	161/65
Medium subtidal	77/31	6/2.4	51/21	33/13
Shallow subtidal	87/35	5/2	3/1	10/4
Intertidal	2/0.8	0.1/0.04	0.3/0.1	3/1
Eelgrass	0.1/0.04	0/0	2/0.8	2/0.8
TOTAL	175.1/70.84	14.1/5.24	98.3/39.9	209/12.8

a. In acres/hectares, rounded-off from estimates.

Photo 4-3. Shoreline along intertidal habitat that benefits shorebirds at Harbor Island, San Diego. Photos courtesy of TDI.

Current Management

Typical projects that relate to shoreline structures have associated impacts such as those of dredging or fill to overall bay habitat, impacts to EFH under the MSA (16 USC 1801 *et seq.*), and impacts to Special Aquatic Sites under the CWA (33 USC 1251 et seq.) §404(b)()(1). These types of projects are typically mitigated for on a 1:1 replacement of like habitat that sometimes requires the conversion of upland habitat to marine habitat. Recently Merkel & Associates (2008) has classified artificial structures in San Diego Bay and the results will be included in the new intertidal/subtidal classification system for coastal San Diego County.

The federal CZMA of 1972 discourages shoreline armoring. The CZMA provided federal guidelines for developing coastal zone management programs, to be implemented by each state's coastal zone management programs, but leaving participation voluntary. The CCC grants a General Consistency Determination for periodic replacement and repair of piers and shoreline structures (CCC 1993). The CCC must find that a proposed project "is consistent with the marine resource, habitat, access, recreational, and shoreline structure policies of the CCMP." The more recent amendment to the CZMA—the CZARA of 1990—established the §309 Coastal Zone Enhancement Grants Program. One of the Program's improvement objectives is to develop and adopt procedures to assess, consider, and control cumulative and secondary impacts of coastal growth and development. The §309 program is administered by the Office of Coastal and Ocean Resource Management of NOAA (Canning 1992). Guidance for implementing §309 discourages shoreline armoring and establishes a preference for alternative approaches such as set back requirements.

A 1978 state policy for directors of state agencies when reviewing environmental impact documents, certifying plans, issuing permits, or granting funds describes general objectives for shoreline modification projects: "When shoreline erosion control projects are necessary, they should restore natural processes, retain shoreline characteristics, and provide recreational benefits to the extent possible…" It appears that implementation is at the discretion of directors of state agencies. Some states have separate shoreline protection legislation, such as Washington's Shoreline Management Act, with which county and local regulations provide the primary driver behind shoreline management, not the CWA. California has no equivalent law.

There are general directives described in state policy for shoreline modification projects. Implementation is at the discretion of state agency directors.

Overwater structures are primarily viewed as changing habitat rather than filling it in the regulatory sense, and impact assessment will address any expected changes in species assemblages or function. Concern about bay surface coverage arises in itself or in isolation from other issues when piers or wharfs that are supported by piles are proposed, and when this construction does not trigger mitigation for dredge or fill (CWA §404). Shading associated with impacts to EFH is addressed during agency consultation, and an effort to improve programmatic consultation for EFH effects from overwater structures due to shading is currently in progress by NOAA (B. Chesney, *pers. comm.* to Loni Adams, CDFG). The effect of shading by overwater structures can come about through alterations in several controlling factors of habitat value: light, wave energy, substrate, and water quality (B. Chesney 2008 presentation to resource agencies). Resource agency concerns have mostly focused on eelgrass habitat, and analysis of impacts has been largely restricted to Puget Sound and the east coast. The expected habitat effects have had little examination regionally or locally (an exception is the Navy shading study described below). They are generally considered to be:

- Limitations (due to light attenuation) on plant growth and recruitment
- Altered plant or algal assemblages
- Altered animal behavior and assemblages
- Changed substrate type
- Changed sediment transport and distribution
- Replacement of native by non-native species.

A qualitative study funded by the Navy on wharf shading effects (Merkel and Associates 1999, 2010 *in draft*) found that fish make use of the shaded area beneath pile supported structures. The patterns of fish biomass, abundance, and species richness changed with regard to the conceptual diagram shown in Figure 4-1, according to exposure to water circulation and light. The purpose of the study was to characterize biological communities along an environmental gradient of shading under pile-supported structures, to determine if shading might affect the forage base for fish and fish-eating birds. An approximately equal number of fish was found in three shading regions, with no pattern of fish species distribution apparent. Encrusting organisms occupied nearly 100 percent of the space available on piles regardless of light exposure. However, there were changes in species composition that paralleled both a light exposure gradient and increasing silt load in the pile communities between exposed area to the dark region. A numerically greater number of infaunal organisms was found under the piers than outside them. The pile community was not as rich as that along pier edges; however, a developed pile community existed in all areas. It was observed that large schools of black croaker were apparent in the dark region under the pier, while pelagic schooling fish amassed around the structures' outer fringes (surveys were conducted during daylight hours, and these species are night foragers, so appeared to be awaiting nightfall to begin foraging activity).

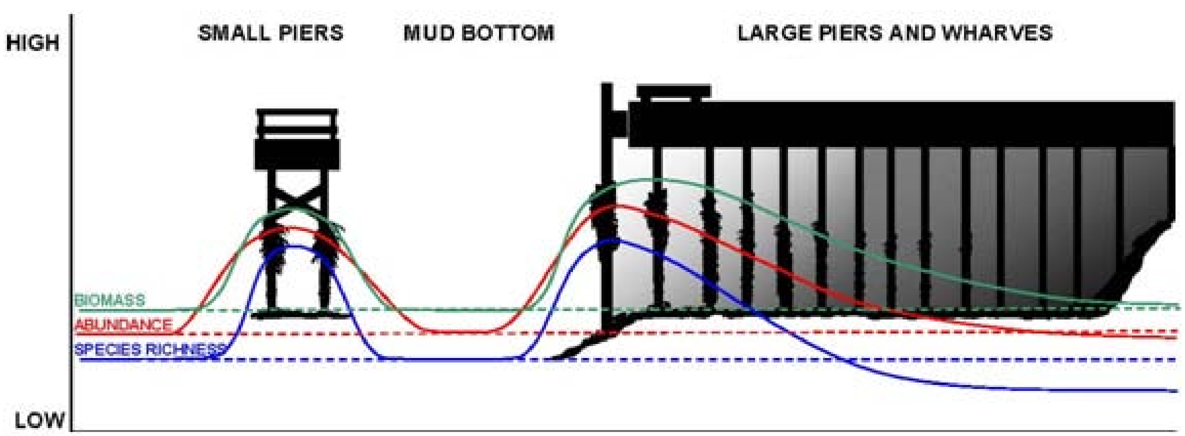


Figure 4-1. Qualitative biological metrics for small and larger piers (from Merkel & Associates 2010).

Evaluation of Current Management

Since the 1800s San Diego Bay has been developed to support a wide variety of human uses. The resulting man-made features, including concrete bulkheads, riprap, pier pilings, marina floats, and other dock structures, are now and will continue to be intertidal and subtidal habitats for marine algae, invertebrates, and fishes.

Shoreline stabilization continues with little consideration of alternative approaches or means to maximize habitat values. Only limited attention has been paid to this aspect of bay development as an issue; partly as a consequence, no permit has been challenged on these grounds. While the CWA applies to all areas of the bay below the +7.8 feet tide line, the need for shoreline access by industry, military, commercial, and recreational users makes finding solutions to habitat loss from placement of artificial structures increasingly problematic. States, such as Washington and North Carolina, that have a coastal shoreline protection law in place appear to be more successful.

The importance of riprap and other artificial structures to marine and estuarine ecology lies not only in its abundance and ability to sustain healthy marine communities, but as a possible tool for conservation, management, and study (Pister 2007). Marine ecologists have performed limited research on creating higher habitat value out of shoreline structures. Exceptions are dock "ecosystems" (Russell *et al.* 1983; Hawkins *et al.* 1992) and littoral flat terraces that have been implanted in riprap stabilized shorelines at the Port of Seattle (Simenstad and Thom 1992). It may be possible to enhance the ecological service provided by these structures through their design. How this might be accomplished is a topic worthy of investigation in light of the amount of riprap and other artificial structures currently in use, and the continuing loss of marine habitat values on a regional scale. It is an increasingly urgent topic facing ecologists today due to the threat posed by sea level rise and warming.

Management Strategy

This Plan proposes a major change in routine management of the bay's shoreline through baywide planning to improve the habitat value of artificial structures; incentives to improve the habitat value of existing shoreline structures; and conservation and enhancement of the remaining natural shorelines.

Objective: Through engineering solutions, minimize the use of shoreline stabilization structures that impact or replace natural intertidal habitats, and maximize the value and function that necessary artificial structures contribute to the bay ecosystem.

Management Strategy—Artificial Shoreline Structures

I. Conserve existing areas of natural or artificial soft shoreline around the bay.

A. Be proactive and develop a list of possible revetment/stabilization options that meet the engineering requirement while maximizing habitat value.

B. Support examination of shoreline modification alternatives. A project proponent should provide in their review an inventory of existing shoreline stabilization devices and unarmored areas that may be impacted adjacent to and near the project site; predicted impact upon area shore and hydraulic processes, adjacent properties, shoreline and water uses, and upland stability; and alternative measures (including nonstructural) that will achieve the same purpose, including offsite measures.

C. Support technical peer review of hard solution applications. Hard shoreline modifications should be allowed only after it is demonstrated that nonstructural solutions are not able to reduce the damage.

D. Experiment with shoreline modification alternatives with habitat values quantified sufficiently to facilitate potential use for offsite or out-of-kind mitigation in the future.

E. Riprapping and other bank stabilization measures should be located, designed, and constructed primarily to prevent damage to *existing* development.

This Plan proposes a major change in routine management of the bay's shoreline through baywide planning to improve the habitat value of artificial structures; incentives to improve the habitat value of existing shoreline structures; and conserving and enhance the remaining natural shorelines.

- F. Shoreline stabilization with the use of artificial structures should be discouraged in eelgrass, salt marsh, identified important shorebird feeding areas, and identified important fish nursery areas (except for fish and wildlife enhancement).
- G. Identify sites for shoreline enhancement projects that would benefit from disposal of dredge material.
- H. Encourage the Navy, Port tenants, and municipalities, in cooperation with permitting agencies to:
    1. Agree on structural design criteria on hard solutions that at least avoid and minimize impacts to fish, shorebirds, and other wildlife.
    2. Restrict inappropriate shoreline development.
        - a. Require setbacks from the tidal area of structures not intended to be affected by tidal surge and that may impact marine life through lighting, shading, noise, runoff, climate change, or other factors.
        - b. Post-construction standards.
        - c. Place limits on hard structures
    3. Support incentives to promote proactive development.
    4. On developed lands, create incentives for relocation or removal of structures threatened by erosion. Encourage replacement of hard structures with soft solutions.

II. Provide enhancement to increase the habitat value of necessary hard structures to make them more like natural rocky shores, such as by including features found in natural rocky shores such as tidepools, or terraces of soft bottom habitats.

- A. Develop a jointly funded, interagency San Diego Bay Shoreline Stabilization and Restoration Plan that arrests erosion and accretion problems around the bay, and that will allow regulators to view the bay as a whole system, rather than piecemeal.
    1. The Plan should provide techniques for adding habitat value to structures as they need to be replaced.
    2. The Plan should identify means to provide economic incentive to improving the habitat value of existing structures.
    3. The planning process should involve the Port, Navy, and regulatory and resource agencies.
- B. Establish general guidelines for shoreline structures for environmental compatibility.
    1. Bank stabilization should be located, designed, and constructed primarily to prevent damage to existing development.
    2. New development should be located and designed to prevent or minimize the need for shoreline stabilization measures. New development requiring shoreline stabilization should be discouraged.
    3. Consider confining bulkheading and filling to the upper one-third of the intertidal zone.
    4. If important nursery or foraging areas are identified for fish of the intertidal zone, then restrict the extent to which bulkheads or riprap may encroach on these zones.
    5. Encourage crenulation of the shoreline (making it more irregular or wavy) to create more shallow water niches and intertidal accretion in small inlets while maintaining the functionality of the stabilization structures. These stabilization structures could include microhabitat, such as micro-crevices, fractures and rock pools, to improve species diversity.
- C. Institutionalize a preference for soft solutions, using natural materials similar to those indigenous to the bay through shoreline planning (see *IIA* above).

1. Require the design and use of naturally regenerating systems for prevention and control of beach erosion over bulkheads or other structures where:
   - the length and configuration of the beach will accommodate such systems
   - such solutions do not detrimentally interrupt littoral drift, or redirect waves, currents, or sediments to other shorelines
   - beach enhancement may be permitted as a conditional use when the applicant has demonstrated that no significant change in littoral drift will result that will adversely affect properties or habitat
   - such protection is a reasonable solution to the needs of the site
   - it will reduce conditions conducive to erosion.
2. Require supplementary beach nourishment to impacted beaches in a drift cell where structural stabilization projects are necessary

D. Reduce reliance on hard solutions through these management measures.

1. Natural materials and processes should be used to the maximum extent possible.
2. Proposals should demonstrate the use of natural materials and processes and that nonstructural solutions to bank stabilization are unworkable in protecting existing development.
3. Bulkheads may be allowed only when evidence demonstrates that (a) serious wave erosion threatens an established use or existing building(s) on upland property and/or (b) bulkheads are necessary to the operation and location of water-dependent and water-related activities provided that all alternatives have proven infeasible.
4. Use of a bulkhead to protect a platted lot where no structure presently exists is discouraged.
5. Shoreline uses should be located in a manner so that bulkheading is not likely to become necessary in the future.
6. Affected property owners and public agencies should be encouraged to coordinate bulkhead development for an entire drift sector or homogenous reach in order to avoid exacerbating erosion on adjacent properties.
7. The cumulative effects of allowing bulkhead segments of shoreline should be evaluated prior to granting individual permits or exemptions.
8. Bulkheads should not be approved as a solution to geophysical problems caused by factors other than wave erosion.
9. Investigate ways to provide market or other incentive to convert existing structures to more environmentally compatible ones.

E. Monitor changes in invertebrate and algae populations that can result from alternative structural designs.

III. Pursue cost-effective, targeted design criteria, materials, construction methodologies, monitoring methods, and applied research to address questions about shoreline structures in support of the management objective.

A. Conduct an analysis of shoreline erosion to determine if any stabilization structures are unnecessary.

B. Determine the ecological functioning of the bay's artificial habitats in relation to other habitats, to develop better conservation and enhancement priorities.

1. Evaluate the "refuge" function of riprap for juveniles and predators.
2. Monitor the quantity and quality of existing and enhanced shoreline structures within the bay.

3. Conduct a project to characterize and compare communities of artificial hard substrate. Identify and prioritize desired ecological function of artificial structures including 1)trophic support for native fishes and birds, 2) habitat for migratory birds, 3) nursery/refugia for subtidal species, and 4) habitat for endangered and other special status species.

C. Promote research into understanding and improving the habitat values of artificial hard substrate.

1. Encourage experimentation with armored shorelines to make them more like natural rocky shores, or find soft solutions.
2. Targeting the key missing habitat components, test various habitat enhancing marine structures (Dyson 2010) to improve the habitat value of artificial structures that cannot be altered or removed.
3. Use the permitting process and cooperative agreements to foster this experimentation.
4. Consider adding light panels to piers to allow light transmission to organisms in the water below. Promote innovation in light-transmission construction.
5. Develop demonstration projects for minimizing the need to armor the shoreline and maximizing the value of necessary hard substrate additions to the environment.
6. Boat ramps have been identified as sometimes providing improved shorebird habitat. Investigate the characteristics that provide this benefit and incorporate it into project designs.
7. Assess the success of projects in developing functional habitat characteristics.

D. Apply successful techniques from demonstrations to additional enhancement projects at appropriate sites.

4.3.8 Salt Ponds

Specific Concerns

- Nearly half of the shorebirds that visit San Diego County may use the salt ponds (Warnock *et al.* 1989), yet the features that most support shorebird use are not understood in sufficient detail or quantified to ensure they are conserved into the future.
- The American Bird Conservancy designated the South San Diego Bay Unit of the Refuge as a Globally Important Bird Area due to the presence of globally significant numbers of nesting gull-billed terns and continentally significant numbers of surf scoters, Caspian terns, and western snowy plovers. The entire southern end of San Diego Bay, including the Sweetwater Marsh and South San Diego Bay Units, has also been recognized as a Western Hemisphere Shorebird Reserve Network Site.
- The USFWS Refuge CCP opens many opportunities for restoration and enhancement of the salt ponds for nesting, foraging, and roosting birds. These opportunities need to be balanced with human access for wildlife viewing, as well as management of the competing requirements of a large number of special status species, of which 26 are identified as Birds of Conservation Concern (USFWS 2002). While trade-offs were considered in the CCP-EIS, a baywide view of these trade-offs may result in a different assessment of priorities, and such trade-offs may change over time, or become more evident as restoration actions are undertaken.
- Implementing the CCP has scientific, technological, as well as financial challenges. Perhaps some regulatory obstacles also exist with respect to the acquisition of local, state, and federal agency permits. These challenges may not allow for restoring marsh or retaining ponds in the desired amounts. The priorities

area also based on knowledge that may improve over time and could be fed back into the decision-making process. Conflicting goals for restoring the salt ponds may emerge as CCP implementation progresses from resource agencies and other organizations.

Current Management

Approximately 1,068 acres of diked salt evaporation ponds and about 100 acres of associated levees occur at the southern end of the bay. Solar salt production has occurred in this location for over 100 years. Of the 32 ponds used in the current operation, 26 are included within the Refuge boundary. The remaining ponds are leased to the salt operator by the Port.

An agreement for acquisition of 800 acres (324 ha) of the Western Salt Company together with the leasehold interest of 600 acres (243 ha), for use as a wildlife refuge was reached with the Port (escrow closed 4/1/99). The Port also negotiated a Cooperative Agreement with the USFWS concerning mitigation benefits to the Port in the approximately 690 acres (279 ha) of Western's property and leasehold interest in the approximately 600 acres (243 ha) of state lands together with the Port's commitment of $900,000 for management and restoration planning, potentially including some substrate enhancement (up to three acres) for the least tern and a small amount for fish foraging enhancement. This agreement was reached in anticipation of the Port's acquiring 25 acres (10 ha) of land on Camp Nimitz, NTC, which had a conservation easement as a least tern nesting site, and is now developed as a commercial center.

Issues related to management and restoration of the salt ponds were considered in the USFWS Refuge CCP-EIS (2006). A summary of habitat changes proposed in the preferred alternatives (Alternative C for the Sweetwater Unit and Alternative D for the South San Diego Bay Unit where the salt ponds are located) is shown in Table 4-10.

Table 4-10. Summary of native habitat changes proposed in the San Diego Bay NWR comparing existing conditions and the conditions proposed under the preferred alternatives of the CCP-EIS.

Habitat Type	Existing Conditions (approximate acres)	Proposed Conditions under Preferred Alternatives for Both Refuge Units (approximate acres)
Open Water (subtidal)	850 acres	850 acres
Tidal Wetlands	470 acres	1,220 - 1,245 acres
Available Nesting Habitat (e.g. least terns, snowy plovers, seabirds)	132 acres	160 acres
Native Uplands	5 acres	65 - 85 acres
Freshwater Wetlands	5 acres	15 - 20 acres

The CCP proposes to enhance seabird nesting habitat, restore native habitat in the Otay River floodplain, and restore tidal circulation within the majority of the salt ponds. Those ponds that are not breached would be maintained in their current configuration and the water in the ponds would be managed to support a variety of migratory birds and wintering waterfowl. This alternative would result in the restoration of approximately 650 acres of existing salt ponds to tidal influence, with much of the restoration targeted for cordgrass-dominated salt marsh habitat. In those ponds to be restored, the only proposed changes to the levees are the openings required to facilitate tidal circulation. The majority of the levee system would be retained in its current configuration to accommodate seabird nesting and shorebird roosting. Approximately 36 acres of new seabird nesting habitat would also be created. A managed water area of approximately 275 acres would be maintained within those ponds that are too high to benefit from tidal circulation. Bay water would circulate through these ponds and the water levels in the ponds would be regulated to meet the seasonal needs of migratory birds, wintering waterfowl, and seabird and shorebird nesting. About 45 acres of this managed water system would be devoted to the production of brine invertebrates, a resource currently exploited by certain avian species, including phalaropes and eared grebes.

The CCP-EIS evaluated three implementation scenarios for the approach adopted for the salt ponds, all of which would ultimately result in the elimination of solar salt production. Under the first scenario, the salt pond complex would be restored in a single action; scenario two described a phased approach to restoration; and under the third scenario, which could occur as a single action or through a phased approach, no reconfiguration of the pond elevations would occur, resulting in a different habitat mix than that anticipated under the first two scenarios.

Evaluation of Current Management

Although not considered a natural habitat, the salt evaporation ponds provide relatively isolated nesting and resting habitat for a wide range of avian species, as well as some unique foraging habitat for several species of birds. During the past 100 years, the salt ponds have been an important stopover point for large numbers of migratory and wintering birds. In addition, the salt pond levees provide regionally important nesting habitat for seven species of colonial seabirds. Due to the hypersaline nature of the ponds, native wetland vegetation and bay invertebrates are essentially absent from the majority of the ponds. The only fish in the ponds are those that come in with the initial intake of tidal water. Once in the system, they can only survive in the lowest salinity primary ponds, cannot escape back into the bay, and do not reproduce. The ponds do however support several species of brine invertebrates that are preyed upon by a variety of birds, particularly eared grebes and phalaropes (USFWS 2006).

Despite its artificial nature, management of the salt ponds has successfully provided major and scarce ecological function for shorebirds, waterbirds, endangered and threatened species, and nesting sea birds by controlling public access, providing substrate for nesting and roosting, and foraging.

The competing requirements of a large number of special status species identified as Birds of Conservation Concern (USFWS 2002), as well as federally listed birds, could benefit from a baywide or regional analysis to understand trade-offs that may result in how the restoration priorities of the CCP are undertaken, and in what sequence.

Management Strategy—Salt Ponds

Objective: Protect and enhance the important wildlife functions of the salt ponds, with emphasis on special status birds, shorebird foraging and roosting, and sea bird nesting.

I. Protect existing values for shorebird foraging, high tide refuge, and sea bird nesting.

- *A.* Ensure the values and functions of the salt ponds are made perpetually available for shorebird and waterbird foraging, roosting, and nesting for special status Birds of Conservation Concern as well as federally and state listed species.
- *B.* Limit human disturbance.
- *C.* Manage predators of the California least tern, western snowy plover, and other nesting species on the dikes.

II. Provide a baywide perspective on CCP goals through this INRMP. Those goals are:

Goal 1: Protect, manage, enhance, and restore open water, coastal wetlands, and native upland habitat to benefit the native fish, wildlife, and plant species supported within the South San Diego Bay Unit.

Goal 2: Support recovery and protection efforts for the federally and state listed threatened and endangered species and species of concern that occur within the South San Diego Bay Unit.

Goal 3: Provide high quality foraging, resting, and breeding habitat for colonial nesting seabirds, migratory shorebirds and waterfowl, and salt marsh-dependent species.

Goal 4: Provide opportunities for compatible wildlife-dependent recreation and interpretation that foster public appreciation of the unique natural and cultural heritage of South San Diego Bay.

A. Monitor restoration results.

1. Participate in baywide or regional surveys to establish a scientifically-valid baseline condition.

2. Provide annual monitoring, perhaps using the monitoring program for San Francisco Bay salt pond restoration as a guide (viewable at http://www.southbayrestoration.org/Project_Description.html).

B. Ensure Refuge goals and decisions, as the CCP implementation progresses, are connected and receive feedback to INRMP goals and objectives.

1. Ensure regular communication with Navy and Port partners through the INRMP process.

C. Continue to inform and receive feedback from the public and local stakeholders about progress and monitoring results.

III. Address information gaps related to enhancement planning for the Salt Works.

A. Characterize the biophysical conditions of nesting and foraging sites selected preferentially by different bird species in order to identify enhancement opportunities.

B. Quantify the relative importance of physical and chemical factors that contribute to wildlife value at the salt ponds, including dike and pond substrate and stability; connectivity or isolation with other habitats or human disturbance; pond size; shape; salinity; water level; invertebrate support; and other physical, chemical, or biological factors that may affect its wildlife value.

4.3.9 Upland Transitions

Specific Concerns

See also Section Section 2.5.6: Upland Transitions.

- Terrestrial habitats along bay margins, including beaches, foredunes, backdunes, and coastal scrub, support numerous rare species, as well as provide essential nesting, roosting, and refuge from high tides and adverse weather for a large number and diversity of avian species. Even nonnative eucalyptus groves along bay margins support substantial use by nesting herons. Yet, these habitats are among the most threatened by development and management trends.
- Many water-dependent species also depend on available uplands. For example, the snowy plover prefers certain plants of southern foredune habitat, which may indicate a need for the conservation of this habitat.
- Beaches (e.g. nesting and roosting sites) as high tide refugia are depleted for shorebirds, and are threatened by sea level rise.
- Although long stretches of beach remain on the ocean side of the Silver Strand Peninsula, few are located on the bay shore, and most are subject to heavy recreational use or are used for military training, possibly limiting their use by wildlife.
- Upland transition habitat serves as crucial habitat for nesting, roosting, and foraging bird species, including the endangered least tern and threatened snowy plover. They comprise habitat for several sensitive plant and animal species of limited distribution found in few other habitats, including Nuttall's lotus, tiger beetles, coast horned lizard, wandering skipper, San Diego jackrabbit, coastal burrowing owl, and coastal horned lark.
- Surrounding development has compressed predator and prey species into the few remaining natural areas, resulting in unnaturally high rates of predation and disturbance, particularly in beach areas around San Diego Bay.
- Currently available upland habitat may be the most threatened habitat on the bay. The D Street fill is the largest parcel of undeveloped acreage and as such has enhancement potential available nowhere else for species that depend on adjacent uplands.

- Areas of relict coastal dune habitat along the eastern edge of Highway 75 and at SSTC support many coastal dune species (RECON 2004, 2006), including specialized invertebrate fauna such as tiger beetles and the globose dune beetle, sand spiders, robber flies, kelp flies, and ants. A few special status species have been recorded including the globose dune beetle *(Coelus globusus),* sandy beach tiger beetle *(Cicindella hirticollis gravida),* mudflat tiger beetle *(Cicindela trifasciata sigmoidea),* a third tiger beetle *(C. latesignata* spp. *latesignata),* wandering skipper *(Panoquina errans),* and the federally listed San Diego fairy shrimp *(Branchinecta sandiegonensis).* The spider fauna of the dunes was found to be diverse (RECON 2006). Funnel web weavers (Family Agelenidae), wolf spiders (Family Lycosidae), trapdoor spiders (Family Ctenizidae), and the endemic sand spiders of the genus *Lutica* (Family Zodariidae) were found. The nocturnal sand spiders are restricted to southern California coastal dunes and are adapted for burrowing in fine sand. Birds that nest in this habitat include the western snowy plover, California least tern, and horned lark. Killdeer, black-bellied plover, least sandpiper, American pipit, western meadowlark, house finch, other shorebirds, gulls, and terns loaf and forage here (Unitt 2004).

- Invasion of invasive plants such as iceplant degrades some upland transition areas that have potential for harboring sensitive species, such as Silver Strand State Beach and SSTC.
- Storm water management approaches that maintain water quality are most important in this interface between the water and terrestrial resources.

Current Management

Although various activities manage and protect least tern nesting sites around the bay, upland transition areas are not protected under the CWA. However, the CCC regulates sandy beaches.

Upland transition areas are not protected under the CWA. However, the CCC regulates sandy beaches, plus a 300 feet (9 m) buffer measured landward from the inland extent of the beach. Also, near the bay these areas are sometimes occupied by species protected under the ESA, such as the California least tern and western snowy plover. Least tern nesting sites around the bay are intensively managed and protected, as described in Section 4.4.6.2: California Least Tern. In addition, the D Street Fill area is designated as critical habitat for the western snowy plover. The level and consistency of activity varies from site to site, but activities range from fencing, grading, predator management, adjustment of sand grain size to discourage predatory ants, and monitoring nesting success.

Current protection mechanisms for adjacent uplands of the bay are summarized under Section 4.1: Ecosystem Approach.” Excluding sandy beaches, close to 300 acres (121 ha) out of about 900 acres (364 ha) of undeveloped uplands have some sort of protection, such as association with a refuge, future refuge, or reserve. Navy land under lease to CDPR and to the County of San Diego is considered vulnerable to development in the long term.

Gunpowder Point uplands are currently managed to support Belding’s savannah sparrow and the California least tern. Work in the marsh by the Refuge and the Port to enhance the status of salt marsh bird’s beak has included seeding and field studies.

Some coastal dune and coastal sage scrub restoration has been under way in upland transition habitat of the Naval Magnetic Silencing Facility at Point Loma. Restoration included acacia, hottentot fig and arundo removal. Small plantings of *Abronia maritima, Ambrosia chamissonis, Lotus nuttalianus,* and *Coreothrogyne filaginifolia* were accomplished. Seeding (with different mixtures for backdune and foredune) was done for *Abronia maritima, Ambrosia cheiranthifolia, Camissonia cheiranthifolia, Eriogonum parvifolium, Cardionema ramosissima, Nemacaulis denudata* var. *denudata.* Seeding for the coastal sage scrub species *Artemisia californica, Baccharis sarathroides,* and *Encelia californica* was also completed.

There is a Navy dune restoration site consisting of a single row of low foredunes, covering 0.5 ha (1.2 ac) along the central portion of the NASNI oceanfront. The Navy also manages its mowing regime at NASNI and on least tern sites to protect and enhance Nuttall’s lotus and coast woolly-heads. In addition, the Navy manages the timing of when training operations may be conducted where vernal pools are located at NRRF to avoid impacts to San Diego fairy shrimp, and also restricts all of NRRF from off-road vehicle use.

The BPC has a policy for "Landscaping and Urban Forestry in Tideland Areas Adjacent to San Diego Bay." It establishes general urban forestry policies for the Port's 250 acres of parks and open spaces and 5,200 trees in parks, open spaces, and along the District's streets and roadways. The management measures are published in a technical manual, Technical Manual - Tidelands Forestry Management, with the recommended standard of care for planting, preserving, removing, replacing, and maintaining trees.

The Navy (the NRSW Botanist and NAVFAC Southwest Landscape Architect), have jointly developed a preferred plan list as well as a "Do Not Plant" list for horticultural plants that are invasive in the wildland environment.

The CCP-EIS included contaminants remediation as a goal for the Refuge's coastal salt marsh and upland habitats by targeting it a priority for Refuge lands, adjacent properties, and upstream developments.

Evaluation of Current Management

Although likely the most impacted habitat, unless tied in to a threatened or endangered species, upland transition areas remain vulnerable.

Upland transition is likely the most impacted of all habitats with some exceptions. Intensive management of upland transition sites for the California least tern has resulted in an improvement in number of nesting pairs of the least tern in California to approximately 6,800 (Marschalek 2008). This is believed to be due to predator management and better site protection from disturbance (Caffrey 1997). Further discussion on the California least tern and other listed species is in Section 4.4.6: Special-Status Species Protection.

Areas of upland transition outside of California least tern nesting sites, the refuge, CVWR, or D-Street Fill remain vulnerable to development or further disturbance, unless a direct tie-in to a threatened or endangered species can be identified. Some, such as the parcels along Highway 75, could be enhanced for intertidal flat or salt marsh values if excavated, and so the upland transition values would be in competition for those.

The integration of storm water management and the built environment in upland transitions is still in very early stages.

Management Strategy—Upland Transitions

Objective: Ensure no net loss of availability, structure, and function of high value adjacent uplands, and achieve a long-term net gain in their quantity, quality, and permanence.

I. Conserve all adjacent uplands known to have important functional values for the bay, such as support of rare species, nesting, roosting, and refuge.
    A. Characterize each parcel with upland transition values with respect to threatened or endangered species support, other rare species support, high tide refuge, marsh buffer, urban buffer, site disturbance history and current pattern, and presence/cover of invasive species.
        1. Protect threatened, endangered, and rare species use as a first priority.
        2. Provide high tide refugia values as a second priority.
        3. Provide buffer areas.
    B. Describe and quantify the relative importance of linkages to bay-dependent uses between adjacent or nearby upland and intertidal parcels. Then provide for these linkage with adequate buffers.
    C. Avoid and minimize wildlife use of upland transition areas from adverse human effects.
        1. Enforce leash laws and keeping of cats indoors by pet owners, especially near least tern or light-footed clapper rail nesting sites.
        2. Organize community cleanups of garbage.

3. Patrol parcels for illegal activity.
4. Control invasives such as hottentot fig.

D. Seek acquisition into public ownership, purchase of conservation easement, or other long-term habitat conservation for upland parcels along Highway 75.

II. Enhance disturbed upland transition areas.

A. Characterize the site potential and target assemblages of each parcel.

B. Control invasives and restore native vegetation to uplands of the SMNWR at least in part by the establishment of adequate buffers between developed areas and marsh habitat.

C. Control invasives on coastal dune remnants as a first priority, because of the rare species that depend upon them.

D. Enhance upland transition habitat on SSTC in support of rare species, balancing the need for intertidal flats and salt marsh habitat.

E. Protect high tide refugia function of D-Street Fill in balance with intertidal enhancement needs.

F. Encourage appropriate native and water-conserving landscape designs or "*bayscaping*."

III. Support use of education, signage, and art as a means of encouraging people to respect wildlife in upland transition areas, such as has been already accomplished at the Navy parcel leased to CDPR, along trails of the natural area at Grand Caribe, and at the South Bay Marine Biological Study Area.

A. Conduct adequate planning to anticipate and control vandalism.

4.3.10 River and Creek Mouths and Floodplains

See also Section 2.5.6.4: River Mouths.

Specific Concerns

- The damming and channelization of local rivers has eliminated much of their natural function. River and creek mouths and their floodplains as a deposition area of sedimentation, organic matter and freshwater input are severely altered. The bay floor has changed from a muddy to a sandy bottom.
- Brackish water is scarce for dependent species such as dabbling ducks, due to lower freshwater input and lack of shallow habitat.
- The channelized nature of the river mouths affects the ability to restore salt marsh habitat that can occur along river mouths or corridors, by narrowing their potential occurrence into a narrow corridor along the dikes that contain the river.
- Otay River's mouth and floodplain provide a valuable restoration opportunity.

Current Management

Organic material and fine sediment that used to be supplied by the seven streams entering the bay no longer enter the bay as they did naturally. Dams for reservoirs have trapped sediment, channelization has blocked streambed and streambank sediment sources, and pavement and buildings have covered much of the landscape. As a result, the bay floor's sediment composition has changed from a muddy to sandy bottom. The nature of change from the natural system to the present one with a large component of urban runoff has not been quantified as to its effects on the ecosystem (e.g. what portions of input are balanced out versus actually changed).

Dabbling ducks are found primarily in shallow brackish water near the mouths of drainages (and similar water on the salt ponds and seasonal wetlands of the SSTC). Brackish water is presently scarce for dependent species such as dabbling ducks. The channelized nature of the river mouths also affects the ability to restore salt marsh habitat that can occur along river mouths or corridors, by narrowing their potential occurrence into a narrow corridor along the dikes that contain the river.

Photo 4-4. San Diego Bay waterfowl. Photo courtesy of John Lovio.

Like the upland transition habitat, freshwater wetlands adjacent to salt marshes have been severely impacted by development and reduced runoff from rivers and creeks (MacDonald *et al.* 1990).

The mouths of the most of the more urbanized creeks (e.g., Switzer, Chollas, Paleta) are located in active harbor areas. As a result, their lower floodplains have been filled for development and their mouths need to be routinely dredged to maintain boat and ship access (see Map 2-3). However, as shown on Map 4-3, Telegraph Canyon Creek's mouth contains wetlands within the Port District's jurisdiction and is near the CVWR. The Sweetwater River's Flood Control Channel lies adjacent to the Sweetwater Marsh Unit of the San Diego Bay NWR, but the remains of several small tributaries flow through the Refuge: lower Paradise Creek and marsh, Sweetwater Marsh, and Marisma de Nacion (USFWS 2006). On the bay side of the refuge is the Port's jurisdictional wetlands and estuary. The Otay River's lower floodplain and mouth were partly channelized before 1916, based on an old map. Formerly entering the Western Salt Works operation, this area is now part of the South Bay Unit of the San Diego National Wildlife Refuge (since 1999).

Evaluation of Current Management

There are few if any opportunities provided through regulation in the urbanized environment to restore river and creek mouths and their floodplains as a deposition area of sedimentation, organic matter and freshwater input. Regulatory guidance is also not in place to guide the restoration of sediment transport from streams and their tributaries. This absence was seen as a “regulatory gap” by the San Diego Bay Advisory Committee for Ecological Assessment in its 2005 final report to the Legislature (as required by SB 68).

Restoration opportunities for river mouths and floodplains appear to mainly lie within the public lands of the San Diego Bay NWR. For the South San Diego Bay Unit, the USFWS’ recent CCP addresses the Otay River's floodplain through several restoration options (USFWS 2006). Each option would increase the acreage of tidally influenced wetlands, freshwater wetlands, and restored upland from the current condition of primarily disturbed vegetation of the floodplain. To restore intertidal habitat, portions of the floodplain would be excavated. The Sweetwater Marsh Unit does not address the floodplain remnants directly but does recommend restoring intertidal wetlands from portions of the filled in areas of the D Street Fill and Gunpowder Point.

Upstream water quality, water supply, and natural resource issues are being addressed in the recent Otay River Watershed Management Plan that was adopted in 2006 by a voluntary coalition of municipalities within the watershed. The Plan's restoration actions may also help influence the future condition of the Otay River mouth and floodplain.

Management Strategy—River Mouths and Floodplains

Objective: Allow river mouths and floodplains to fulfill or at least mimic their natural ecological function as an intermittent and episodic source of sedimentation, organic matter, and freshwater input for the bay.

I. Conserve the best functioning of what remains. Investigate ways to restore or substitute natural functions.

- *A.* Conserve and enhance the structural habitat complexity of the riparian portion of the lower Otay River.

II. Enhance river mouth and floodplain functions and values as a natural corridor, linkage, and buffer between salt water and freshwater habitats.

- *A.* Identify opportunities to replace or mimic the episodic siltation function formerly played by uncontrolled streams.
  - *1.* Investigate the option of disposal of appropriate dredge material at the river mouth to help restore more natural sediment composition of the bay's floor.
- *B.* Restore the ecological functioning of the Otay River mouth and its floodplain within the South Bay Unit of the San Diego Bay NWR.
  - *1.* Support the CCP's efforts to:
    - *a.* Enhance the floodplain functions of the Otay River near its mouth.
    - *b.* Reestablish the natural salt marsh function at the mouth of the Otay River.
    - *c.* Retain the area's function as an ecological transition between the salt marshes of the Otay channel and freshwater riparian habitat.
  - *2.* Promote actions of the Otay River Watershed Management Plan that will help restore some of the ecological functioning of the river's system, including natural sediment delivery.
- *C.* Support improvement of the ecological functioning of the Sweetwater River floodplain and tributaries within the Sweetwater Marsh Unit of the San Diego Bay NWR through its CCP's efforts to:
  - *1.* Restore intertidal wetlands in the D Street Fill and Gunpowder Point, consistent with the critical habitat designation for the snowy plover.
  - *2.* Other restoration actions deemed important for mimicking natural functions.

III. Study the importance of natural functions of river and stream mouths relative to substitutes of these functions.

- *A.* Investigate the ecological implications of an estimated 75% reduction in sediment load entering the bay (Smith and Graham 1976), especially with regard to salt marsh habitat.
- *B.* Investigate the ecological implications of changes in the volume and nutrient content of water delivery to the bay of current versus historic conditions.
- *C.* Investigate nutrient loading into the bay and its connection with algae and phytoplankton blooms.

4.4 Strategy by Species Group

4.4.1 Invasive Species

Specific Concerns

As noted in Section 2.6.7: Invasive Species, about 100 aquatic nonindigenous species are found within this INRMP's footprint. Moving from acknowledgment to management of the possible invasiveness of these organisms must address these concerns:

- Invasive species are one of the leading causes of degraded ecological condition and ecosystem services (National Research Council 1995). AIS are used as biological indicators to measure ecosystem condition.
- AIS in the context of climatic change requires increasing feedback to management in order to develop adaptive strategies to accommodate these environmental changes. Climate change has the potential to interact with invasives as a stressor to healthy conditions through multiple mechanisms (EPA 2008), and together they may overtake the gains made in habitat restoration.
- Bays and estuaries like San Diego Bay are known to be particularly susceptible to AIS.
- AIS are increasingly coming under the purview of regulatory and resource agency scrutiny, including ballast water and NPDES permits, TMDLs and impaired waters, economic consequences, and pesticide usage for control.
- Specific vectors of invasive species for San Diego Bay have not been identified.
- Species invasion of San Diego Bay is less studied than in other coastal bays, with very little known about the vast majority of invading species and their effects on native species or the ecosystem.
- During Bight '98 (Bay *et al.* 2000), the invasive bivalve *Musculista senhousia* was present in more than 70% of the samples, making it the most widely distributed trawl caught invertebrate in the bay. *Musculista senhousia* and *Microcosmus squamiger* together, both nonindigenous species, accounted for over 50% of the total catch of benthic invertebrates. Impacts are unknown. The ability to monitor population densities of invasive species such as Musculista senhousia may be vital to understanding any changes that take place in whole communities.
- Experience elsewhere shows that ignoring an alien species often leads to a crisis situation where the species can no longer be eradicated and actions to limit the population become very expensive, if not impossible (Cohen and Carlton 1998).
- Monitoring for invasive species in areas where they do not exist yet is an important aspect of controlling them. A monitoring program is lacking for the bay.
- Since impact assessments require knowledge of the natural processes that influence community structure, further investigations into the relationship between bay hydrodynamics and resident fish and invertebrate assemblages may help direct proper management of a healthy bay.
- Invasive plants can threaten the composition of salt marshes and mudflats, and displace native coastal plants (Zedler 1992a; Talley *et al.* 2001). A key concern is assessing the modification of wetlands by invasive plants (e.g. *Spartina alterniflora, Zostera japonica, Phragmites australis)* and animals (e.g. *Eriocheir sinensis, Ficopomatus enigmaticus)* and determining ways to minimize impacts of these species in natural and restored systems.
- Not all exotics or nonnatives are a problem for ecosystem health. However, the interaction between natives and exotics could change with shifts in global temperature.
- There is a lack of available government funding for AIS work, and this is a key issue preventing progress on the issue in San Diego Bay.

- Specific harm to native species and the ecosystem has not been identified for most of the invasive species that occur in San Diego Bay. An exception is the Australasian isopod *Sphaeroma quoyanum,* which burrows into the banks of the marsh's tidal channels and along marsh edges often in very high densities, resulting in increased bank erosion and loss of salt marsh habitat (Talley *et al.* 2001). Previous regional monitoring studies indicated that non-indigenous species were not a serious impact to native species in terms of total abundance or species richness. It is possible that detailed studies, however, will identify native species that are negatively impacted by increases in non-indigenous fauna.
- The recent ecological release of *Sphaeroma quoyanum* in Paradise Creek after a long lag period since the species' introduction also illustrates one of the problems in dealing with nonindigenous species—their potential for impact may be underestimated and take years after the initial invasion to become manifest, by which time it is often impossible to control.
- Phytoplankton species are the cause of some of the detrimental blooms along the east coast of the United States which have resulted in major fish kills. Detection capability is needed for organisms that are difficult to sample. Sampling of zooplankton is usually accomplished, to the exclusion of phytoplankton. As the phytoplankton community is easily transported by ballast water, there is a potential for introduced phytoplankton species occurring in bays and estuaries. In addition, rock crevices and riprap were not sampled in previous studies.
- Some commercial nurseries still sell invasive plants.

Background

In 2005, CDFG's OSPR conducted a statewide survey (Foss et al. 2007) that included San Diego Bay. Combining their list and incorporating the results of the CDFG work in 2000, and in earlier studies, the documented invasive species include four marine alga, one protozoan, 89 invertebrates, and six fishes (yellowfin goby; sailfin molly; rainwater killifish (*Lucania parva*); striped sea bass (*Morone saxatilis*); chameleon goby (*Tridentiger trigonocephalus*); and threadfin shad (*Dorosoma petenense*)). These non-indigenous marine species were found in benthic, fouling, and water column habitats.

The most studied invasive locally is probably the Japanese mussel (*Musculista senhousia)* (Takahashi 1992; Crooks 1996; Scatolini and Zedler 1996; Crooks 1997). Its rapid spread, population explosion, and extreme densities (up to 27,000 mussels/m^2 in the intertidal zone and up to 178,000/m^2 carpeting the shallow subtidal bay bottom) have attracted attention. Research has shown that its effects can be both negative and positive (Crooks 1998b). While its dense mats can crowd out native clams and dominate marsh restoration sites, the mats also provide a new substrate condition that supports greater species diversity and densities of native macrofauna than similar uninvaded areas. However, the mussel's dense beds can inhibit growth and vegetation propagation of eelgrass (Crooks 1997; Reusch and Williams 1998, 1999). If the eelgrass beds are dense and unfragmented, the mussel starves. The mussel has established so well in San Diego that its removal is considered impossible.

Another invasive species in the bay producing "ecosystem-level effects through habitat alteration" is the isopod *Sphaeroma quoyanum* (Crooks 1997). Though known to inhabit the bay since 1927, it was not detected as a problem until the early 1990s. High densities (>10,000/m^2) were observed in the banks of the salt marsh in Paradise Creek, causing the overlying vegetated marsh flat to slump into the creek and the creek to widen. This recent ecological release after a long lag period since the species' introduction also illustrates one of the problems in dealing with nonindigenous species—their potential for impact may be underestimated and take years after the initial invasion to become manifest, by which time it is often impossible to control.

Current Management

Legal Framework and Plans

Federal law defines "invasive species" as one that is nonnative to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. In other literature and in legislation, such invaders are also sometimes referred to as "nuisance" species. Table 4-11 lists federal authorities and agencies with regulatory authority over the introduction and transport of aquatic species that may be invasive or noxious.

The major laws driving management of natural resources are described in Section 3.6. For detailed information on federal AIS authorities, agencies and programs, see http://www.anstaskforce.gov and www.invasivespecies.org.

Table 4-11. Federal authorities and agencies with regulatory authority over the introduction and transport of aquatic species that may be invasive or noxious.

Authority & Primary Agency	Responsibility
NANPCA (Title I of P. No.101-646, 16 USC 4701 et seq. 1990) *USFWS* *NOAA*	Established a federal institutional framework that promotes and coordinates research to assist state governments, develops and applies prevention and control strategies, establishes national priorities, educates and informs citizens, and coordinates public programs. The act calls upon states to develop and implement comprehensive state management plans to prevent introduction and control the spread of aquatic nuisance species. Established the national Aquatic Nuisance Species Task Force to coordinate governmental efforts related to prevention and control. The Aquatic Nuisance Species Task Force consists of ten federal agency representatives and12 *ex officio* members representing nonfederal governmental agencies
NISA 1996 and 1993-2005 Coast Guard Regulations Under NISA (33 CFR 151) *USCG*	NISA amended the NANPCA of 1990 to mandate ballast water exchange for all vessels with ballast on board that enter U.S. waters from outside the EEZ. It required vessels to submit a report form to the USCG documenting specific ballast water management practices. After voluntary guidelines proved unsatisfactory, the USCG made compliance with ballast exchange guidelines mandatory in 2004. NISA authorized funding for research on aquatic nuisance species prevention and control. In addition, NISA required a ballast water management program to demonstrate technologies and practices to prevent aquatic non-indigenous species from being introduced into and spread through ballast water in U.S. waters. The mandatory program requires ships to use one of three ballast water management methods: 1) retaining ballast water on board, 2) conducting a mid-ocean exchange, and/or 3) using an approved ballast water treatment method. All vessels are required to submit ballast water management reports (failure to submit a report can now result in penalties). Federal regulations also require vessels to maintain a ballast water management plan that is specific for that vessel and assigns responsibility to the master or appropriate official to understand and execute the ballast water management strategy for that vessel.
EO 13112 Invasive Species (64 CFR 6183) 1999	The order directs all federal agencies to address invasive species concerns, as well as to refrain from actions likely to increase invasive species problems. The NISC was established and released the first National Management Plan in 2001. Federal activities are now coordinated through NISC (established by the executive order) and the Aquatic Nuisance Species Task Force (established by NANCPA and NISA).
Lacey Act (16 USC §§ 3371-3378) *USFWS* *NMFS* *Animal and Plant Health Inspection Service*	One of the purposes of the Act is to regulate the introduction of American or foreign birds or animals in localities where they have not previously existed. Current List of Injurious Wildlife Species found at 50 CFR 16.11-16.15 (10/4/2002). The Act prohibits trade in wildlife, fish, and plants that have been illegally taken, possessed, transported or sold. The Act prohibits the falsification of documents for most shipments of wildlife (a criminal penalty) and prohibits the failure to mark wildlife shipments (civil penalty).

Management of ballast water from ships in port is the major focus of federal policy to control invasive aquatic species.

Management of ballast water from ships in port is the major focus of federal policy to control invasive aquatic species. In 2005, a federal judge ruled that the EPA must consider invasive plants and animals in ballast water pollutants. Regulations are currently being considered for invasives emphasizing best practices such as ballast water exchange. As shore-based treatment is yet to come on line, ballast water exchange, the process of exchanging coastal water for mid-ocean water, is presently the most broadly applicable method for managing the risk of AIS introductions. During the ballast exchange process, biologically rich water loaded at the last port of call is flushed out of ballast tanks with the water from the open ocean, typically beyond 200 nautical miles from land. Organisms are generally less numerous in the open ocean, and it is expected that they will be poorly adapted to survive once discharged in the very different environmental conditions of a nearshore port. Scientific research indicates that offshore ballast exchange typically eliminates 70% - 95% of the organisms originally taken into a tank while at or near port (Zhang and Dickman 1999; Parsons 1998; Cohen 1998). Other studies suggest that exchange efficiency is inconsistent, and ranges from 50- 90% (USCG 2001). Most experts view ballast water exchange as a short-term solution, with the final resolution being a combination of treatment technologies and management options. In the meantime, agencies are considering the development of performance standards for ballast water exchange (Takata et al. 2006).

Under NANPCA/NISA, states are specifically permitted to regulate ballast water on ships. Concerned that national and international efforts to provide guidance and regulations for minimizing and preventing introductions from ballast didn't go far enough to protect state waters, California passed the Ballast Water Management for Control of Nonindigenous Species Act of 1999. With this legislation, the state became the first to require ships to exchange ballast water at sea to minimize the possibility of transporting invasive species. Other states, such as Washington and Oregon, soon followed with their own legislation.

In addition to reporting requirements, California required the state to issue a ballast water discharge standard in 2007. In January 2006, the SLC approved the report titled "California State Lands Commission Report on Performance Standards for Ballast Water Discharges in California Water (Falkner *et al.* 2006). This report included interim performance standards, an implementation schedule, final discharge standards and other programmatic recommendations. The report's recommendations were adopted by the California Legislature in 2006 under SB 497, which among other provisions required the SLC to adopt, via regulations, the interim standards and implementation schedule. This legislation also deleted the sunset provision that would have ended CDFG's Marine Invasive Species Monitoring Program.

Vessel operators are now required to develop and maintain a Ballast Water Management Plan and to train their crews. Vessels bringing ballast or sediment into state waters must employ one of the following ballast management practices: 1) conduct a mid-ocean ballast water exchange before entering state waters; 2) retain ballast water on board; 3) use an alternate method approved by the SLC; 4) discharge all ballast water to an approved shore-side facility; or 5) conduct a ballast water exchange in an area approved by SLC. CDFG's OSPR conducts research in support of the new law. SWRCB is responsible to implement studies to evaluate alternatives to treating or managing ballast water. The Board of Equalization will collect vessel fees into the "Exotic Species Control Fund," which will support the statewide programs.

The SLC oversees management of aquatic invasive introductions through the vector of commercial shipping and ballast water as directed by the 2003 Marine Invasive Species Act. Commission inspectors board approximately 25% of all vessels that arrive to California to verify compliance with regulations, and to disseminate outreach materials to vessels and crews new to California. Multi-agency, multi-interest advisory groups are continually convened and consulted regarding evolving policy considerations. In addition to its regulatory activities, the Commission facilitates scientific research and technology development to enhance management efforts of the program, and to inform policy makers.

While also sharing responsibility for ballast water management and compliance, the CDFG is one of the lead agencies for managing other aspects of invasive species. Its Habitat Conservation Branch houses the state Invasive Species Coordinator. CDFG is the lead agency in developing the statewide AIS management plan, as well as a rapid response plan for invasions. CDFG is responsible for enforcement of regulations concerning the aquaculture industry; recreational fishing; commercial fishing; the importation and transport of live wild animals, aquatic plants and fish into the state; and the placement of any such animals in state waters. Recent programs have focused on the aquarium plant *Caulerpa taxifolia,* the voracious fish northern pike, and the New Zealand mudsnail, among others. All species of *Caulerpa* are regulated in the state of California under CDFG Division 3, Chapter 3.5 §2300.

CDFG is also responsible for conducting biological surveys to assess the amount and types of AIS present in state waters. Starting in 1999, CDFG's OSPR conducted biological surveys to determine the degree of success of ballast water management activities. The first survey of major ports, harbors and bays of California helped determine a baseline of non-indigenous aquatic species introduced from the ballast of ocean-going vessels. The survey revealed that all areas of the California coast have experienced some level of invasion by species not native to California. Since then, CDFG/OSPR has revisited baseline monitoring sites and expanded monitoring to include intertidal and subtidal habitats at 22 outer coast sites.

Other state agencies involved with invasive aquatic species are summarized below by agency, while Table 4-12 organizes similar information by authority.

Table 4-12. State authorities and agencies with regulatory authority over the introduction and transport of aquatic species that may be invasive or noxious.

Authority & Primary Agency	Responsibility
California Fish And Game Code & Title 14 Of Code Of Regulations	At least five code sections address or relate to AIS, restricting or limiting in various ways: the impacts of AIS control measures on state listed species; the importation and transportation of restricted live wild animals and plants; the placement of live fish, fresh or saltwater animals or aquatic plants in any state waters of this State; and the operation ofaquaculture industries. The code also prescribes state surveys of ballast water-related invasive species. Most of these regulations are enforced by CDFG. F& G Code §§ 2080–2089, 2118, 2270-2272, 6400-6403, 6430-6433: 15000 et seq. http://www.fgc.ca.gov/html/regs.html and http://www.dfg.ca.gov/ospr/organizational/scientific/exotic/exotic%20report.htm.
California Food and Agriculture Code	Over 30 different code sections address the state's mandates to prevent the introduction and spread of injurious animal pests, plant diseases and noxious weeds. These codes describe procedures and regulations concerning, among other things, plant quarantines; emergency pest eradications to protect agriculture; pests as public nuisances; vectors of infestation and infection; the sale, transport and propagation of noxious weeds; and the protection of native species and forests from weeds. Most of these regulations are enforced by CDFA.
California Water Code	The Porter-Cologne Water Quality Control Act (California Water Code, Division 7) lists a number of types of pollutants that are subject to regulation. §13050, for example, specifically includes the regulation of "biological" pollutants by defining them as relevant characteristics of water quality subject to regulation by the Board: AIS are an example of this kind of pollutant if they are discharged to receiving waters. The Water Code generally regulates more substances occurring in discharges, and also defines discharges to receiving waters more broadly than the federal CWA.
Ballast Water Management Act and Marine Invasive Species Act of 2003 (AB 703 and AB 433)	The Ballast Management for Control of Nonindigenous Species Act of 1999 created the state's first program to prevent non-indigenous species introductions through the ballast water of commercial vessels. The act required that vessels originating from outside the United States Economic Exclusive Zone carry out mid-ocean exchange or use an approved ballast water treatment method, before discharging in California state waters. State enforcement of the act took the form of monitoring ballast discharges and reports, inspecting vessels for compliance, and assessing vessel reporting rates and compliance. PR Code §§ 71200-71271; CC 2271. http://www.slc.ca.gov/Division_Pages/MFD/MFD_Programs/Ballast_Water/Ballast_Water_Default.htm

For plant pests, the California Department of Food and Agriculture (CDFA) has long regulated and managed aquatic and terrestrial weeds, with a particular emphasis on those that are agricultural pests or cause economic harm. CDFA activities and regulatory authority include quarantine, exterior pest exclusion (border stations, inspections), interior pest exclusion (pet/aquaria stores, aquatic plant dealers, and nurseries), and detection and control/eradication programs. The CDFA maintains a rated list of noxious weed species, which, depending on the rating, require various levels of eradication, containment or holding actions. For all plants, the CDFA Plant Pest Diagnostic Center identifies plant species and assigns plant pest ratings. In 2005, the CDFA and the California Invasive Weed Awareness Coalition completed the state's first comprehensive noxious and invasive weed action plan.

The California Department of Boating and Waterways (CDBW) manages the state's largest and oldest aquatic weed control program to keep waterways free for navigation from aquatic weeds. The CDBW also has the authority to manage the recreational boating vector of AIS in California. The Department leads the California Clean Boating Network – a collaboration of government, business, boating, and academic organizations working to increase and improve clean boating education efforts, including invasive species education, across the state.

The California Coastal Conservancy has been involved for over 20 years in the control and eradication of aquatic invasives, particularly plants. Most recently its management focus has been on developing, funding and operating the Invasive Spartina Project in San Francisco Bay. The project's aim is to eradicate various invasive species of Spartina, and its hybrids, that threaten to destroy mudflats and drainage channels. The Conservancy is also heavily involved in efforts to control Arundo in many coastal watersheds, and has been a partner in developing this state AIS management plan.

For impacts on water quality and supply, the California Department of Water Resources (CDWR) addresses invasive species issues. Recent activities have focused on monitoring AIS within the water column and food web, developing key early detection programs, and undertaking structural improvements such as a barrier at Lake Davis (to prevent northern pike escape) and a screen at the State Water Project (to collect Chinese mitten crabs). On the early detection front, CDWR is responsible for implementing the California Zebra Mussel Watch Program (which includes risk assessment, early detection, public outreach, and the development of a rapid response plan for the Central Valley watershed and a centralized reporting system for mussel sightings).

The SWRCB, and its nine regional water quality control boards have no specific policies and programs related to AIS but have been working in support of, and in an advisory capacity to, other state agencies on various related activities such as hull fouling and ballast water management. Invasives come under water board purview as part of the state's efforts to implement and enforce the CWA. A 2005 federal court ruling defining non-indigenous species as "pollutants" present in discharges from vessels, and finding that such discharges are not exempt from NPDES permitting requirements. In terms of AIS management, some of the regional boards have also sought to place specific water bodies within their regions on the CWA's 303(d) list, as impaired by exotics. San Francisco Bay was listed in 1998. In 2006, the State Board will consider listing proposals for the Delta, the upper San Joaquin River and the Cosumnes River. Once on the 303(d) list, the regional boards are required to develop discharger/source based programs for managing pollutant loads (called TMDLs), which in the case of exotics has proved somewhat difficult to develop. Trying to allocate loads, or goals for zero loads, among dischargers, water users and municipalities is challenging when most of the water bodies in question are already heavily invaded.

Other regional boards have become involved in AIS-related water quality issues through watershed management projects, non-point source pollution management programs, and wetland mitigation and restoration programs (raising issues about the use of non-native aquatic plant species for these programs, and the control of invasives, for example). The State Board has also participated in AIS management activities concerning the use of aquatic pesticides.

Beyond authorities and legislation, some of the other major activities related to AIS management in California include:

- USFWS' 100th Meridian Initiative to stop the zebra mussel from spreading west.
- NOAA's Sea Grant Program, and its support for the West Coast Ballast Outreach Project (which educates the maritime industry about the ecological seriousness of aquatic exotic species), as well as funding for research on key invasive species.
- The U.S. Department of Agriculture's (USDA's) federal noxious weed list, maintained through the Animal and Plant Health and Inspection Service Cooperative Agricultural Pest Survey, and its Agricultural Research Service units at Davis and Albany, California, whose work includes improving management of invasive aquatic and riparian weeds affecting agriculture and natural resources;
- EPA's commitment to providing federal coordination for AIS rapid response planning and associated permitting.
- The newly completed California AIS Management Plan (CDFG 2008) provides a framework to respond to AIS in California. It meets requirements to develop a statewide Nonindigenous Aquatic Nuisance Species Management Plan (under §1204 of the NANPCA of 1990 (amended as NISA of 1996), and is tiered under the National AIS Plan. It targets both marine and freshwater environments. This new decision-making structure will ensure action on high priority activities, and help identify and bridge gaps in coverage. The plan also outlines the state's first rapid response process for high-risk invaders.

EO 13112 established the national Invasive Species Council to provide coordination, planning, and leadership for federal invasive species programs. The USACE and DoD have been tasked to act as participants in various performance elements of this plan.

EO 13112 established the NISC to provide coordination, planning, and leadership for federal invasive species programs that support state, tribal, local, and private entities. To meet this goal, in 2001 the National Invasive Species Monitoring Plan was developed. As of August 2008, the updated 2008-2012 plan has been released. NIMSP outlines strategic goals and tasks for participating agencies. The USACE and DoD have been tasked to act as participants in various performance elements of this plan.

Websites and Databases for Technical Support

Twenty sites in San Diego Bay were sampled for invasive species in 2005 (OSPR 2005). Results of this work are reported as part of a statewide survey in a database managed by OSPR that contains the name and location of every known non-native species on the California coast. The California Aquatic Non-native Organism Database includes information about the pathway of introduction (e.g. ballast water, hull fouling, etc.), date of introduction, locations observed, and native region of each species. The California Aquatic Non-native Organism Database is a tool to help monitor new introductions and to understand the patterns associated with those introductions.

The 2000 survey results of CDFG's Marine Invasive Species Monitoring Program are reported at http://www.dfg.ca.gov/ospr/about/science/misp.html.

Other agencies provide technical support as follows:

- Fact sheets regarding all recognized nonindigenous aquatic species is maintained by the USGS at http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=67.
- An Aquatic Species Database and Aquatic Invasions Research Directory is hosted by the: Smithsonian Environmental Research Center.
- Ballast water requirements may be researched at http://www.slc.ca.gov/Division_Pages/MFD/MFD_Programs/Ballast_Water/Ballast_Water_Default.htm.
- The California Invasive Plant Council (Cal-IPC) ranks plants by their invasibility. Their data base is hosted at http://www.cal-ipc.org/.
- An Internet-based, searchable database containing up to the minute information on people, research, technology, policy, and management issues relevant to aquatic invasions is hosted by the National Invasive Species Information Center by the USDA National Agricultural Library at http://www.invasivespeciesinfo.gov/toolkit/main.shtml. The scope of the Directory falls into four broad areas: 1) The ecology of aquatic invasions: vectors, impacts, risk assessment and response, 2) The ecology of ballast water, 3) Prevention and treatment technologies, and 4) Policy and management.

San Diego Bay Practices

Currently all USACE permit projects involving disturbing activities in bay substrates require surveys for *Caulerpa* spp. All species of the genus *Caulerpa* are regulated in the state of California under CDFG Division 3, Chapter 3.5 §2300.

Foreign and domestic commercial vessels exchange ballast water within San Diego Bay as a standard operating procedure when off-loading cargo. In addition, ship ballast tanks are emptied at shipyard dry docks during maintenance and repairs. Besides the discharge of ballast water, ballast sediment of up to 500 gallons per ship is also emptied at drydock. While empty ships are said to be "in ballast" when carrying ballast and no cargo, ships that are carrying cargo may also contain considerable amounts of ballast water.

Ballast discharges from commercial vessels in the bay must be in compliance with the Port's tariff that addresses water quality concerns.

Acting under the marine discharge regulatory authority of the Clean Vessel Act (33 CFR part 157), the USCG urged the Port to provide some controls for ballast discharge. As a result, the Port adopted a tariff in 1994 that requires all commercial ships off-loading or on-loading cargo at Port terminals to minimize discharge to protect water quality (Tariff #1-G.0475). To discharge clean ballast, the ship master must have a Clean Ballast Water Discharge Permit signed by the Port's marine operator and posted on the gangway. Violations call for immediate removal of any pollutants (e.g. oil, sludge) and payment for cleanup. Additionally, the USCG performs annual boarding inspections of foreign vessels and can check ships' logs for records of any open ocean ballast exchange. These logs are signed by licensed shipmasters.

The Port currently includes the USCG reporting form in their ballast water permit. California requires each vessel to fill out a ballast water report form, which allows the state to quantify how much ballast water is coming into California, where it is coming from, and how it is managed. For example, discharges reported by the Port based on reports to the SLC for voyages through August 2001, was 298,387.62 metric tons.

The DoD is currently promulgating joint regulations with the EPA covering discharges from DoD vessels (40 CFR 1700) to implement §312(n) of the CWA (33 USC §1322[n]). When complete, they will set discharge standards for vessel ballast water to address the environmental effect of non-native species introduction via that ballast water (as well as addressing chemical pollution from other Armed Forces vessel discharges). The regulations are being developed in three phases. The first, completed in May

1999, determined which ballast water discharges would require control. The second, currently in progress, will set performance standards, and the third will promulgate regulations for meeting those standards (Congressional Research Service 2010).

Open ocean ballast water exchange is a standard operating procedure of the Navy ships that enter San Diego Bay. Navy policy for ballast water is presently spelled out in its Environmental and Natural Resources Program Manual (OPNAVINST 5090.1C, Chapter 22, Section 10). The Navy adopted the intent of the existing USCG standards, which promote the International Maritime Organization guidelines as voluntary public health measures "to decrease the possibility of further introduction of cholera and other pathogens into U.S. waters." While no mention is made of environmental concerns, Navy policy requires that ballast water taken from potentially polluted areas be offloaded outside of 12 nm from shore, with clean sea water taken on and discharged two times prior to closer entry. Invasive species will soon be addressed also as NISA requires that the Navy "shall implement a ballast water management program for seagoing vessels."

In addition, surface ships must comply with Navy requirements to routinely wash down anchors, chains and vessel appendages with seawater when retrieving them to prevent on board collection of sediment, mud and silt. Where possible following anchor retrieval, surface ships shall also wash down chain lockers outside 12 nm from land to flush out sediment, mud or silt. Amphibious vessels launching and recovering amphibious vehicles must ensure those vehicles, including their treads, are washed down after completion of operations. Ships shall dispose of wash water before entering within 12 nm of the next operating area (OPNAVINST 5090.1C).

Partially in compliance with this EO 13112, the Pentagon's acquisitions chief has directed the military services to incorporate invasive species prevention measures into existing operational and transportation policies, as well as into INRMPs and pest management plans. In OPNAVINST 5090.1C, Navy installations are directed to prevent the introduction of invasive species and provide for their control. "The Navy will identify actions that affect the introduction of invasive species, prevent their introduction, respond rapidly to their control, monitor populations, restore affected native species and their habitat, conduct research and develop technologies to prevent further introductions, and promote public education of the issue. The Navy will not authorize, fund, or implement actions that are likely to cause or promote the introduction or spread of invasive species in the United States or abroad. Proper ecosystem management requires the control of noxious weeds, aquatic nuisance species, and other invasive species. Use of native plants in landscaping, grounds maintenance, and land restoration projects is required. Installation natural resources managers shall ensure that invasive species prevention recommendations are incorporated into new construction programs and operations. Land or ecosystem restoration projects shall require the use of native species only. Natural resources managers shall monitor invasive species populations and identify areas where research and new technology may be needed to better control invasive species in the military environment."

Evaluation of Current Management

Figure 4-2 shows the process of invasion and a range of opportunities for management response (adapted from CDFG [2006]). Whatever the species or impacts, experts agree that the most costly response of all is inaction. In general, costs mount as management activities shift from prevention to rapid response to eradication to control. California's eradication efforts for the introduced marine alga, *Caulerpa taxifolia,* for example, have totaled over $7 million in federal, state, and local dollars since June of 2000. Costs increase as invasions spread and become irreversible, and when the technology or chemicals do not exist to selectively eradicate species.

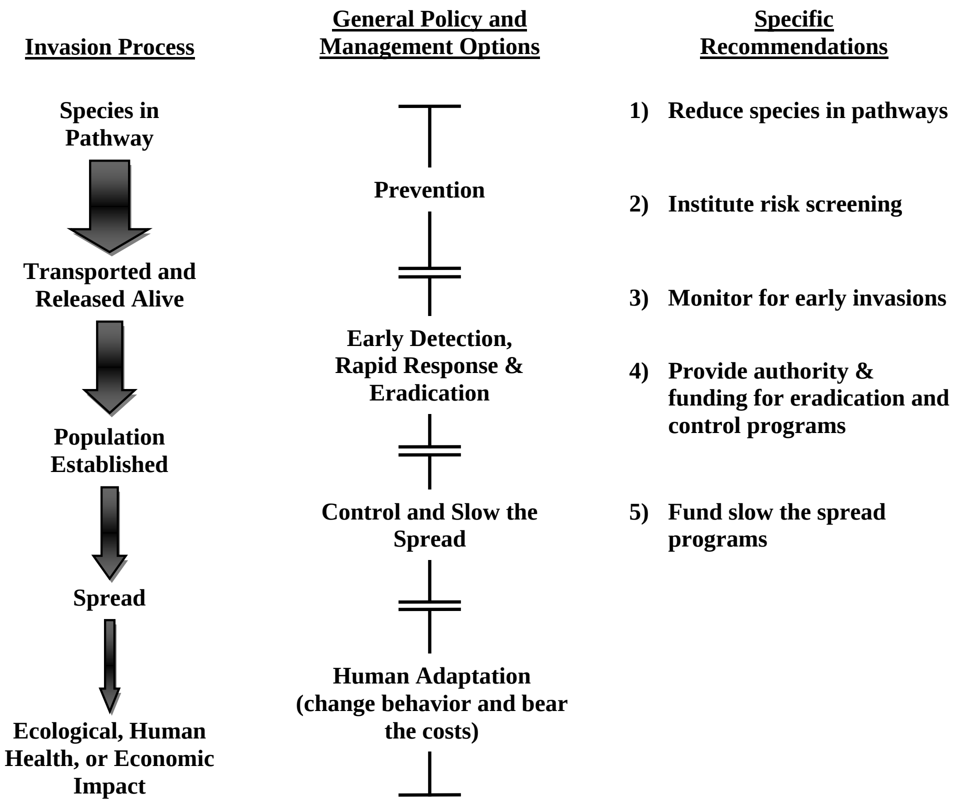


Figure 4-2. Aquatic invasion process and management response options, adapted from California Aquatic Invasive Species Action Plan (2008).

Preventing aquatic invasive introductions through exclusion is the single most cost-effective and environmentally beneficial management approach, and the first line of defense. Prevention programs focus on identifying specific vectors. This is because it is very difficult to predict which species will invade and cause significant impacts, and because it is difficult to identify taxonomically many potential AIS (especially very small invertebrates, parasites, and unicellular organisms). Inspection programs are part of prevention, but generally target specific species rather than vectors.

Analyzing the risk of specific vectors represents a critical first step in preventing invasions. Only by understanding the larger picture can scarce resources be applied in the most cost-effective manner. In this way, the relative risks each vector poses to the environment, human health, and the economy can be better evaluated. New genetic tools are now helping investigators detect the point sources of invasions. This information has helped provide a more quantitative analysis of pathway invasion risks (Lodge *et al.* 2006).

Some states including California are leading invasive species legislation, and this has caused a federal concern about a patchwork of regulation that becomes unenforceable. Recently, the EPA has proposed to control ballast water and other discharges incidental to the normal operation of vessels through the mechanism of CWA permits.

It is a question whether the standard-setting, permit, and enforcement authorities of the CWA are better tools for managing ballast water discharges than new legislation. The EPA has proposed permits for large recreational vessels such as cruise ships which routinely use ballast water. EPA is emphasizing practices that reduce the risk of invasion (ballast water exchange) rather than requiring any numeric treatment standards for the discharge of living organisms because treatment technologies that effectively reduce viable living organisms in a manner that is safe, reliable, and demonstrated to work on board vessels are not yet commercially available.

No effort is being made to control pleasure boats from transporting invasive species on their hulls from port to port.

Management is absent for controlling an important source of invasive species—thousands of pleasure-craft traveling from port to port. A survey of southern California harbors and marinas found a pattern of introductions of nonindigenous ascidians (tunicates) coming from the hulls of traveling recreational boats (Lambert and Lambert 1998). The non-indigenous species have become fouling pests in marinas, covering docking facilities and other artificial structures in the water with a slimy coat. However, research is pursuing effective anti-fouling paints that are environmentally safe (e.g. no metals like TBT) that could help minimize the attachment of organisms to boat hulls (see also Section 5.2.2: Receiving Water Monitoring and Trend Analysis). The Port is currently implementing a EPA grant investigating “Safer Alternatives to Copper Antifouling Paints for Marine Vessels” to support its TMDL compliance work at Shelter Island Yacht Basin.

See also: Section 5.2.2 Receiving Water Monitoring & Trend Analysis.

The aquarium trade has legally imported sailfin mollies, but they were probably released into local streams by aquarium hobbyists unaware of the species’ potential impact. The mollies are now commonly found in the Sweetwater Marsh, probably causing ecological harm to native species and communities (Williams *et al.* 1998).

Systematic surveys of invasive species in the bay are not being done, unlike other major bays in the Pacific.

The lack of local information necessary to develop a targeted management strategy is a dilemma. Systematic ecological surveys of the introduction, distribution, abundance, and effects of nonindigenous species are not being conducted within San Diego Bay, unlike other major Pacific bays (e.g. San Francisco, Honolulu). Awareness of new invasive species, their locations, and impacts usually comes about as a secondary product of studies and inventories performed for other purposes (Fairey *et al.* 1996; Zedler 1996a; Allen 1997).

Prevention is a better tool than control for invasive coastal plants, with only limited success stories in wetland weed control. Local landscaping regulations could be improved as a tool for prevention.

Control efforts have focused primarily on invasive coastal plants, particularly in the transition zone from wetlands to uplands and when a highly valued resource is affected. The City of San Diego’s Biological Mitigation Ordinance prohibits the use of invasive plant species near a designated “open space” area. However, the bay is not so designated. While some local cities have ordinances requiring native plant species for new landscaping or mitigation, no similar policies could be found for the Port. The Navy NAVFAC Southwest Botanist and Landscape Architect maintain a preferred landscape plant list that includes a “Do Not Plant” list of horticultural plants in the trade that have invasive characteristics.

Maintaining quality habitat should also help prevent or minimize exotic species invasions. Disturbed sites, even when disturbed temporarily for restoration purposes, show an increased number of nonindigenous species (Crooks 1998). Increased freshwater inflows and altered hydrologic regimes from the bay’s watershed also have contributed to invasive plant germination and establishment, a problem particularly apparent at Sweetwater Marsh (Kuhn and Zedler 1997).

Timing of control is very important, as delays can allow a population to explode beyond the capability of any known control measures.

Studies reveal that observed effects may range from “relatively large spatial (baywide) and temporal-scale (decades) to small-scale interactions that take place in a matter of weeks in small patches on a tidal flat” (Crooks 1998; Reusch and Williams 1998). To be effective, management actions need to understand invasions in the context of the existing and historical natural systems (L. Levin, *pers. comm.*). Some species have taken decades since introduction to become a “pest,” showing that it is “potentially dangerous” to predict future status of an invader from its current status (Crooks 1998).

Continued monitoring of California coastal waters is essential for determining if the rate of new introductions is changing and whether recent ballast water regulations have been successful in limiting introductions of new organisms (Foss *et al.* 2007). Future monitoring by SCCWRP Bight studies and by OSPR should include relative abundance data, to be used to determine the extent of impact that introduced organisms are having on the native biota and coastal ecosystems and should give us a better basis for determining the relative risk that invasives may pose should they spread to other areas. Two habitats, the crevices within the rocks and rip-rap of breakwaters and the hard bottom benthic substrate were not sampled successfully in previous work by these programs.

The best opportunity for accomplishing more is with partnerships at the local, watershed, regional, state, national, and international levels. A Nonnative Species Advisory Council, formed in 2003, oversees, coordinates, and sets policies for the CALFED Bay-Delta Program invasive species programs throughout the region. The Council is composed of 30 experts from myriad organizations, both governmental and nongovernmental, including the Nature Conservancy and universities. The National Aquatic Nuisance Species Task Force and the western regional Panel on Aquatic Nuisance Species (created when NISA was reauthorized in 1996) have developed a 100th Meridian Initiative, a collaboration among state and federal agencies, private industries, and citizens working to prevent the westward spread of zebra mussels and other aquatic invaders, The partnership includes the six states that straddle the 100th Meridian, the Canadian province of Manitoba, and most of the western states including California.

Management Strategy—Invasive Species

The basic framework of 1) Prevention, 2) Monitoring and Early Detection, 3) Rapid Response and Eradication, 4) Long-Term Control and Management, 5) Education and Outreach, 5) Restore high-value ecosystems across scales, and 6) Organizational Collaboration is well established on a national level, and is also reflected in California's existing Pest Prevention Program and Weed Plan. It forms the foundation of management actions described in this INRMP. The objective and outline that follow parallels this structure and many elements of the state and federal AIS plans.

Objective: Minimize the harmful ecological, economic, and human health impacts of aquatic invasive species in San Diego Bay.

Prevention is first priority.

I. Prevent the introduction of invasive marine and coastal species into San Diego Bay, as a first priority for control.

- *A.* Conduct an invasive species vulnerability analysis to focus how the bay should be monitored for invasives and to set priorities to prevent invasion. Likely vectors should be analyzed for introduction of invasives and their potential damage to vulnerable habitats.
- *B.* Promote ballast water management for all vessels entering San Diego Bay.
  - *1.* Reduce the introduction and transfer of marine AIS via ballast water, ballast sediment, and hull fouling from commercial vessels and maritime structures. Assess the impacts of hull fouling and ballast water as mechanisms for the introduction and dispersal of AIS in San Diego Bay in concert with SLC and CDFG.
  - *2.* Co-sponsor a UC Sea Grant forum in San Diego to inform the maritime industry of safer ballast water management alternatives in order to obtain better practices.
  - *3.* Support the continuation of the Navy's ballast water exchange policy for open ocean exchange and encourage the implementation of a ballast water management program that explicitly addresses the nonindigenous invasive species problem.
- *C.* Reduce or prevent the number of new invasive species.
  - *1.* Periodically update and distribute the list of known invasive species found at San Diego Bay (see Table 2-46 and Table 2-47).

2. Create a comprehensive list of local pathways. The known and suspected AIS vectors and pathways include ship ballast water, hull fouling, aquarium trade, live seafood industry, aquaculture, research, recreation, and others. A more comprehensive, local vector assessment is needed in order to identify prevention strategies.
3. Identify ecologically sensitive waters as targets of additional precautionary protocols.
4. Request local aquarium and bait shops to inform their customers about the existing, potential harmful effects on San Diego Bay from the intentional or accidental release of invasive fish and marine invertebrates into local streams, ponds, and the bay.

D. Reduce the risk of invasive species harm transferred through recreational activities.

1. Limit new AIS introductions through recreational boating, fishing, diving, and other water-based activities.
2. Distribute CDFG guidelines for cleaning fishing gear and equipment.
3. Develop and distribute guidelines for disposal of live bait in cooperation with CDFG.
4. Link activities above to the national Stop Aquatic Hitchhikers campaign. This campaign, organized by USFWS, seeks to educate boaters, fishers, divers and others about aquatic hitchhikers and how to prevent them from spreading (ProtectYourWaters.net).
5. Link the activities above to the national Habitattitude outreach campaign developed by the Pet Industry Joint Advisory Council, USFWS, and NOAA National Sea Grant College Program.

E. Limit new introductions of AIS as a result of restoration, landscaping and construction activities, and other human activities in sensitive ecological areas.

1. Encourage the use of native species (with propagules from appropriately local stock) or noninvasive non-native species, and minimize the transfer of AIS through restoration, landscaping, and construction projects.

II. For early detection of high priority AIS, develop a standardized monitoring system.

A. Provide for an early warning system for newly discovered species.

1. Identify whether the introductions are simply non-native versus dangerously invasive.
   a. Distinguish between truly invasive species and those that are simply expanding their ranges. Range expansions are expected to be more common as climate changes. These new species are perhaps best left alone.
2. Identify and monitor locations with a high invasion rate.
3. Target locations with higher probability for newly arrived species (e.g. marine terminal docks, marinas, near dry docks, poorly flushed (back bay) settings, and disturbed sites).
4. Involve and educate professional divers – who are frequently in the water and under boats cleaning hulls – in detection and management, among them the California Professional Divers Association. Link with appropriate educational and outreach activities.
5. Evaluate the results of all species monitoring in the bay for the presence of new invasives on an annual basis at least.
6. Notify the bay Invasive Species Committee proposed by this INRMP if any new invasive species are identified.

B. Track all current monitoring of the state's coastal marine and inland waters for opportunities to incorporate early detection of AIS. High priority AIS for early detection for introduction or change in status include the zebra mussel, Northern Pacific seastar, snakehead, Caulerpa, hydrilla, salvinia, and others.

1. Map the existing problem areas and determine priority sites and control measures.
2. Monitor progress, evaluate the effectiveness of measures, and revise as needed.
3. Track the work of CDFA, who monitors specific target species listed as noxious, or regulated in some way, in order to undertake early detection or eradication.
4. CDFG monitors populations over time, and notes new populations or changes in species abundance.
   a. Identify and monitor the population growth and dispersal of established AIS in cooperation with CDFG.
   b. Species-specific monitoring should occur for those species identified as high risk or high priority.

C. Evaluate the status and biology of invaded ecosystems and nonindigenous marine and coastal species in San Diego Bay, focusing on those with the most potential for ecological disruptions.
   1. Anticipate that the interaction between natives and exotics could change with shifts in global temperature, and monitor indicators of such a change.

D. Conduct outreach to those regularly sampling coastal, marine and inland waters for other purposes, so they can easily identify and report high priority AIS. Those already conducting field work or surveys – researchers, graduate students, resource managers, water quality monitors, law enforcement personnel and others – should be encouraged and trained to identify key AIS. Organizations should assess where it is possible to broaden the scope of work of existing staff to build AIS detection and monitoring into existing workplans.
   1. Special identification materials for high priority AIS should be developed and distributed to support the early detection effort.
   2. Develop a prototype early detection booklet for use by local watershed groups.

E. Enjoin financial resources from public and private sources.
   1. Pursue research grants from the National Sea Grant Program targeting NISA implementation.
   2. Seek appropriations for the National Aquatic Nuisance Species Task Force and its Western Regional Panel for the above studies and for an ecological survey of San Diego Bay, as provided in NISA 1996.
   3. Approach private foundations as a sole or matching grant source.
   4. When feasible, minimize costs by using knowledgeable volunteers to assist with invasive species inventories at the bay.

III. Control emerging invasive species problems and restrict their future expansion in San Diego Bay with Rapid Response and Eradication.

A. Form a San Diego Bay Invasive Species Task Force of resource managers, researchers, and interested public to implement the above strategy.
   1. Coordinate invasive species control actions.
      a. Eradication is most effective during the lag phase of low numbers and isolated locales.
      b. Hold an annual workshop on the topic, including a brainstorming session on alternative measures.
      c. Provide an information center on invasive species and control measures.
   2. Oversee an Invasive Species Control Endowment Fund.
      a. Monies to the endowment from grants or other sources can be contributed to offset impacts from certain proposed projects in the bay.
      b. Use interest payments on the principle for species control projects.

B. To control new invaders with the potential to become problems, provide a rapid response, and respond at the appropriate spatial scale.
   1. Implement a coordinated system for rapid response to contain newly detected AIS. Conduct a pilot project to demonstrate rapid response to new invasions of aquatic species.
   2. Identify and prioritize which species are most likely to become a problem.
   3. Identify and prioritize the best available techniques to eradicate or reduce the species of concern.
   4. Work on developing biological controls that could be used for existing and potential arrivals, while ensuring safety of nontarget species.
   5. Encourage the formation of volunteer efforts, such as Spartina Watch or Adopt a Beach to be able to identify and respond to the removal of new infestations at their first appearance.
   6. Coordinate with CDFG's Statewide Rapid Response Plan. The California Rapid Response Plan for AIS (in draft form as of fall 2006) is being developed. New guidelines for local and state rapid response coordination with federal agencies were published in 2005 by the EPA.
      a. This system will likely be in the form of a website and/or a toll free AIS hotline. It could be modeled on existing hotlines for other environmental or public health threats. Outreach and training related to early detection and rapid response should include instruction in how to use this system.
      b. Clarify among the agencies and organizations involved, and within the new rapid response process, who is responsible for which areas and/or species, and what these responsibilities entail.
      c. A clear chain of command is needed for a successful rapid response. It is also necessary to identify all federal, regional, state, county, and non-governmental resources that can be mobilized to assist to limit any high-risk introductions.
C. Develop species- and/or location-specific rapid response plans in collaboration with CDFG and CDFA. These plans should include lead agencies, chain of command, specified lists of appropriate control measures (biological, chemical, and physical), methods to address the introduction pathways, and regular updates and drills to ensure the contingency plans remain current.

IV. Plan long-term control and management of invasive species for San Diego Bay by containing and reducing the spread of invasive populations.
   A. Determine the potential of the new species to become invasive, based on case histories in other areas and lag timing.
      1. Study the basic biology of existing and probable new arrivals that have the potential to become pests or alter habitats (see Table 2-27 and Table 2-26). Determine habitat requirements, native predators and parasites, food requirements, and other life history elements.
      2. Determine negative and positive effects on native species, the bay's food web, and habitat quality, as well as assess the magnitude of each species' impact.
      3. Rank the relative impact of the known invasive species found in the bay in order to determine control priorities. Long-term control and management activities should be focused on populations of established species where there is a clear and significant impact on economically important species, sensitive native species, human health and infrastructure, or recreation and navigation, and where the control of specific populations is feasible both economically and technically.
      4. Conduct research into the effects of invasive species on the abiotic environment.
      5. Analyze native-invasive species interactions. Identify use of invasives by native animals (e.g. insect use of plants).

B. Provide invasive species control measures to substantially reduce existing problem areas and to prevent new problem sites.
   1. Develop a descriptive list of possible control measures, including mechanical, chemical, biological, and harvest management.
   2. Consider boat washing stations and disposal facilities at infested water bodies.
   3. Install warning and information signs in infested areas at local kiosks, boat ramps, and on floating buoys to limit the spread of existing AIS by boats, personal watercraft, movement of live fish and bait buckets.
   4. Develop GIS-based maps that show coincidence of AIS and critical ecosystems (CDFG, CDFA Years 3-5).
C. As species taxonomy can be quite difficult and is frequently changing, encourage careful taxonomic identifications to species level, particularly of marine invertebrates and marine algae.
D. Promote cooperative interagency efforts to collect and analyze comprehensive monitoring data, including shared funding and staffing.
   1. Take advantage of state and federal technical assistance to watershed councils, irrigation districts and other local boards for development of AIS management plans.
   2. Land managers should be informed that if, by following these guidelines, they address issues regarding areas of special significance it may expedite environmental review and permitting.
E. Develop new species- and site-specific control plans as necessary based on lessons learned from relevant projects inside and outside California, in cooperation with CDFG, CDFA, CDBW, USFWS, and NOAA.
F. Prevent spread that could occur through landscaping and restoration projects.
   1. Distribute CDFG guidelines for riparian, wetland and shallow water habitat restoration projects to prevent invasions.
   2. Promote the use of native plants and/or non-invasive non-native species in restoration and shoreline landscaping.
   3. The Navy and Port should develop boilerplate AIS prevention language for agency comments on project plans and other activities. Boilerplate language addressing the need to prevent AIS introduction, or control AIS spread, should be available to agencies commenting on environmental documents, landscape plans, restoration plans and research proposals. Such language should be distributed to all appropriate state, federal and local agency staff.
G. Coordinate state AIS management activities with the SWRCB and the RWQCBs. AIS often exacerbate or complicate pollution control and water quality management. State AIS management activities should be coordinated, through the state and regional water quality control boards, with state Watershed and Basin Plans, TMDLs for water bodies on the 303 (d) list, and the NPDES permitting process.
H. Develop and annually or biennially update a list of AIS experts in California, including taxonomic experts for AIS identification. The federal Aquatic Nuisance Species Task Force, USGS, and USFWS are currently working on developing a list of experts. State agencies should collaborate with the federal agencies on developing and updating the list and making it available to AIS resource managers.
I. Continue and expand participation in regional, national and international efforts and task forces focusing on AIS issues.
   1. Inform the National Aquatic Nuisance Species Task Force and its Western Regional Panel of San Diego Bay's problems and concerns with existing and potential aquatic pests.

2. Participation should extend to the federal Aquatic Nuisance Species Task Force, the Western Regional Panel, federal ballast water and hull fouling activities, the Pacific Ballast Water Group, the Global Invasive Species Programme, the Invasive Species Advisory Council, the 100th Meridian Project, among others.
3. Participate in national and international conferences concerning the management and control of AIS. AIS conferences increase knowledge of efforts and successes elsewhere, as well as ensure awareness of California's issues and activities outside the state. Authorization for key out-of-state and out-of-country travel should be promoted. Funding for attendance and participation of resource managers and scientists in these conferences needs to be identified.

J. Continue and expand participation in localized efforts and task forces focusing on AIS issues. Participation should extend to the Southern California Caulerpa Action Team, the Lower Colorado River Giant Salvinia Task Force, Team Arundo, the CALFED Bay-Delta Authority Nonnative Invasive Species Program, among others.

V. Conduct education and outreach.

A. Promote education about appropriate preventative methods toward those who may be potential sources for AIS introductions. Target audiences may include the owners and employees of pet and aquarium stores, and nurseries; wholesalers and shippers dealing in aquarium organisms; operators of water-based businesses (such as boat charter operators, marinas, angling guides, fishing tournament organizers, habormasters, dive shops, seaplane operators, dredging contractors); and university researchers.
1. Develop and distribute printed material (posters, brochures and articles) for specific industry sectors and user groups in collaboration with CDFG, CDFA, SLC, CDBW, CDWR, and CCC.
2. Develop permanent interpretive displays at appropriate marinas, boat ramps, and fishing access sites.
3. Work directly with promoters of industry trade shows to deliver the AIS message.
4. Continue to include information on AIS in fishing and boating regulations and licenses.
5. Publish information about AIS in local fishing and recreational newspapers and magazines.
6. Develop AIS identification cards to be distributed to all appropriate audiences.
7. Develop "California-friendly" or "green species" lists for specific user groups and industries.

B. Ensure the general public is aware of the problem so that they may become part of the solution.
1. Develop a press kit for specific AIS and work closely with the media to ensure the accuracy of any information they publish.
2. Identify key state publications and websites to which AIS information can be added.
3. Ensure appropriate website links are established so that public information on AIS is easy to find and gets good exposure.

C. Develop and promote a "bayscapes" program to benefit the bay through compatible landscaping practices along the bay and in the watershed, which includes the following components (see also Sections 4.2.1.9 Upland Transition and 5.1.3 In-Water Construction):
1. Provide local nurseries with a list of existing and potential invasive plant species known to cause problems in San Diego Bay and encourage them not to offer these plants to their customers.

2. Provide local, state, and federal agencies with the invasive coastal plant list and encourage them to prohibit these species through their development review and permitting processes.
3. Present a model by having the Port and Navy take the lead in practicing bayscaping on its own properties.
4. Notify homeowners, landscapers, and gardeners of the list and encourage them not to use these plants in their landscaping.
5. Define a management corridor within which measures are taken during construction and other activities that minimize the disruption of coastal soils or native sods in order to prevent weed invasion.
6. Encourage citizens, organizations, and local government to become bayscapers through the practice of bayscaping.
7. Develop a list of native species useful for landscaping and encourage use of these plants.
8. Update Navy documents, including Base Exterior Architecture Plans, to advocate use of native plants in landscaping plans.

D. With the assistance of volunteers, promote workshops and small-scale eradication demonstration projects at bay sites.

VI. Restore high-value ecosystems across meaningful scales related to the health of San Diego Bay, by planning projects to prevent invasions and monitoring for health.

A. Where appropriate and cost effective, work with partners at the watershed scale.

VII. Maximize organizational collaboration efforts among federal, state, local, and private groups for more effective and efficient invasive species control in San Diego Bay.

4.4.2 Plankton

Specific Concerns

- The lack of understanding about plankton dynamics in the bay underlies a lack of understanding about the relative importance of various human activities and how they impact ecosystem health and ecosystem function.
- Fish that eat plankton are driven by the abundance and distribution of this food source, and therefore so are the birds that depend on these fish. The lack of knowledge about what drives phytoplankton productivity in the bay contributes to an inability to protect the plants and animals that depend upon it.
- The lack of understanding about zooplankton use of and dynamics in the bay by both resident and open coast species hinders understanding of habitat values, and thus sound decision-making about habitat protection.

Current Management

There is no direct management of bay plankton. However, laws that protect water quality and habitat indirectly protect plankton populations.

Evaluation of Current Management

There exists a lack of basic understanding of plankton assemblages in different areas of San Diego Bay and their changes relative to seasonal and other fluctuations in environmental conditions. Evaluating both primary (phytoplankton) and secondary (zooplankton) productivity is important to understanding the bay. It would also allow an assessment of the strength of the dependency between plankton productivity and changing conditions in the water column. Information about the dynamics of the larval stages of benthic invertebrates and bay fish species would lead to a more complete understanding of reproductive activity among resident species. Finally, the information obtained will make it easier to interpret human impacts in the open water environment of the bay.

The current inadequacy of understanding affects management all the way up the food chain. Since there are certain efficiencies in identifying the strength of dependencies of physical and chemical factors on species at the bottom of the food chain, filling this information gap is considered a critical need.

Management Strategy—Plankton

Objective: Identify and manage the physical and chemical factors in the bay that contribute to plankton productivity, and use of the bay by zooplankton from coastal waters.

I. Conduct long-term investigations of the plankton in bay waters in a way that can provide indications of bay health, the role of plankton in fish and bird abundance, and be integrated with plankton studies in coastal waters and those of other bays.

A. These investigations should address the following:

- Strength of the dependency of bay physical and chemical factors on plankton dynamics.
- Phytoplankton productivity and its relationship to nutrient inflow and general water quality conditions.
- Fate of both resident and open coast zooplankton in the bay, its use of various habitats, and its diurnal, tidal, and seasonal dynamics.
- Identification of any direct or indirect influence of human activities on plankton in the food webs of San Diego Bay.
- Larval exchanges with other bays.
- Plankton as food for benthic invertebrates.
- Causes of fluctuations in zooplankton populations.
- Understanding biodiversity.
- Tracking invasive introductions.
- Understanding of pollutant transport.
- Effects of toxic chemicals on plankton species and assemblages.

B. Interpret and disseminate findings on an annual basis to a broad audience of scientists, natural resource policy makers, planners, project proponents, and the public.

II. Ensure the physical and chemical factors that contribute to the health of plankton populations and needed use of the bay by larvae drifting in from the open coast are considered in NEPA assessment.

4.4.2.1 Benthic Algae

Specific Concerns

- The lack of understanding about algal dynamics and how they are affected by pollution and disturbance in the bay is a lost opportunity to use algae as an indicator of ecosystem and individual habitat health.
- The lack of knowledge about what drives algal standing crop and seasonality in the bay contributes to an inability to identify threats and protect the plants and animals that depend upon it.

Current Management

Algae is not managed directly, but regulatory protection from pollution, disturbance, and habitat loss is likely to protect the function algae plays in ecosystem health.

Evaluation of Current Management

There is a lack of understanding of benthic algae and its role, especially in the northern and central regions of the bay. Standing crop and seasonality are important characters that can reveal much about ecosystem dynamics, especially in habitats such as intertidal flats and unvegetated shallow subtidal where algae can impart important physical structure to a site.

Management Strategy—Benthic Algae

Objective: Identify and then conserve the food web and other functions of algal functional groups that reflect bay ecosystem health.

I. Conserve the structure contribution, abundance and diversity of beneficial algal assemblages in the bay.

- *A.* Relate physical/chemical/biological factors to algal types and abundance, and actively manage the substrate or related factors.
- *B.* Seek to reduce the abundance and standing crop of algal types that indicate pollution or disturbance by managing the pertinent disturbance.
- *C.* Identify food web functions of algae for key indicator species in the bay.
- *D.* Determine the ecological role and productivity contribution of *Gracilaria* algal mats that dominate some portions of the bay's unvegetated shallows. How are they formed, what allows them to remain, and are they at risk from disturbance?
  - *1.* Determine if dredging new channels may change hydrodynamics enough to affect algal mats that may have an important role in unvegetated shallows.
  - *2.* Determine if boat traffic negatively affects algal mats.

II. Take advantage of opportunities to efficiently and effectively use attributes of algal communities to monitor ecosystem health.

- *A.* Investigate the use of periphytic diatoms as indicators of pollution, which have specific responses to both thermal and chemical disturbances.
- *B.* Investigate the usefulness and practicality of using opportunistic or successional algal species as indicators of habitat or ecosystem health.

III. Fill important information gaps that contribute to understanding algae's contribution to ecosystem health.

- *A.* Combine any studies of invertebrate assemblages with quadrat sampling for algae.
- *B.* Improve understanding of the ecological role of algal mats in unvegetated, shallow subtidal habitat.
- *C.* Improve understanding of the ecological role of algae in intertidal flats.
- *D.* Improve understanding of the relative importance of the role algae played by algae in salt marsh productivity.
- *E.* Investigate alternative structure designs to compare abundance and diversity of invertebrate and algae populations.

4.4.2.2 Invertebrates

Specific Concerns

- Invertebrates that have not previously been managed for harvest are now being harvested by certain ethnic groups for human consumption (see also Section 4.4.3.1: Harvest Management").
- A lack of understanding of the relative importance of attributes of sediment and water quality compared to predation and other factors in shaping the invertebrate community makes management difficult.

- It is difficult to interpret benthic invertebrate information without information on the sediments where they are located. As bay sediment composition changes so does the types of invertebrates found.
- Invasive, exotic invertebrates can affect native invertebrate assemblages and the higher trophic species that depend upon them, or they can be benign. Specific harm has not been well described in San Diego Bay.
- Bight '03: Regional climatic events, such as El Ninos and La Ninas, can affect benthic communities. Inputs from anthropogenic sources may increase or decrease over time. Non-indigenous species that previously were absent may establish populations that dominate communities and modify habitat.
- The biointegrity of benthic macrofauna is a direct measure of a living resource that environmental laws and regulations intend to protect. Benthic macrofauna also integrate the effects of multiple types of stress and multiple insults over time. As such, benthic macrofauna are one of the most relevant measures of sediment quality.

Current Management

Marine invertebrates are not managed directly, having protection mechanisms built in through normal regulation of habitats under the CWA. However, they are under scrutiny through local, regional, and state-wide monitoring programs because they are the leading class of marine invasive organism, and because they are routinely used as indicators of sediment and water quality for enforcement and permitting actions under the CWA by the State and RWQCBs. They are used as indicators because they both bioaccumulate pollutants directly from water and sediment more quickly than other organisms, and because these pollutants can "biomagnify" as fish and wildlife higher in the food chain consume vast quantities of these lower-level organisms.

Studies were begun in the 1990s to systematically assess the health of the benthic community in San Diego Bay and other embayments (Fairey *et al.* 1996). New measures were recently developed and tested to assess the condition of the benthic macroinvertebrate community—as indicators of environmental stress—in the SCB as part of the 2003 Regional Monitoring Program (Ranasinghe *et al.* 2007). The SQO26 biointegrity index combines four benthic indices for better predictive results in bays and estuaries. Benthic communities were described in detail: species composition, diversity, and abundance. Changes in their condition depend upon regional climatic events, inputs from anthropogenic sources, local flushing actions, and the effects of non-indigenous species.

For the Bight'98 (Bay *et al.* 2000), specific results for San Diego Bay were summarized. Hydrodynamic conditions such as tidal flushing were assessed to be the primary factor influencing the distribution of macrobenthic assemblages throughout the bay, while anthropogenic impacts were hypothesized to represent a secondary factor. Macrobenthic community structure was summarized for each of the 46 stations sampled and then compared to various environmental and sediment parameters (e.g. depth, percentage fines, TOC, nitrogen, and several COCs). Additionally, ordination and classification analyses were performed to compare the similarity of the different assemblages present in the bay. Overall, 38,187 macrobenthic organisms representing 340 taxa were identified, of which polychaetes, molluscs and crustaceans were the dominant groups. Many taxa (> 27%), however, were composed of a single rare or unidentifiable individual. Non-indigenous species were an important component of the bay benthos, comprising at least 18 species and representing about 24% of the total macrofauna. Two species of polychaete worms, the capitellid *Mediomastus* sp (likely a species complex) and the spionid *Prionospio heterobranchia,* occurred at all stations. *Mediomastus* sp. was also numerically dominant, comprising 13% of all animals collected. The non-indigenous bivalve *Musculista senhousia* was the second most abundant species, followed by the sabellid polychaete *Euchone limnicola.*

Most of the animals common in San Diego Bay were also present in the other bays and harbors sampled during Bight'98. For example, many of the most abundant taxa in San Diego also occurred in high numbers in the other bays. Likewise, widely distributed species in San Diego Bay had similar broad distributions in the other embayments. Differences among assemblages in all bays and harbors, however, appeared to be due to multiple environmental and biological factors, including different hydrodynamic conditions, anthropogenic impact, and the presence of dominant, habitat altering species.

Sediment toxicity to marine organisms was evaluated for the region and San Diego Bay in the 2003 Bight survey (Bay *et al.* 2005). Tests were conducted in part I of the survey using one benthic invertebrate species, the amphipod *Eohaustorius estuarius.* Of the 19 samples collected in the bay, 53% were nontoxic, 47% were moderately toxic (amphipod survival was > 50% and < 83%), and none were highly toxic. These sites were primarily located in marinas. High levels of copper (a known biocide used in hull paints) and other metals and trace organics were also found in marina sediments.

The Port and its tenant marinas are under a TMDL enforcement program from the San Diego RWQCB to reduce copper discharges in Shelter Island Yacht Basin by 76% over a 17-year period. The Port is currently preparing a study of copper discharges and impacts related to in water hull cleaning. The Port and the Shelter Island Yacht Basin tenets are also forming a TMDL required program to implement education, BMP and monitoring programs. In 2007, the BPC approved the acceptance of a $100,869 grant from the EPA authorizing a study that would explore alternatives to copper-based hull paints that are commonly used by vessel owners to protect the hulls of their boats from corrosion. The results of the study will assist with an environmental initiative to reduce the level of copper in San Diego Bay and in particular, the Shelter Island Yacht basin, which has high levels of copper contaminant. The BPC approved an agreement with the Institute for Research and Technical Assistance to research non-toxic coatings. The grant funding will be used for this research. The grant project will take approximately 24 months, during which the Institute for Research and Technical Assistance will analyze available and newly emerging coatings. The Port continues to request that the State address the copper antifoulant issue on a statewide basis.

The Navy participates in the national water quality monitoring program called Mussel Watch for protection of human health but only for those areas in the San Diego Bay where mussels 1) can be found and 2) can be harvested (some areas of the bay are restricted access DoD sites and as such have no shell fish harvesting possibilities) (R. Chichester, U.S. Navy, *pers. comm.* 2007). NOAA's National Status and Trends Program Mussel Watch Project (1986- present) monitors bioaccumulation in 21 mussels, plus other parameters offshore in south San Diego Bay and intertidal and offshore in north bay. NOAA also conducts the National Benthic Surveillance Program (1984-present) to examine physical, chemical, and biological (diseases and bioaccumulation in fish) parameters in offshore areas of central and north San Diego Bay. The SWRCB and CDFG, State Mussel Watch Program (1977-present) also looks at bioaccumulation in mussels (transplanted), plus other parameters, offshore throughout the entire bay and bay approaches. Also the Surface Water Ambient Monitoring Program (SWAMP) performs periodic trend monitoring of water and sediments. The relative quality of the bay's benthic (bottom-dwelling) invertebrate community was analyzed from 1992-1994 as an indicator of sediment quality and toxicity (Fairey *et al.* 1996, 1998). These data, combined with toxicity and chemical data, were used to recommend priority areas for more intense evaluation as “toxic hot spots.” To test for short-term toxicity of copper and other metals, the embryos of the native mussel *Mytilus galloprovincialis* are being used in certain San Diego Bay studies (Schiff *et al.* 2006). Abnormal embryo development is an indicator of toxic effect. Other benthic invertebrate species are also used for sediment toxicity testing to evaluate survival or growth rates, following EPA or state standard protocols (e.g. SWRCB 2006).

The health of the benthic organism community was also evaluated in another Bight '03 assessment through the use of a “biointegrity” index, SQO26, developed and validated for marine bays and estuaries as part of the 2003 survey (Ranasinghe *et al.* 2007). The SQO26 combines four benthic indices to evaluate benthic condition, which is rated in four categories. San Diego Bay's benthic condition for the sites sampled revealed the following. See Table 4-13.

Table 4-13. Benthic condition at sites sampled in 2003 for Bight'03 in San Diego Bay (Ranasinghe et al. 2007.

Benthic Condition	Number of Sites	% of Sites
Reference-Undisturbed	3	16%
Level 1 - Low Disturbance	11	58%
Level 2- Moderate Disturbance	4	21%
Level 3- High Disturbance	1	5%

Evaluation of Current Management

The lack of information about invertebrate community structure in the bay has led to difficulty in managing these species. This data gap is a missed opportunity for better ecosystem management, since these species can be an early indicator of problems. The Bight '03 benthic macrofaunal monitoring helped address this data gap (Ranasinghe *et al.* 2007). Relative levels of benthic community disturbance in San Diego Bay were determined using the new biointegrity index, with only one site highly disturbed and most sites at low to moderate disturbance. Data from the State's Sediment Quality Objectives program could be used to improve the measure as a tool, the authors recommended. Bight '08 should build on the experience of the Bight '03 monitoring efforts for benthic community assessment. Invertebrates in San Diego Bay must be compared with the bay sediments found in the particular location. As bay sediment composition changes so does the types of invertebrates found. For example, Bight'98 results found that sites at which multiple contaminants exceeded the thresholds typically had high percentages of fine sediments (i.e. > 60% fines) and were located near or within marinas or shipyards; this distribution pattern was similar to those described in previous studies.

Management Strategy for Invertebrates

Objective: Identify and conserve the abundance, biomass, and diversity of invertebrate functional groups that reflect health in each habitat and the ecosystem as a whole. Ensure that harvested invertebrate species are safe for human consumption.

I. Conserve invertebrate populations as a source of food for shorebirds, fishes, and rays.

- *A.* Provide priority conservation of invertebrates of intertidal and shallow subtidal flats.
- *B.* Relate the diversity and abundance of invertebrates to attributes of the substrate and water quality where they live, and manage substrate and water quality directly.
- *C.* Determine the relative ecological contribution of invertebrates of artificial structures compared to those of indigenous unconsolidated substrate.
- *D.* Determine the relative importance of predation by fishes, rays, and shorebirds in shaping the invertebrate community, compared to attributes of the sediment and water quality.

II. Ensure the safety for human consumption of harvested invertebrates.

- *A.* Support continuation of the Mussel Watch Program to detect trends in bioaccumulation of toxics for protection of human health, for those areas in San Diego Bay where mussels can be found and access for harvesting is permitted.
- *B.* Determine the effects of toxic chemicals in bay sediments on infaunal invertebrate assemblages.
  - *1.* Encourage the continuation of studies such as those of Fairey *et al.* (1996, 1998) and Bight '03 to assess health of the benthic community, the effects of toxics and their degree of severity, and associated substrate or water quality conditions.

III. Develop and implement methods that detect changes in the quality of the benthic invertebrate assemblage, especially with respect to food for shorebirds, water quality and toxics, and overall ecosystem health.

  A. Monitor for introduction of invasive invertebrates, and populations of those already occurring in the bay.

  B. Conduct a baseline inventory of the bay's benthic invertebrates, with emphasis on functional groups and developing indices of health, or on identification of "keystone" species that may be used for long-term monitoring of habitat and ecosystem health.

    1. Relate results to attributes of substrate and water quality. Continue to refine benthic biointegrity indices, such as the SQO26 index developed for Bight '03.

    2. Conduct studies on a seasonal basis to evaluate changes within years and between years.

  C. Standardize the protocols used when conducting impact assessments so that work may be more directly comparable.

  D. Investigate the importance of the regeneration of nutrients by benthos for phytoplankton.

4.4.3 Fishes

Specific Concerns

See also Section 2.6.4: Fishes

- Though the bay is an important nursery and refuge area for marine fishes, success in the protection of fish habitats has been variable.
- Fish health may be affected by water quality conditions within the bay, especially by contaminants.
- Important information gaps need to be filled through new monitoring and research.

Specific fish topics of Harvest Management and Artificial Propagation are addressed separately in detailed subsections following this section.

See specific subsections on Harvest Management and Artificial Propagation below.

Current Management

Management of fish habitats occurs through implementing the CWA's §404 protecting Special Aquatic Sites and the federal "no net loss" policy. Ocean and nearshore habitat conditions greater than three nautical miles offshore are now being addressed through identification of EFH under the Magnuson-Stevens Fishery Management and Conservation Act. These habitats must be identified for all commercially and recreationally harvestable species that are listed in the Coastal Pelagic and Pacific Groundfish Management Plans. The program allows NMFS to comment on all federal actions that may impact designated EFH. CDFG's Bay and Estuary Ecosystem Program identified the roles that nearshore habitats have in the life history of certain species, such as corbina, spotfin croaker, yellowfin croaker, sand bass species, and kelp bass (www.dfg.ca.gov/Mrd).

San Diego Bay includes areas identified as EFH for various life stages of fish species managed under the Coastal Pelagics and the Pacific Groundfish FMPs. FMPs are developed for fisheries operating in the EEZ/federal waters (3-200 nm from the mainland). The FMP for Coastal Pelagic Species identifies five species (four finfish and one invertebrate), including northern anchovy, jack mackerel, Pacific sardine, Pacific (chub) mackerel, and market squid *(Loligo opalescens)* (PFMC 1998). All but the market squid could be expected in the bay. The remaining species all have wide distributions throughout California, as well as in international waters outside the U.S. EEZ and are taken directly or indirectly with a variety of fishing gear. Non-fishing related activities that have the potential to harm groundfish species could also have the same effect on these pelagic species. Detailed life history information about federally protected fish in the groundfish management plan is available as an appendix to Amendment 19 of the Pacific Coast Groundfish FMP (PFMC 2005). These data are culled from fishing records, where available, and from scientific literature about the species' preferences for certain latitudes, substrates, and depths. Based on this information, species for which the habitat in the bay is at least 40% suitable for at least one life stage of the fish are listed in Table 4-14. Fish are also listed if previously identified in San Diego Bay (Merkel & Associates 2000; Allen 1999; Hoffman 1995). These fishes are expected to occur to varying degrees, because of the highly suitable nature of the habitat for one or more stages of their life cycle. Habitat Suitability Probabilities for all fish in the Groundfish FMP are available in Appendix B to the Amendment of the FMP.

Table 4-14. Groundfish covered in the Pacific Groundfish FMP for which the habitat in the bay is at least 40% suitable for at least one life stage of the fish, and are documented in San Diego Bay (Merkel & Associates 2000, Allen 1999, Hoffman 1995).

Scientific Name	Common Name	Scientific Name	Common Name
Triakis semifasciata	leopard shark	*Sebastes rastrelliger*	grass rockfish
Raja binoculata	big skate	*Sebastes chlorostictus*	greenspotted rockfish
Raja inornata	California skate	*Sebastes umbrosus*	honeycomb rockfish
Raja rhina	longnose skate	*Sebastes atrovirens*	kelp rockfish
Ophiodon elongates	lingcod	*Sebastes diploproa*	splitnose rockfish
Sebastes chrysomelas	black and yellow rockfish	*Sebastes saxicola*	stripetail rockfish
Sebastes mystinus	blue rockfish	*Sebastes serriceps*	treefish
Sebastes paucispinis	bocaccio	*Pleuronichthys decurrens*	curlfin sole
Sebastes dallii	calico rockfish	*Citharichthys sordidus*	Pacific sanddab
Sebastes goodei	chilipepper	*Scorpaena guttata*	California scorpionfish
Sebastes carnatus	gopher rockfish	*Parophrys vetulus*	English sole

As well as designating EFH, the PFMC designates Habitat Areas of Particular Concern. These are ecologically important, rare, or sensitive habitats that should be given special attention when evaluating the effects of non-fishing impacts. San Diego Bay meets two criteria for an Habitat Areas of Particular Concern, being an estuary and a site where eelgrass grows.

In contrast, fish health is another concern but one subject to little management. Most observations of diseased fish have either been an anecdotal or a secondary result of studies focused on other topics like water quality. For example, an ecological monitoring program of constructed wetlands in SMNWR by PERL noted "heavy loads of protozoan parasitic cysts and fluke metacercariae" on longjaw mudsuckers (PERL 1996), which are suspected to be related to poor water quality. Fish health as it poses a risk to human health from fish caught and eaten from the bay was the topic of a recent study (San Diego County Department of Health Services 1990). Based on potential human health risks, only the levels of mercury in the round stingray and PCBs in the Pacific mackerel showed significant results. Barred and spotted sandbass also were contaminated with lower levels of mercury.

As noted in Section 2.6.4: Fishes, baseline characterization surveys of fish fauna were completed in the bay (Allen 1998a) with an ongoing baywide study that included sampling sites seasonally for two five-year updates (Pondella *et al.* 2006). Topsmelt was the most abundant fish caught in Allen's (1998a) intertidal habitat surveys in San Diego Bay. However, the sampling was only conducted in lower intertidal regions; this result was repeated in 2005 (Pondella *et al.* 2006). The second most abundant was slough anchovy in 1998 and deepbody anchovy *(Anchoa compressa)* in 2005. Other primary intertidal fishes observed by Allen in 1998, and Pondella in 2005, were California killifish, and California halfbeak, as well as arrow goby, shadow goby *(Quietula y-cauda),* cheekspot goby *(Ilypnus gilberti),* and yellowfin goby. Young-of-year halibut and diamond turbot also use the intertidal flats. They are even commonly found in the high intertidal salt marsh, while older juveniles and young adults are in the shallow subtidal areas (Nordby 1982; Drawbridge 1990; Johnson 1999). Over 100 species of native fishes have been documented in San Diego Bay (Macdonald *et al.* 1990; Allen 1999; Pondella *et al.* 2006). The most recent surveys by Pondella *et al.*

(2006) for two quarterly samples in 2005, collected 57 species. This is not substantially different from the reports of Allen (1999) who collected species assemblage data over a much longer period. During seasonal sampling periods (July 27 1994–April 1999), Allen (1999) reported 78 species of fishes from throughout San Diego Bay. This contrasts with 56 species in 1892 (Eigenmann 1892), and only 25 species between 1968-1979 (Ford 1968; Ford *et al.* 1971; Lockheed 1979) which corresponded to a period when waters of the bay were recovering from many decades of raw sewage delivery. Pollution peaked in the late 1950s and early 1960s. In August of 1963, the new San Diego Metropolitan Sewage System went into operation. This sewage system discharged effluent offshore of San Diego, and by February of 1964, all domestic sewage was redirected to the new system and away from the bay.

Results of the most recent (VRG 2006) survey are similar to Allen *et al.* (2002) in which topsmelt, round stingray, northern anchovy (ranked 8th in 2005), slough anchovy and spotted sand bass were ranked first through fifth, respectively. The similarity between these data sets suggests that these species are critical components of the trophic structure of the bay and that they may serve as good proxy to the overall “health” of the fishes in the San Diego Bay ecosystem (VRG 2006).

Evaluation of Current Management

A habitat success story is the eelgrass mitigation policy developed cooperatively by a group of federal and state resource agencies. Since its implementation, there has apparently been no net loss in the acreage of eelgrass habitat within the bay, with the exception of normal cycles associated with El Niño events. This important fish habitat is well described in Section 2.5.3.2: Vegetated Shallows (0.0 to -24 feet [0.0 to -7.3 m] MLLW), with management evaluation and proposed strategy presented in Section 4.3.4: Vegetated Shallows. Other fish habitats may not be faring as well. Unvegetated shallow subtidal sites that are critical for bat rays, halibut, and other species do not receive the same level of protection as vegetated sites since they are not classified as “special aquatic sites” under §404 of the CWA (see Section 4.3.3: Unvegetated Shallow Subtidal). Marina areas in the bay lack the abundance and diversity of fish that would be expected there by biologists (R. Hoffman, *pers. comm.*).

Primarily through their feeding, bottom-dwelling, resident fish may bioaccumulate toxins from sediment contaminated many years ago. What effects the contamination of fish with mercury and PCBs have on reproduction and viability of fish within the bay is unknown. A review of the literature on lethal and sublethal effects of copper on fish and other animals was recently completed by the USGS, indicating a wide range of physiological effects at nominal copper concentrations of 4–10 μg/L (Eisler 1998). Larvae of topsmelt, a common species in the bay, showed increasing sensitivity to copper with increasing age. However, little research has been done on marine species. Much of the copper found in the bay is within the sediments, a long-term legacy of its use as a biocide in anti-fouling paints on boat and ship hulls. Elevated copper levels (>108 ppm) were found throughout sediments along the developed margins of San Diego Bay (Fairey *et al.* 1996).

While the five-year, baywide fish sampling study by Allen provides a very useful database on abundance, biomass, and frequency of occurrence, this program does not provide information concerning some important factors for management. As noted above, artificial, man-made habitat areas were not sampled so implications for their management are absent. Age class data were apparently not gathered, so an analysis cannot be made of the relative contribution of the bay for juvenile and adult phases of the fish surveyed. If bays are reportedly critical habitat as nurseries and refuge, the age structure and growth rates of fish inhabiting the bay should also be evaluated.

The issues of habitat protection, water quality improvement, and monitoring and research are addressed in several other sections of this INRMP as noted below. Additional recommended actions are as follows.

Management Strategy—Fishes

Objective: Conserve and enhance fish population abundance and diversity, with priority to those using the bay as a nursery or refuge, and to indigenous bay species.

See Section 4.2.1: Protected Sites.

I. Maintain and improve habitat that provides reproductive and nursery functions.

A. Continue the successful eelgrass strategy as described in Section Section 4.3.4: Vegetated Shallows.

B. Improve management of other fish habitats as proposed in Section 4.2.1: Protected Sites, Section 4.3.6: Salt Marsh, Section 4.2.1.5 Intertidal Flats, Section 4.3.3: Unvegetated Shallow Subtidal, Section 4.3.2: Moderately Deep Subtidal, and Section 4.3.1: Deep Subtidal.

C. Compare the success of different fish enhancement structures based on material characteristics and fish abundance and diversity.

II. Protect the health of the fish inhabiting the bay.

See compatible use strategies related to water quality improvement in Section 5.3: Watershed Management Strategies.

A. Implement the Compatible Use Strategies to protect and improve water quality proposed in Chapter 5 (i.e. Ship and Boat Maintenance, Stormwater Management, Oil Spill Prevention and Cleanup, Remediation of Contaminated Sediments).

III. Support research and monitoring that will help improve fish management decisions.

A. Continue to conduct fish surveys every five years for abundance, diversity, and biomass.

B. Assess the abundance, diversity, and biomass of fish occupying artificial habitats of the bay.

C. Evaluate the age structure and growth rates of fish inhabiting the bay.

D. Promote research on the toxicity levels and effects of the contaminants on the marine fish species, at all life stages, found in the bay.

E. Conduct a thorough, quantitative study to assess the recreational fishery and food gathering by ethnic groups:

1. To estimate species taken and fishery take by species.

2. To evaluate the effects of this take on bay species.

IV. Promote education and outreach.

A. Increase environmental education programs and availability of informational literature and signs to raise awareness of threats, concerns, and management needs for fishes.

B. Assemble an interagency team to develop strategies for implementing internal and external educational programs and identify possible funding mechanisms for conservation and enhancement of fishes in the bay.

4.4.3.1 Harvest Management

Specific Concerns

Harvesting of finfish and shellfish in the ocean and in the bay has triggered these concerns:

Fish habitats and population status in the bay are described in Section 2.6.4: Fishes.

- Juvenile California halibut between 10 and 200 mm standard length (SL) are known to inhabit the shallow waters of protected embayments and estuaries in the SCB (Haaker 1975; Allen 1988; Kramer 1990; Allen and Herbinson 1990). Impacts to juvenile fish could result into poor recruitment on the open coast.
- Overfishing of some marine species in the ocean is depleting populations, while little information is known about the status of most harvestable species.
- Few FMPs exist for the commercial species inhabiting the bay, although they are required by federal policy.
- Sport harvesting of fish and shellfish caught in San Diego Bay is not well monitored.

- Enforcement of sport fishing regulations is not adequate due to budget limitations.
- Overfished populations in the ocean may cause ripple effects in the bay ecosystem.
- Ethnic groups fishing in the bay are harvesting nontraditional species. This has unknown management implications and possible effects on the bay ecosystem.
- Management activities that the Port or Navy can implement are not likely to influence species that are harvested outside the bay.

Current Management

The abundance and diversity of fish populations within San Diego Bay can be affected by management of the commercial and sport fisheries in the ocean, at long distances from the bay. On the other hand, harvest management within the bay can affect the status of ocean populations. Evaluating the effects of harvesting can be complicated by other causes of change in fish abundance and diversity, such as weather conditions.

See Section 3.5.3: Fisheries Economics for use and value of the bay fishery.

Management of marine fish stocks is a dual responsibility of the state and federal governments. Within the state's 3-mile (5-km) offshore jurisdiction, CDFG provides the lead, while the NMFS oversees ocean stocks between the 3- and 200-mile (5- and322-km) limits. Fish Management Plans are to be prepared under the MSA (PL 94-265) (as amended by the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (PL 109-479) through January 12, 2007). A Pacific Coast Groundfish Management Plan and a Coastal Pelagics Plan have been adopted by the PFMC, a federally appointed regional body of managers and fishermen.

The recreational harvesting of fish and shellfish in San Diego Bay is managed directly by CDFG. Ocean fishing regulations are drafted by the Marine Resources Division, reviewed in public hearings, revised if needed, and adopted by the Fish and Game Commission. Emergency actions to close a fishery temporarily can be taken on short notice, following approval by the Commission and the Office of Administrative Law. Such action was taken to close the red abalone fishery in California (CDFG 1997b).

CDFG is the responsible agency for managing fishing within the bay.

California's management of its marine fisheries was fundamentally changed in 1998 with the passage of AB 1241, under which fisheries management authority was transferred from the legislature to the California Fish and Game Commission (University of California Cooperative Extension [UCCE] 1998). Fishery management plans are now mandated to be developed by the CDFG, with the Fish and Game Director authorized to adopt regulations implementing those plans. The plans will be the primary basis for managing the state's marine recreational and commercial fisheries, and must include measures needed for a sustainable fishery.

A Nearshore Fishery Management Plan (NFMP) was approved in 2002. The passage of the Marine Life Management Act (MLMA) in 1998 mandated resource sustainability as the highest priority. Also mandated were science-based management, fishery sustainability as key to minimizing socioeconomic impacts, and management based on fishery management plans including preparation of a NFMP. The necessity of preparing a NFMP was in response to increasing pressure on vulnerable nearshore reef fish species, particularly from a lucrative, relatively unregulated commercial nearshore live-fish fishery. The NFMP was written within the context of the MLMA's fishery sustainability goals, objectives, policies, and mandates. The Department selected 19 species of nearshore finfish for management under the NFMP. This process relied upon such criteria as changes in catch levels, biological characteristics, and habitat needs. The 19 species are listed in Table 4-15.

Table 4-15. Nineteen species selected for management by the California Fish and Game Commission in the Nearshore Fishery Management Plan (2002).

Black rockfish *Sebastes melanops*	Gopher rockfish *S. carnatus*
Black-and-yellow rockfish *S. chrysomelas*	Grass rockfish *S. rastrelliger*
Blue rockfish *S. mystinus*	Kelp greenling *Hexagrammos decagrammus*
Brown rockfish *S. auriculatus*	Kelp rockfish *S. atrovirens*
Cabezon *Scorpaenichthys marmoratus*	Monkeyface prickleback *Cebidichthys violaceus*

Table 4-15. Nineteen species selected for management by the California Fish and Game Commission in the Nearshore Fishery Management Plan (2002).

Calico rockfish *Sebastes dallii*	Olive rockfish *S. serranoides*
California scorpionfish *Scorpaena guttata*	Quillback rockfish *S. maliger*
California sheephead *Semicossyphus pulcher*	Rock greenling *H. lagocephalus*
China rockfish *Sebastes nebulosus*	Treefish *S. serriceps*
Copper rockfish *S. caurinus*	

The core of the NFMP is to meet several of the MLMA's sustainability objectives: preventing overfishing; rebuilding depressed stocks; ensuring conservation; and promoting habitat protection and restoration. Five general measures are implemented that form an integrated approach to meeting the MLMA guidelines:

1. *Fishery Control Rule:* The NFMP describes a Fishery Control Rule that includes three stages, recognizing the practical level of knowledge and understanding of the fishery. As knowledge increases, management can become less precautionary. The Fishery Control Rule provides a protocol for determining sustainable levels of fishing that then are enforced through the adoption of specific management tools such as size limits, time/area closures, or gear restrictions.
2. *Regional Management:* The NFMP recognizes the significant geographical differences in the nearshore fishery and proposes developing management tailored to conditions specific to each of four regions.
3. *MPAs:* The NFMP uses MPAs to ensure that the MLMA's objectives for protection of habitat and ecosystem integrity as well as sustainable fisheries are met. The NFMP recognizes the authority of the Marine Life Protection Act to design a Master Plan for MPAs in California. The Master Plan will make recommendations on specific sites for MPAs, implementation and phasing, funding, monitoring, enforcement, and management. The 2002 NFMP includes a recommended approach to MPAs to benefit nearshore finfish.
4. *Restricted Access:* The NFMP bases its approach to restricted access upon the Fish and Game Commission's restricted access policy, and presents four initial options for regional restricted access programs in the commercial fishery.
5. *Allocation:* The NFMP builds upon the allocation policy adopted by the Commission in December 2000. Total allowable catch will be allocated between commercial and recreational fisheries based on historical catches, on a regional level. Finally, effective implementation of the NFMP's measures will benefit from transfer of management authority to the State for some or all of the nearshore species currently managed under the federal groundfish fishery management plan.

Monitoring specifics for fish and invertebrate populations is in Chapter 6 Monitoring and Research.

Garibaldi.

Harvest regulation seeks to manage sustainable populations through a combination of techniques: area and seasonal closures; gear limitations; and size, catch, and possession limitations. For example, the daily bag limits for species of interest for sport fishing in San Diego Bay are found in Table 4-16. If no specific limit is listed in the CDFG sport fishing regulations for a species, then the general daily limit is ten finfish of any one species (or 20 in combination) and 35 shellfish (CDFG 1997b). Some species are listed in the regulations as having no limit: grunion, topsmelt, jacksmelt, starry flounder, and most clams, among others. Zero take applies to a few protected species, such as garibaldi, black sea bass, and speckled (bay) scallops. Zero take applies to California grunion during April and May peak spawning season (grunion are considered a sensitive and managed species by CDFG, with no take regulations during April and May of their peak spawning season (Loni Adams, CDFG, *pers. comm.*). Several species of marine plants are also prohibited from being cut or disturbed: eelgrass, surf grass, and sea palm. Seasonal restrictions apply to a few bay species: white sea bass, grunion (as mentioned above), and California spiny lobster, among others. Wardens from the Department's Wildlife Protection Division enforce the sport and commercial regulations. Sport fishing licenses are required for everyone except those fishing from certain public fishing docks.

Penalties for most violations are misdemeanors, with the amount of fines imposed by judges in local municipal courts. A portion of the fine monies may go to the County's Fish and Game Advisory Commission for use in local fish conservation projects.

Landing data collected at local docks do not separate fish caught in the bay from those caught in the ocean.

Commercial and some recreational catches are monitored through landing data at local docks, including how much, what kind, and the price paid for commercial fish at the boats. Statistics are processed annually on commercial fish landing receipts, commercial passenger fishing vessel records (sport fishery), and commercial fishing logs by the Marine Fisheries Statistics Unit (Read 1996). A logbook system is maintained for the spiny lobster trap fishery. However, published records do not include a separate listing for fish caught in San Diego Bay, only those landed at docks in the county, which would include pelagic and Mexican-water fish. Commercial fishing no longer exists in the bay. An experimental gillnet fishery for striped mullet was started in 1977, but ended in 1997 because of the mandated closure of gillnet fisheries in southern California (Duffy 1987; K. McKee-Lewis, CDFG, *pers. comm.*).

Table 4-16. Sport fishing limits on fish and invertebrate species of San Diego Bay (CDFG 2007a; California Fish and Game Commission 2007).[a]

Species	Limit/day (Season)	Species	Limit/day (Season)
Fish			
leopard shark	3	Pacific bonito	10
blue shark	2	kelp bass	10
Pacific angel shark	10	barred sand bass	10
soupfin shark	1	spotted sand bass	10
bat ray	10	queenfish	no limit
striped bass	2	barracuda	10
jacksmelt	no limit	cabezon	1 per person/1 bag limit
topsmelt	no limit	white sea bass	3, or 1 (3/15–6/15)
grunion	no limit (6/1–3/31)	California corbina	10
northern anchovy	1 bag	yellowfin croaker	10
Pacific herring	no limit	spotfin croaker	10
Pacific sardine	no limit	white croaker	10
California halibut	5	barred surfperch	10
rock sole, sand sole, butter sole, curlfin sole, rex sole, flathead sole, dover sole, English sole	10	pile surfperch	10
starry flounder	no limit	rubberlip surfperch	10
diamond turbot	10	walleye surfperch	10
opaleye	10	sculpin	10
jack mackerel	no limit	longjaw mudsucker	10
California tonguefish	10		
Shellfish (crustaceans and other invertebrates)			
bay (grass) shrimp	5 lbs	chione, littleneck, soft-shelled clams (5 spp.)	50
ghost shrimp	50	Pismo clams	10
rock crabs (3 spp.)	35	gaper clams	10
California spiny lobster	7 ((9/29--3/19)	jackknife clams (3 spp.)	35
rock scallops	10	razor clams (2 spp.)	20
whelks	35	sand dollars	35
mussels (4 spp.)	10 lbs (in shell)	octopus	35
limpets	35		

a. See species list for scientific names in Appendix C.

Bay boat anglers tend to release their catch while shore anglers tend to keep and eat their catch.

The recreational fishery is the most important harvest activity on the bay. Most of the boat fishing is by the catch-and-release method, while shore fishing is primarily catch-and-keep. When ocean conditions are unsafe, charter boats will switch to fishing in the bay (R. Fletcher, California Sportfishing Association, *pers. comm.*). The Marine Recreational Fisheries Statistical Survey (operated by NMFS) provided statistical data, but this program has not been used for management since 2003. The California Recreation Fisheries Survey replaced it in 2004. The California Recreation Fisheries Survey is a coordinated sampling survey designed to gather catch and effort data from anglers in all modes of marine recreational finfish fishing (CDFG 2009c). The program incorporates and updates the comprehensive sampling methodologies of the former Marine Recreational Fisheries Statistics Survey. This database contains information on private, rental, and Commercial Passenger Fishing Vessels (“party boats”); estimates of beach/bank and private access angler effort using an angler license database; and effort and catch estimation on man-made structures using instantaneous angler counts, roving effort surveys, and angler interviews from nearly 200 geographic locations, called “blocks”, along the California coast in San Diego County and including San Diego Bay (CDFG 2009c). Survey data for both programs are housed in RecFIN:http://www.recfin.org/cntrbtrs.htm. The Recreational Fisheries Information Network managed by the Pacific States Marine Fisheries Commission also offers data summaries (see Table 4-17).

Table 4-17. Recreational angler catch sampling list of major species for inland marine San Diego County, September 2006–October 2007.[a]

Species	Sampler Examined Catch Numbers
Barred sand bass	15
Barred surf perch	1
Black perch	4
California corbina	1
California halibut	7
California scorpionfish	2
Chub (Pacific) mackerel	97
Halfmoon	1
Jacksmelt	31
Pacific bonito	1
Rubberlip seaperch	1
Sargo	4
Shortfin corvina	1
Shovelnose guitarfish	1
Silverside family	15
Spotfin croaker	5
Spotted sand bass	62
White sea perch	3
Yellowfin croaker	4
All taxa	258

a. Information from Pacific States Marine Fisheries Commission catch numbers sampled from marine recreational anglers for all modes of fishing in inland marine areas for San Diego County for 2006–2007 (Pacific States Marine Recreational Fisheries Monitoring 2008).

Research on some marine sport fish is managed by CDFG’s Resource Assessment Project to provide a biological basis for improvement in management practices, with current emphasis on white seabass, halibut, and barred sandbass. The Ocean Resources Enhancement and Hatchery Program (under the Aquaculture and Bay Management Project) is involved with the management of white seabass.

Evaluation of Current Management

How well these harvest management efforts are succeeding in sustaining the finfish and shellfish populations of the bay is difficult to evaluate. Debate continues on classifying stocks as “overexploited” or “underutilized.” Monitoring of most California stock is very limited or nonexistent. No monitoring occurs of the bay’s commercial or recreational bait fish harvest (e.g. ghost shrimp, topsmelt). Currently, commercial fisherman are required to fill out a log when taking sardine for live bait. They are not required to fill out for other species such as anchovy; however, some fishermen voluntarily include those species as well. See Pacific Fisheries Council website for specifics (www.pcouncil.org). Despite the lack of data, sampling data on some bay stocks appear to indicate relatively healthy populations although historical population levels are not available for comparison of many species (Allen 1997; Chapter 2).

See Chapter 2 for more information about the status of fish in the bay.

Through the 1976 Magnuson Act, Congress changed the federal fisheries management focus from expansion of fisheries to their conservation and allocation (McEvoy 1986). However, economic and social factors were to be considered in producing the “optimum yield” of the fisheries and fishermen were decision-makers on the PFMC setting regulations. Some scientists believe the “incessant sociopolitical pressure for greater harvests” in combination with “the intrinsic uncertainty in predicting the harvest” are the causes for federal management failing to achieve the principle goal of sustainability of much of the ocean fisheries (Botsford *et al.* 1997).

As a result of the 1996 Sustainable Fisheries Act (reauthorizing the 1976 Act), NMFS was directed to report to Congress on the status of fisheries and the identification of overfished stocks. The NMFS uses a fisheries stock sustainability index as a performance measure for the sustainability of 230 U.S. fish stocks selected for their importance to commercial and recreational fisheries. The fisheries stock sustainability index will increase as overfishing is ended and stocks rebuild to the level that provides maximum sustainable yield. The NMFS published the status of several important bay groundfish and coastal pelagic species for the year ending in December 2007 (NMFS 2008). The species include cabezon, jack mackerel, Pacific mackerel, Pacific sardine, and Northern anchovy among others. Sufficient information was collected to determine that the stocks were not overfished and all bay species listed above had a fisheries stock sustainability index of 4 out of a possible 5, except Jack mackerel which ranked as a 1.5 which had limited data available to determine whether the species is “approaching an overfished condition” (NMFS 2008). Fish stocks within the bay are not separately assessed from the larger Pacific coast region. Estimates of standing stock of important species within the bay have been previously investigated (Allen 1997, 1998a, 1999; VRG 2005). The relative health of fish stocks within the bay likely tracks the trajectory of the overall Pacific coast stock assessments, though regional conditions may have localized effects to bay populations of specific species.

Bycatch of nontargeted species had been a problem in the past when commercial fisheries existed in the bay. When gillnets were set across the bay’s channel for striped mullet, for example, green sea turtles became a bycatch even when the nets were attended (McDonald *et al.* 1994). The PFMC allows a minimally acceptable biological catch of incidentally caught fish, in such categories as “Other Flatfish” (e.g. sanddabs) (Leet *et al.* 1992). Commercial harvest of ground fish and coastal pelagic species known to occur within the bay takes place nearly exclusively in offshore waters outside of San Diego Bay.

Harvest controls are one of the few direct management tools available. More attention is needed on the bait fishery harvest and its effect on the nearshore food chain.

Trends in harvest levels are often used as the only evidence of population size, and therefore, the sole indicator of problems with harvest management. Declines in harvest may reveal poor breeding replacement (recruitment) too late to halt reversals. In the example of the Pacific angel shark fishery, researchers and agency biologists began in 1979 to collect information on angel shark distributions, migrations, growth rates, and reproductive rates. A management plan followed in 1986, creating regulatory guidelines. Although a new minimum size limit was required to protect immature sharks, the drop in landings that followed was determined to be a reflection that management regulations were initiated too late to maintain a sustainable yield angel shark fishery with mid-1980s harvest levels (Leet *et al.* 1992). Factors other than harvest can cause increases or declines in the size and structure of harvestable species, but harvest controls are one of the few direct management tools available. The NMFS is currently implementing several fishery dependent and independent studies to examine population trends of groundfish and coastal pelagic species as well as essential fish habitat (PFMC 2006).

Currently all sectors of the groundfish fishery are constrained by the need to rebuild groundfish species that have been declared overfished. The PFMC is developing FMP amendments to incorporate rebuilding plans for these species. Because of the low biomass of some species, the overall groundfish harvest has been significantly reduced. This has led the Council to question the ability of the groundfish resource to support current levels of participation in the fishery (NMFS 2008). Coastal pelagic fish species important within the bay (sardines, anchovies, and mackerel) are regulated by the PFMC through the Coastal Pelagic fishery. Sardine fisheries are reviewed once a year in the fall and the Pacific mackerel fishery are reviewed in the spring to assure sustainable yield. Harvest management of important bay fish species is regulated by state and federal agencies examining SCB or Pacific coast populations.

California lobster, an intertidal invertebrate. Photo courtesy of TDI.

Intertidal invertebrates have been protected from wholesale collecting for over 25 years, yet "shore pickers" in the past decade have decimated sites of species previously thought to be of little interest (CDFG 1972; Knudson and Vogel 1996). A combination of reasons are suggested: new ethnic groups are seeking nontraditional seafood species; poachers are more effectively getting commercially valuable species; interest in the "live fishery" for the aquarium trade; and underfunded, understaffed enforcement efforts (Knudson and Vogel 1996). The principle problem is one of a lack of an adequate enforcement budget (S. Crooke, CDFG, *pers. comm.*; W. Tippetts, CDFG, *pers. comm.*; R. Hoffman, *pers. comm.*). CDFG's primary funding source continues to come from the sale of fishing licenses, which has declined in number and revenue despite an increase in population and management duties. As the stocks decline, the number of people fishing legally decreases, yet the management responsibilities rapidly rise in response to the crises.

Management Strategy—Harvest Management

Objective: Foster harvest management that can support viable, self-sustaining populations and promote native species richness within the San Diego Bay ecosystem.

I. Support adequate monitoring and research of harvestable species in the bay.
    - A. Continue to promote more effective measurement of all types of recreational harvesting within the bay through the California Recreational Fisheries Survey.
        1. Expand periodic censusing (e.g. boat and dock checks) of all species.
        2. Increase censusing of California halibut and sandbass.
        3. Continue to require through California Recreation Fisheries Survey that data collectors keep separate data for the San Diego Bay sport fishery so that their catches can be considered separately from those in the ocean.
        4. Evaluate the effect of recreational harvesting on those bay species with "no limits" in the CDFG regulations.
        5. Encourage a bait fishery monitoring program, including for ghost shrimp. Support CDFG's review of log book structure to ensure reliability of reporting.

II. Advocate effective enforcement of existing state and federal fishery management regulations.
    - A. Encourage better public education about the need for fishing regulations and their meaning.
        1. Seek publishing of sport fishing regulations and notices in the languages of the ethnic populations fishing the bay.
        2. Encourage CDFG to develop unambiguous, clear language in stating their regulations, including a more user-friendly format.
        3. Locate access and facility sites to minimize or avoid conflicts with sport fishing access and high-value habitats.
    - B. Support improved publicity and deterrents.
        1. Promote the use of appropriately stiff fines by local judges as a deterrent for future fishing violations.
        2. Encourage CDFG to publicize the arrest, conviction, and awarded court fines to discourage additional violations and poaching.
    - C. Seek stable revenue sources to supplement license revenues for CDFG's enforcement efforts.
        1. Investigate establishing a San Diego Bay Harvest Management Endowment Fund that can receive funds as in-lieu mitigation, grants, donations, and fines.
        2. Encourage alternative state funding sources to supplement fishing license fee revenues for CDFG budget.

D. Pursue improved regulation of sport fisheries if present state and federal harvest regulations and enforcement cannot meet the above objective.

E. Encourage NMFS (even though NMFS does not have jurisdiction in State waters in most cases) to complete FMPs for all commercially and recreationally important fish that use the bay, as required under the MSA of 1996.

4.4.3.2 Artificial Propagation

Specific Concerns

- Some fish species are declining and it may be necessary to enhance depleted populations by stocking.
- Other fish species are declining and may need special conservation measures, such as surfperches.
- Water quality in some marinas in the bay may limit their use as mariculture sites for less tolerant species like white seabass.
- Concentrated feeding and rearing of fish can increase nutrient levels and may cause eutrophication and changes in the benthic habitats near mariculture installations.
- Mariculture pens may concentrate diseases, and use of antibiotics (only Romet and Terramycin are used for white seabass) to control such diseases can have unforeseen effects on native fish and wildlife.

Background

As ocean fishery stocks and yields continue to decline, there is increasing interest in mariculture, the techniques applied to growing marine organisms in captive, semicontrolled conditions. This approach to artificial propagation of marine life for commercial sale or to enhance existing fisheries is often conducted in bays because of the protection and quiet water conditions they provide. Surprisingly, there has been little mariculture activity in San Diego Bay until recent years, but interest is now increasing.

In the late 1960s and early 1970s, Dr. George Schuman operated a mariculture laboratory at the South Bay Power Plant through an agreement with SDG&E. His intent was to use thermal effluent from the generating station as a warm water source in which to culture American lobsters (*Homarus americanus*) and penaeid shrimp, thereby shortening the time required to produce them. There were also plans to carry out this penaeid shrimp culture on a large scale, using the adjacent ponds of the Western Salt Company. After initial exploratory work, these projects ended and the laboratory was closed. Similar cooperative mariculture research on American lobsters and other species was then continued by SDSU at the SDG&E Encina Power Plant on Agua Hedionda Lagoon in Carlsbad, California.

In 1996, the fishing group of the Southwestern Yacht Club, working in cooperation with the United Anglers of California, established a floating raceway culturing system for young white seabass (*Atractoscion nobilis*). The white seabass is an important species in both sport and commercial fisheries with a very high market demand.

Current Management

Existing Mariculture Projects

Rare and endangered green abalone is being grown in the laboratory at the SSC San Diego. The purpose and ultimate outcome of this program is to re-establish breeding populations along Point Loma (D. Lapota, *pers. comm.*). Divers from Scripps Institution of Oceanography selected a planting site for 200 abalone at a depth of approximately seven meters. The outplanting habitat includes large boulders with crevices, smaller broken rock reefs, and flat pavement. Other location criteria were predator presence, food availability, and ease of monitoring progress. Records will be made of abalone densities, predators, scavengers and kelp species. An additional 300 abalone from the laboratory were housed in plastic holders and transported in insulated coolers to several sites (SSC San Diego 2005). By confining the outplanting, abalone should be more easily accounted for than prior attempts at assessments in the open ocean. The City of San Diego's Metropolitan Wastewater Department is making plans for similar outplanting activities using SSC San Diego's green abalone (SSC San Diego 2005). Red abalone are currently being grown to a similar size for continued outplanting activities (D. Lapota, *pers. comm.*).

The state is evaluating the feasibility of enhancing white seabass populations through artificial propagation in southern California.

The Ocean Resources Enhancement and Hatchery Program (OREHP) was established by the State Legislature in 1983, with CDFG as the lead agency, to evaluate the feasibility of culturing and releasing juvenile fish to enhance depleted populations of white seabass in southern California. The decline of white seabass between the 1950s and 1980s was the driver behind the legislation. The long-term stock enhancement evaluation program (Kent *et al.* 1995) is being conducted in part at the Leon Raymond Hubbard Jr. Marine Fish Hatchery in Carlsbad, California, which is operated for OREHP by the Hubbs-SeaWorld Research Institute. Here, young white seabass are cultured in large numbers from fertilized eggs produced by a broodstock of adult fish. When these juvenile fish reach a total length of approximately 3–3.5 inches (51–64 mm), they are marked by insertion of a coded wire tag used to identify the spawning group and release site of individual fish when they are subsequently recaptured following release into the ocean. The marked fish are transported to one of a series of net pen culturing facilities, which include the San Diego Bay installations at the Southwestern Yacht Club and at the end of Grape Street. These facilities are located in bays or other protected nearshore ocean locations extending from San Diego Bay to Catalina Island, Santa Barbara, and Channel Islands Harbor (Kent *et al.* 1995). Most of them are operated under the auspices of United Anglers of California and San Diego Oceans Foundation, whose members donate their time in feeding and maintaining the young white seabass. About 80 volunteers regularly take care of pens in Mission and San Diego Bays. OREHP has a benthic monitoring program set up where the white seabass net pens are sampled every three years. So far no significant adverse affects have been found.

OREHP has a benthic monitoring program set up where the white seabass net pens are sampled every three years. So far no significant adverse affects have been found.

After a time period averaging four to six months in the net pen systems, these fish are released into ocean or outer bay locations known to be inhabited by young, white seabass. At the time of their release, the fish are approximately 8 inches (203 mm) in total length. OREHP also supports directly associated field studies conducted by scientists from Hubbs-Sea World Research Institute and California State University Northridge. These studies include sampling for white seabass along the open coast of southern California and in selected bays and estuaries from Imperial Beach and San Diego Bay to Santa Barbara and Catalina Island. The studies are designed to recapture tagged white seabass, with the data used to evaluate the success of stock enhancement, and also to learn more about the distribution, abundance, and population characteristics of this species.

The first experimental release of more than 2,000 juvenile white seabass took place in October of 1986 in Mission Bay (San Diego, California). Since then, the program has released more than one million juvenile white seabass into embayments and nearshore coastal areas in southern California (T. Mason, CDFG, *pers. comm.*). Locally, the Port, San Diego Oceans Foundations, Hubbs-Sea World Research Institute, and CDFG collaborated on the development and installation of two 18'x18' mariculture net pens located at the foot of Grape Street Pier in San Diego Bay, called the San Diego Bay Grow-out Facility. The 18'x18' pens have the capacity to release 70,000 seabass annually after the fingerlings reach a size of 7 to 9 inches.

Rearing the white seabass to a relatively large size before they are released also helps to ensure that fewer of them will be taken by predators and thus more will survive to augment the population.

One of the goals of OREHP is to release cultured white seabass that have genetic diversity very similar to that of the wild population. OREHP currently uses BMPs to maximize the number of parents contributing to white seabass production. These BMPs will remain in place until a genetic management plan is developed as part of the WSEP. The genetic management plan will be based on the results of genetic research currently being conducted by Hubbs-Sea World Research Institute and should be completed and approved by the Scientific Advisory Committee within the next five years (V. Taylor, CDFG, *pers. comm.*).

Floating culture systems, such as the one operated at the Southwestern Yacht Club in San Diego Bay, form an extremely important part of the program. Holding the fish in floating net or raceway enclosures makes it possible to rear them to a large size without having to employ large culturing tanks or ponds and eliminates the associated high cost of pumping seawater to such land-based systems. Natural movement of bay water through the net enclosures ensures a supply of oxygen-rich water and efficient removal of wastes. Rearing the white seabass to a relatively large size before they are released also helps to ensure that fewer of them will be taken by predator, thus more will survive to augment the population. The floating raceway system in use at the Southwestern Yacht Club measures 24.0x6.0x5.0 feet (7.2x1.8x1.5 m) and is suspended in a water depth of approximately 5 feet (1.8 m). This facility has successfully reared and released 3,588 fish. Capacity to release for this facility is 5,732 seabass per year. Raceways are used at three other sites along the southern California coast. Net pens are being used at nine facilities, and the remaining facility, which uses two above ground pools, is land-based. Equally important, participation in the project by volunteer members of United Anglers of California helps to reduce production costs during this very labor-intensive phase of culture and also provides a hands-on opportunity for the volunteers to contribute directly to the stock enhancement process.

Regulatory Process

Mariculture operations require approval from CDFG and a permit from the CCC.

When a volunteer group wants to set up a growout facility, they must then get approval from the OREHP site selection committee, which consists of the OREHP Coordinator (CDFG employee), Hubbs-Sea World Research Institute's Growout Facility Coordinator, a CDFG Fish Pathologist, and the growout facility operator. Proposals for mariculture installations, such as those in San Diego Bay, are normally subject to review and approval by both the CDFG and the CCC, and they must be permitted by the USACE. No additional approval is required by the San Diego RWQCB unless waste discharge through an outfall is involved. CCC requires a permit to culture or release these fish. As an established part of this program, net pen systems for producing white seabass, such as the Southwestern Yacht Club installation, require approval by CDFG as the lead agency through its OREHP Advisory Panel. Net pen installations also require an administrative approval from the CCC (D. Kent, Hubbs-Sea World Research Institute, *pers. comm.*).

Evaluation of Current Management

It appears that there is potential for at least some additional mariculture in San Diego Bay. Production of marine fish and invertebrates for commercial sale or for use in stock enhancement could be accommodated in suitable bay locations using net pen systems.

However, there are several factors that limit this potential in San Diego Bay. First, commercial and military installations and areas set aside as natural habitats already occupy many sites in the bay suitable for mariculture. There are simply very few adequate mariculture sites remaining. Mariculture using floating net pen or raceway systems lends itself best to this situation because these can be operated within existing, developed areas, such as marinas, and in open water away from the shore.

In addition, all mariculture operations require consistently good water quality and associated water circulation. This probably will limit the use of some marinas and other developed areas in San Diego Bay, at least for culturing less tolerant species. The initial problems encountered in rearing young white seabass at the existing Southwestern Yacht Club site are a case in point.

It is also important to recognize that large mariculture operations can have adverse effects on the bay ecosystem. Concentrated feeding by animals in culture can lead to uncontrolled growth of invasive species. In addition, concentrated production of wastes by cultured animals can cause blooms of noxious algal species and changes in bottom conditions. These problems must be considered in evaluating the design, operation, and placement of mariculture systems.

Successful mariculture also requires an installation that is reasonably secure from vandalism and other human intrusion. In a busy, urbanized commercial port such as San Diego Bay, such security may be difficult to maintain.

None of these limitations will prevent further development of mariculture installations in San Diego Bay. However, they must be given very serious consideration in the site selection process.

Proposed Criteria

While there are no firmly established guidelines, several practical criteria are normally employed in evaluating the merits and possible shortcomings of a proposed mariculture project and its installations in the marine environment. The first, and most important of these, is the biological or commercial need for culturing a particular species of fish or invertebrate. Species such as the white seabass, for which the population size, fishery yield, and market supply have declined markedly, would have the highest priority for mariculture production. This would be true both for culture leading directly to commercial sale in fish markets or the production of juvenile fish released for stock enhancement. In contrast to the approach normally employed for species in terrestrial habitats, high ranking of candidate species for mariculture does not require that they be threatened or endangered species, only that the fishery stocks and yields are substantially depressed and, usually, that commercial or recreational demand for the species exceeds its natural supply. These effects on the population are caused by fishery and environmental problems normally involving overfishing, associated ineffective fishery management practices, changes in habitat conditions, or a combination of these factors.

A second important criterion is the degree to which existing mariculture technology for a species is well established and will likely lead to successful culture. In the case of the white seabass program, for example, production techniques such as use of net pen systems are already well established and very successful, which would lead to a high ranking.

A third set of criteria involves questions about water quality. Two primary, general questions are normally considered. First, are water quality conditions (e.g. good water circulation, low concentrations of toxic chemicals) at the proposed mariculture site adequate to help ensure successful production of the species? Water quality problems encountered thus far with the floating raceway system for white seabass at the Southwestern Yacht Club in San Diego Bay were solved after some problems the first year. Second, is the proposed mariculture installation likely to cause any degradation of water quality conditions (e.g. from animal wastes or uneaten food) at the site?

Management Strategy—Artificial Propagation

Objective: Explore the potential for enhancing the numbers of fish species that are in decline through artificial propagation in San Diego Bay while protecting the bay ecosystem.

I. Allow only the propagation of those fish species with populations declining due to fishing pressure and other effects.

- *A.* Support the continued evaluation by CDFG of the culturing of white sea bass.

II. Support the use of state-of-the-art mariculture technology.

III. Ensure good water quality in the vicinity of the propagation facility and avoiding impacts to the bay's ecosystem.

- *A.* Identify whether adequate water quality conditions (e.g. good water circulation, low concentrations of toxic chemicals) are available at a proposed location to ensure successful propagation of the species.
- *B.* Require that any mariculture installation in the bay does not degrade the water quality conditions of the site (e.g. from animal wastes or uneaten food).
- *C.* CDFG to continue to ensure that the cultured fish are not diseased and that the potential for the spread of any introduced disease or antibiotics from the operation to wild fish stocks is not possible. This is currently accomplished by commitment of a full time Fish Pathologist for OREHP and veterinary participation in disease management.

D. Encourage development of a policy to ensure that genetic diversity of propagated species will be protected through cultural practices.

1. Continue the current use of BMPs to maximize the number of parents contributing to white seabass production until a genetic management plan is developed as part of the White Seabass Enhancement Project. The genetic management plan will be based on the results of genetic research currently being conducted by Hubbs-Sea World and should be completed and approved by the Scientific Advisory Committee within the next five years.

4.4.4 Birds

Specific Concerns

See also Section 2.6.5: Birds.

- Effects on Pacific Flyway bird populations from substantial losses of historic nesting, foraging, and loafing habitats within the Bay are not well documented or understood for most bay-dependent birds
- In recognition of the importance of the foraging and nesting habitats of the south bay and the specific species these habitats support, the south bay has been designated a Western Hemisphere Shorebird Reserve Network Site and each Unit is recognized as a Globally Important Bird Area by the American Bird Conservancy. Yet the remaining habitat—especially intertidal mudflats and upland transitional habitats—are degraded and fragmented by a host of factors, including invasion of invasive plants and animals, reconfiguration of sub- and intertidal topography and substrate type, shoreline stabilization structures, watercraft grounding or anchor impact, contamination from localized terrestrial runoff, and compaction by vehicle wheels.
- Intertidal mudflats and upland transitional habitats are not adequately protected in existing regulations, nor is there an institutional mechanism similar to the Southern California Eelgrass Mitigation Policy to advance innovation and develop management techniques for these important bird habitats.
- Predation is intensified as birds subsisting on fewer and smaller habitat patches are targeted by locally thriving urban populations of predators and scavengers, such as domestic cats and dogs, rats, opossums, kestrels, ravens, crows, gulls, raccoons, and the recovering peregrine falcon. This problem will probably always require intensive management for declining populations.
- Some shoreline armor along the bay, such as riprap, harbor predators such as feral cats, crows, skunks and rats and they impact endangered birds such as the western snowy plover and California least tern, as well as other birds.
- Human disturbance at or near feeding, nesting, and roosting areas places birds at risk when the birds are displaced, forced to expend excess energy in flight, exposed to higher risk of predation, or excluded altogether from these habitats due to disruptive effects of watercraft, aircraft and kites, lights and pyrotechnics, and vehicles at or near bird habitats.
- Human-produced contaminants and toxins, including oil, threaten all bay-dependent species from potential accidental spills, nonpoint and point source runoff, and bioaccumulation.
- Potential for disease outbreaks such as avian cholera, avian influenza, and botulism are heightened as birds are crowded into diminished habitat patches, and water quality is impaired.
- Monofilament line, fish hooks, plastic six-pack rings, plastic balloons, and other items of human-generated refuse potentially threaten individual birds with injury or mortality, as do above-ground utility lines across flight paths.
- Changes to the invertebrate and vertebrate prey base of bay-dependent birds due to direct, indirect, and cumulative impacts raise concerns.
- Creative initiatives for conservation of bay birds and their habitats have not been fully explored, including public information and education, garnering volunteer support of conservation projects, supporting ecotourism, and others.

Current Management

The Migratory Bird Treaty Act and associated EOs and guidance memos provide basic protection for the majority of the avian species in the bay.

The majority of bird species around San Diego Bay are federally protected under MBTA. Introduced and pest species are not protected. EO 13186 on the MBTA requires that federal agencies whose actions may affect migratory birds must develop and begin implementing, within two years, an MOU with the USFWS aimed at conserving these birds. It also establishes a Council for the Conservation of Migratory Birds to help agencies implement the Order. In addition, the EO requires NEPA evaluations to include effects on migratory birds and that advance notice or annual reports must be made to the USFWS concerning actions which result in the taking of migratory birds. The EO also requires agencies to control the establishment of invasive species that may endanger migratory birds and their habitat.

DoD policy states that neotropical migratory bird programs shall be established in support of and consistent with the military mission. DoD's strategy focuses on inventory, on-the-ground management practices, education, and long-term monitoring (DoD 4715.DD-R 1996). A means of achieving these strategies is offered through the Partners In Flight cooperative program. Partners In Flight is an international effort involving partnerships among federal, state, and local government agencies, professional organizations, conservation groups, and all other interested parties to improve monitoring, research, management, and education programs involving birds and their habitats. Partners In Flight offers DoD the opportunity to participate in an international program to enhance stewardship of natural resources and implement conservation objectives on a landscape level.

Migratory Bird Rule and DoD Guidance

The new Migratory Bird Rule relates to military readiness activities and was established in accordance with §315 of the National Defense Authorization Act for fiscal year 2003. The final rule, "Migratory Bird Permits: Take of Migratory Birds by the Armed Forces", was published as 50 CFR Part 21 in the February 28, 2007 Federal Register, pages 8931-8950. It authorizes the military to "take" migratory birds under the MBTA without a permit, but if the military determines that the activity will "significantly" affect a population of migratory birds, they must work with the USFWS to implement conservation measures to minimize/mitigate the effects.

This is different from the USFWS/DoD MOU (Federal Register 8/30/06) which addresses the conservation of migratory birds on military lands in relation to all activities except readiness. The MOU is a guidance document on how the DoD will conserve migratory birds and does not authorize any take. Key to implementing the MBTA Rule and guidance documents on the MOU between the USFWS and DoD are the wording of the authorization for take that requires an understanding of the definition of the following terms:

Population, as used in Section 21.15, a group of distinct, coexisting (conspecific) individuals of a single species, whose breeding site fidelity, migration routes, and wintering areas are temporally and spatially stable, sufficiently distinct geographically (at some time of the year), and adequately described so that the population can be effectively monitored to discern changes in its status.

Significant adverse effect on a population, used in Section 21.15, means an effect that could, within a reasonable period of time, diminish the capacity of a population of migratory bird species to sustain itself at a biologically viable level. A population is "biologically viable" when its ability to maintain its genetic diversity, to reproduce, and to function effectively in its native ecosystem are not significantly harmed. This effect may be characterized by increased risk to the population from actions that cause direct mortality or a reduction in fecundity. Assessment of impacts should take into account yearly variations and migratory movements of the impacted species. Due to the significant variability in potential military readiness activities and the species that may be impacted, estimates of significant measurable decline will be determined on a case-by-case basis.

In April 2007, guidance was issued by the Under Secretary of Defense for Acquisition, Technology and Logistics on implementing the MOU to Promote the Conservation of Migratory Birds between the USFWS and DoD in accordance with EO 13186 (17 January 2001). This guidance covers all activities on Navy property around San Diego Bay, including natural resources management, routine maintenance and construction, industrial activities, and hazardous waste cleanups. The guidance emphasizes interdisciplinary collaboration in framework of NABCI Bird Conservation Regions, collaborative inventory and long-term monitoring.

Conservation measures undertaken under the Migratory Bird Rule require monitoring and record-keeping for five years from the date the Armed Forces commence their conservation action. During INRMP reviews, the Armed Forces must report to the USFWS migratory bird conservation measures implemented and the effectiveness of the conservation measures in avoiding, minimizing, or mitigating take of migratory birds.

The destruction of habitat is somewhat limited by the permit and review process required under the NEPA, CEQA, CCA, and §1600d of the California F&G Code, §401. Dredging and filling of wetlands is further limited by the CWA §404 under the USACE. Each process requires review by the USFWS, CCC, and CDFG. Specific review criteria only indirectly related to birds may be performed by the NMFS, EPA, RWQCB, and San Diego County Health Department. Additional limitations are imposed by local jurisdictions (U.S. Navy commands; County of San Diego; SDUPD; cities of San Diego, Coronado, National City, Chula Vista, and Imperial Beach) in the form of land-use planning tools including overlays, zoning, buffer restrictions, and permitting. Disturbance to waterfowl is somewhat reduced through watercraft speed limits by Port Ordinance, and some roosting and nesting areas of sensitive species are protected by limiting public access. Portions of the bay also fall within the San Diego NWR Complex planning zone and the MSCP, requiring additional oversight by USFWS, CDFG, and local agencies. The Port or the Navy did not participate in the MSCP, whereas the cities did participate.

Additional management and review input is provided by public and special interest groups, including nonprofit conservation organizations, such as Environmental Health Coalition, baykeeper, the Audubon Society, and the Sierra Club.

Additional Management

Additional protection is afforded to endangered and threatened species under the federal and state ESAs. These species are monitored and managed to varying degrees depending on perceived threats, conflicts, habitat requirements, and project funding. Intensity and frequency of management efforts vary widely from year to year and can range from no regular monitoring to intensive daily monitoring and management, depending on the species, agency involved, and other variables. For example, the Navy and Port have funded long-term extensive monitoring and management of California least tern nesting areas on its properties. Other agencies fund less intensive measures on an irregular basis: snowy plovers receive less intensive monitoring than least terns by the Navy (plover monitoring is not funded directly), Belding's savannah sparrows are only monitored for population estimates every five years by USFWS. Light-footed clapper rail surveys are conducted annually and are funded by federal Section 6 funds that are administered by CDFG.

Existing management and recovery plans provide a framework of threats, recovery goals, and actions for a variety of bay-dependent avian species.

The USFWS has prepared recovery plans for the federally listed species that occur within the Refuge Units. These recovery plans, which include the California Least Tern Recovery Plan (USFWS 1985a), Salt Marsh Bird's Beak Recovery Plan (USFWS 1985b), Light-footed Clapper Rail Recovery Plan (USFWS 1985c), Recovery Plan for U.S. Pacific Populations of the Green Turtle (NMFS and USFWS 1998), the draft Western Snowy Plover Pacific Coast Population Recovery Plan (USFWS 2001), and, formerly, the California Brown Pelican Recovery Plan (USFWS 1983), are intended to serve as guidance documents for agencies, landowners, and the public. Each plan includes recommendations for actions considered necessary to satisfy the biological needs and assure the recovery of the listed species. These plans also emphasize opportunities for improved management of listed species on federal and state lands. Recommended actions generally include protection, enhancement, and restoration of those habitats deemed important for recovery, monitoring, research, and public outreach.

The San Diego Bay NWR is also located within the Southern Pacific Shorebird Planning Region, as defined by the U.S. Shorebird Conservation Plan (Brown *et. al.* 2001). The Southern Pacific Region is an important wintering area for shorebirds that breed in the arctic and temperate zones, but is also important during migration, particularly for arctic breeding species. Important shorebird breeding populations also occur in the region. The major regional goal of the U.S. Shorebird Conservation Plan is “to ensure that adequate quantity and quality of habitat is identified and maintained to support the different shorebirds that breed in, winter in, and migrate through each region.”

The Southern Pacific Shorebird Conservation Plan (Hickey *et al.* 2003) includes several conservation priorities that are relevant to San Diego Bay. These include increasing the breeding population of the western snowy plover to 2,750 breeding adults; increasing or maintaining the breeding populations of the black-necked stilt, American avocet, and killdeer by restoring, enhancing, or creating nesting habitat; and increasing migratory and wintering populations of all key shorebird species in the region using various protection, restoration, enhancement, and management strategies. The Plan identifies tidal flats as the most important shorebird habitat within the coastal embayments of California. The San Diego Bay NWR includes the largest remaining area of tidal mudflat habitat and the largest remaining area of coastal salt marsh habitat within San Diego Bay; therefore, the Regional Shorebird Plan’s habitat goals for tidal wetlands are relevant to this Refuge. These goals include restoring tidal flats and marshes on the southern California coast; enhancing tidal action in existing wetlands as needed; and limiting human disturbance to shorebirds in all seasons. The Plan also includes goals for managed wetlands, which call for improving the value of existing management to benefit shorebirds; restoring additional wetlands to support shorebirds; and retaining and managing a sufficient amount of salt ponds and other shallow open water habitat to support shorebird populations.

Similarly, the North American Waterbird Conservation Plan (Kushlan *et al.* 2002) provides a continental-scale framework for the conservation and management of 210 species of waterbirds, including seabirds, coastal waterbirds, wading birds, and marshbirds. Eighty percent of the species addressed in this plan are colonial nesters and, of this group, approximately one third of them are considered to be at risk of serious population loss. Many non-colonial waterbirds are also considered at risk. Threats to these species include habitat loss (e.g. destruction of coastal wetlands), introduced predators and invasive species, pollutants, human disturbance, and conflicts among species. The habitat goal for this plan is “to protect, restore, and manage sufficient high quality habitat and key sites for waterbirds throughout the year to meet species and population goals.” Brandt’s cormorant (*Phalacrocorax penicillatus),* black skimmer, least tern, tricolored heron *(Egretta tricolor),* pelagic cormorant *(Phalacrocorax pelagicus),* and gull-billed tern, all known to occur in the bay, are identified as high concern species in the plan.

A variety of surveys and monitoring programs have been conducted throughout the bay in recent years.

Baseline data on waterbird species diversity, abundance, and distribution on the bay was documented in three studies (USFWS 1995; Ogden 1994; Ogden 1995), but methodology was not standardized. The three sections of the bay were monitored in different years and focus was on subtidal habitats. Only minimal data were collected on intertidal and shorebird usage. Funding was provided by the Navy and USFWS. A year-long bay-wide survey focusing on shorebirds and waterbirds was funded by the Navy and the Port in 2006-2007 (TDI 2009) and again in 2009-10 (Tierra Data *in prep*). These surveys have augmented understanding of the population and distribution of all bird species in the bay. The U.S. Navy is currently funding shoreline bird monitoring along its properties on the Silver Strand. Previous monitoring included bird surveys along the NASNI shoreline (Copper 1997a, 1997b). The USFWS monitors nesting species in south San Diego Bay on a yearly basis (B. Collins, *pers. comm.*). The Point Reyes Bird Observatory previously coordinated a five-year monitoring program of Pacific Flyway shorebirds (Page *et al.* 1991), and annual Audubon Society Christmas Bird Counts provide nonstandardized but long-term data on abundance and diversity. Bird species diversity, abundance, and distribution data may be supplemented by a five-year Bird Atlas project that was started in 1997 by the San Diego Natural History Museum using volunteers (San Diego Natural History Museum 1997).

The U.S. Navy funds snowy plover and least tern monitoring at the NAB, NRRF, and at the NASNI tern site (Copper 1997a, 1997b, 1997c; Copper and Patton 1997). Previous funding included snowy plover monitoring at NASNI, least tern monitoring at the NTC (Copper 1997a; Copper and Patton 1997), and least tern foraging studies (Copper 1985; Baird 1997). The Port currently funds monitoring of least terns at three nesting properties (Patton 1997) and USGS/National Biological Survey have monitored for snowy plovers (Powell *et al.* 1997). Funding has also been provided by the Navy to assess the population status of the light-footed clapper rail on NBC (Hoffman 2007). The Chula Vista Nature Center, in partnership with the USFWS, the Zoological Society of San Diego Wild Animal Park, and Sea World, developed a captive-rearing program with the goal of releasing light-footed clapper rails in salt marshes along the southern California coast (four birds were released in the Saltwater Marsh in 2002 and eleven birds were released at the same location in 2005). Light-footed clapper rail surveys are done annually (e.g. 2006, 2007, 2008) and are funded by federal Section 6 funds that are administered by CDFG.

Evaluation of Current Management

Legislation, enforcement, planning, and review processes have been successful in slowing the loss of species, habitat, and populations of waterbirds. In the case of some species and groups, such as herons and egrets, remarkable rebounds in population numbers were noted following protective legislation earlier this century. However, while most waterbirds and shorebirds dependent on San Diego Bay and other southern California coastal habitats are migratory and the cause of decline may be far distant, the downward trend continues. This trend is evident through a combination of sources studying these populations throughout the region, yet there remain no long-term monitoring programs for these species as a whole. Though the recent bay-wide survey efforts are beginning to close this information gap. Among those species classified as endangered or threatened, the monitoring, management, and population estimates are nonstandardized and vary widely among not only species but nesting sites. Intensive management of California least terns has proven effective in increasing their population and securing terrestrial habitats around the bay where other species also benefit, including snowy plovers, horned larks, and roosting shorebirds. However, neither the funding nor physical sites of these programs are secure indefinitely, and habitat degradation, predation, and population reductions are likely if such management were to cease.

Rates of habitat loss and degradation have slowed, but habitat issues remain the primary concern for waterbirds. Habitat degradation and disturbance need to be addressed through education, as well as through controls in planning and review processes. Clear identification of bird population and habitat management priorities for the bay are lacking and this risks cumulative loss of habitats. While progress has been slowly made in some areas, such as the control of nonnative predators, populations of native predators and scavengers continue to increase and magnify the impacts of predation on bird populations dependent upon the bay. The persistence of contaminants and toxins in the substrate and food chain of the bay and continuing potential for new spills or leakage should be acknowledged in continued planning efforts. The complex nature and multiple sources of potential influence on factors such as water quality, nonnative species establishment and impact, and fisheries size and production indicate that these issues will remain threats to birds around the bay without a multi-pronged approach to their solution.

Management Strategy—Birds

Objective: Maintain, enhance, and restore habitats on San Diego Bay aimed at providing for the health of resident and migratory populations of birds that rely on the bay to complete their life cycle. Foster broader public knowledge and appreciation of the functional, aesthetic, recreational, and economic values of the bird resources of the bay.

I. Protect, enhance, and restore habitats that migratory bird populations depend upon.

A. Maintain and enhance primary roosting, foraging, and nesting sites.

   1. Complete a comprehensive habitat classification system for the bay that clearly defines the tidal, upland, and transitional habitat subsets (e.g. how a mudflat is partitioned) used on a recurring basis by bay birds.

   2. Map distribution of these habitats across the bay and relative importance to birds based on existing information and additional survey data as needed.

   3. Identify opportunities for maintaining and enhancing these primary habitats.

B. Establish long-term priorities for management and conservation of habitat for bay birds.

   1. Prioritize birds species groups and associated habitats most in need of future management and conservation based on local population and habitat declines, and Flyway and national priorities established by the North American Waterfowl Management Plan, Partners in Flight Bird Conservation Strategy, and the U.S. Shorebird Conservation Plan.

   2. Establish biologically appropriate planning units within the bay ecosystem as needed and defined by the priority conservation needs.

   3. Establish specific habitat acquisition, enhancement, restoration, protection and management objectives, and completion timelines based on priorities within the planning units. Tie in where possible expectations for anticipated population responses based on habitat management.

C. Maintain a policy of no net loss of subtidal, intertidal, or terrestrial transition habitats, and a long-term net gain in the carrying capacity of these habitats.

   1. Continue enforcing no net loss of subaquatic vegetation throughout the bay, since this habitat provides forage and harbors prey for many bay-dependent birds.

   2. Acquire or protect high priority remnant habitats.

D. Identify opportunities through mitigation and nonmitigation funding to protect existing, restore degraded, and recover priority bird habitats.

   1. Establish a southern California intertidal mitigation policy that will provide incentive for protecting and increasing the acreage or function of intertidal habitat for sensitive birds.

   2. Seek means to maximize the impact of mitigation effort for small projects by combining funds from multiple projects at a single site.

   3. Seek nonmitigation funds to expand and restore intertidal, upland transition and other habitats identified as important to declining species.

   4. Develop an incentive-based means (such as mitigation banking) to allow entities other than USFWS Refuges to participate in safeguarding and enhancing the function of the Salt Works for foraging and nesting shorebirds.

   5. Identify opportunities for restoration of severely degraded or lost priority habitats.

E. Establish a baywide policy of reducing invasive nonnative vegetation that impacts bird habitat.

F. Support cleanup efforts to reduce contaminants and toxic buildup in the ecosystem, including monitoring and reducing nonpoint sources.

   1. Identify priority locations, schedules, and funding mechanisms to achieve cleanup efforts in high priority habitats, in concert with the Ecological Risk Assessment work being conducted at SPAWAR.

   2. Support south bay cleanup using volunteers.

G. Encourage bay interests and jurisdictions to adopt uniform environmental protection, enforcement, management plans, and policies that affect priority bird habitats in the bay.

H. Allow for management plans that address bird habitat management to adapt to new knowledge based on research and monitoring.

I. Coordinate with current local, regional, and national bird conservation initiatives to reduce duplication of effort and maximize local conservation of bay birds.

II. Protect bird populations that use the bay ecosystem.

A. Establish a long-term standardized population monitoring program throughout the bay.

1. Continue to conduct avian surveys every five years using standardized, scientifically sound survey protocols to collect and analyze population abundance and distribution of birds across water, upland, and transitional habitat types and seasonally.

a. Ensure that survey protocols will establish current local population sizes and also permit credible estimates of population trends at five-year intervals.

b. In interim years, conduct shorebird and waterbird annual point count and boat transect monitoring at a reduced effort.

2. Consolidate existing information and determine how current established monitoring programs might contribute to bay databases and monitoring protocols, including the Breeding Bird Survey, Breeding Bird Atlas, Colonial Waterbird Surveys, International Shorebird Survey, Hawk Migration Surveys, Breeding Bird Census, Christmas Bird Counts, Winter Bird Population Studies, survey information collected locally by federal and state agencies, and the Service's Bird Banding Laboratory.

B. Increase the bay's carrying capacity for shorebirds.

C. Establish specific population goals for priority resident bird populations and secure and conduct the necessary management of habitat to support those populations.

1. Identify focus species and sources of information that can be used to establish realistic population goals, such as known peak population sizes within the past 20 years.

2. Ensure full representation of species groups and habitats at the bay level.

3. In association with establishing population goals, identify the quantity and feasibility of habitat needed to support those population goals.

D. Provide secure colonial nesting sites, allow for population recovery, manage predators, and protect adjacent foraging areas for the California least tern and other declining species.

1. Promote cooperative agreements on predator management that result in more effective protection of nesting birds.

2. Promote pet management and keeping trash receptacles covered (that may otherwise attract crows) year-round in housing areas and on public lands near nesting sites.

3. Urge that predator management measures be integrated into the design, development, and management of habitat areas.

4. Implement predator control programs in areas where introduced predators are a constraint to maintenance and restoration of native populations.

E. Take practical steps, such as watercraft speed reduction, noise and light reduction or shielding, pet control, avoidance of bird assemblages, and habitat disturbance.

1. Continue to enforce 5 mile-per-hour speed limits and encourage watercraft avoidance of bird assemblages, in cooperation with the USCG and SDUPD harbor police.

2. Investigate whether speed limit zone and buffers can be made more focused based on bird behavior.

   3. Identify areas of significant waterbird use that could be enhanced by rerouting boat traffic, in consultation with the USCG.
  - F. Establish a central repository database of existing and new information on bird populations and habitat use in the bay.
  - G. Coordinate with current local, regional, and national bird surveys and conservation initiatives to reduce duplication of effort and maximize local conservation of bay birds.

- III. Conduct research in support of the management objective.
  - A. Continue to develop and update cost-effective, standardized survey protocol across species groups and habitats.
  - B. Improve understanding of how each bay habitat functions to support avian species.
    1. Investigate shorebird partitioning in microhabitats of intertidal mudflats.
    2. Identify and monitor juvenile and larval fish populations and other prey bases within the bay.
    3. Identify primary roosting and foraging sites, taking into consideration that these will change to some degree.
  - C. Conduct focused studies in feeding ecology of sensitive species to improve understanding of habitat functions in the bay and in relation to coastal waters.
    1. Supplement feeding ecology studies with post-mortem analysis of stomach food content.
    2. Conduct post-mortem analyses (within 24 to 48 hours after death for usable results), including tissue analysis to discover if death was caused by such things as toxics in the food chain.
    3. Conduct direct observation studies of foraging.
    4. Study the habitat and feeding dependencies of sensitive species dependent on coastal waters.
  - D. Investigate the direct and indirect effects of shoreline stabilization structures on remaining priority bird habitats.
  - E. Investigate the technical feasibility and mechanics of restoring intertidal habitats.
  - F. Identify and monitor fish populations and other prey bases within the bay.
  - G. Continue monitoring boater disturbance of birds, including disturbance patterns before and after implementing new management to evaluate efficacy.
  - H. Consider the possible influences of El Niño, global warming, and other broader effects on local habitat availability and suitability, especially those located on habitat edges that are most likely to be affected (e.g. cordgrass at low edge of salt marsh, or upper intertidal, which may be invaded by native salt marsh).

- IV. Promote education and outreach.
  - A. Increase environmental education programs and availability of informational literature and signs to raise awareness of threats, concerns, and management needs.
    1. Identify birdwatching locations for potential ecotourism development and encourage use of public lands consistent with maintaining local resource values.
    2. Promote the Salt Works as a prime birding area and opportunity to relate the value of habitat to bay birds.
    3. Find means to designate areas for nondisruptive viewing opportunities for wildlife-oriented recreation.
    4. Develop appropriate access facilities, use schedules, regulations, and enforcement to support nondisruptive forms of active recreation.

B. Assemble an interagency team to develop strategies for implementing internal and external educational programs and identify possible funding mechanisms for bird conservation in the bay.

4.4.5 Marine Mammals

Specific Concerns

See also Section 2.6.6: Marine Mammals.

- Physical harassment from boats and other activities in the bay can disturb resting and feeding areas.
- Harbor seals and sea lions are particularly vulnerable to oil spills.
- As in other California bays, a potential exists for harbor seals and sea lions to become nuisances around piers, fishing boats, or other haul out sites in public places.
- Little is known about coastal bottlenose dolphin use of the bay or the bay's contribution to supporting this coastal stock's population of only 250 to 350 individuals.
- Bioaccumulation of environmental contaminants can affect the health of predator species, particularly bottlenose dolphins.

Current Management

Optimum sustainable population levels is the goal of the MMPA.

All marine mammals are listed and protected by the MMPA of 1972 (as amended), which serves as the principal statute for the nation's marine mammal programs (Weber 1985). The act requires that marine mammals be restored to their optimum sustainable population levels within the 200-mile (322-km) offshore federal fishery management zone. Its focus is the establishment of a moratorium on the taking of all marine mammals. "Taking" includes hunting, capturing, killing, or harassing. Allowable "takes" are for tagging, branding, surveying, and collection of scat.

As part of the Department of Commerce's NOAA, the NMFS is charged with administering the federal species acts for most marine mammals (with USFWS charged with otters, polar bears, and walrus). Overseeing the implementation of MMPA is the independent Marine Mammal Commission. It reviews permits for the taking of marine mammals and supports research and studies addressing problems related to the conservation and protection of marine mammals and their habitat.

Navy policy addresses marine mammal protections.

Navy policy reflects the MMPA: (a) no Navy vessel shall deliberately harass a marine mammal; and (b) the protection of marine mammals shall be taken into consideration during operations and planning (OPNAVINST 5090.1C 30 October 2007 Chapter 22 §12).

Title 10 of the MMPA authorizes the Navy to conduct a Marine Mammal Program for national defense purposes. The Navy is authorized to "take" not more than 25 marine mammals for the purposes of national defense, with the concurrence of the Secretary of Commerce. Locally, Navy dolphins, primarily bottlenose, are kept and trained at the Point Loma Naval Complex.

State management of marine mammals defers to federal authority for the most part.

At the state level, the MMPA preempted state management authority over marine mammals and state policy now only refers to the federal act (F&G Code §4500). In addition, the California Marine Resources Protection Act of 1990, which was adopted as an initiative constitutional amendment (Proposition 132), banned fishing after 1994 with gill nets and trammel nets within 3 nm offshore of southern California (F&G Code Chapter 3, Article 1.4). These nets were known to contribute to by-catch problems of certain marine mammals.

Oil spill prevention and cleanup are another management action potentially affecting marine mammals. CDFG's Office of Oil Spill Prevention and Response takes the lead for the state, while several agencies are involved at the federal level (i.e. USCG, NMFS, Navy). In addition, medical care of oiled wildlife is required under state (Lempert-Keene-Seastrand Oil Spill Act, SB 2040) and federal (OPA) laws.

Evaluation of Current Management

See Section 2.6.6: Marine Mammals, for status details.

Overall, the MMPA appears to be successful. Population trends of all marine mammal species in the SCB seem to be stable or increasing, except for the natural cyclical loss of pinnipeds during El Niño events and disease and outbreaks (such as the marine toxin, domoic acid, etc.). In particular, the population of sea lions may now be higher than their historic levels, with 160,000 to 200,000 sea lions in the Channel Islands area (M. Fluharty, *pers. comm.*). The population estimate of sea lions for the U.S. stock is 238,000 (Carretta *et al.* 2007). The dolphin populations were probably never common in the nearshore or bay environments around San Diego (J. Barlow, NMFS, *pers. comm.*). Gray whale populations are increasing about 2 to 3% each year over the past several decades (Allen & Angliss 2010). In 1994, the eastern north Pacific stock of gray whales was removed from the federal list of threatened and endangered species under the ESA.

The MMPA allows the tuna purse-seine fishing industry to minimize its incidental capture of porpoises using the best available technology, which appears to have reduced conflicts (Weber 1985). Recently, additional take was proposed by Congress, with critics asserting that this change will not be sufficiently protective. By banning coastal gill nets, California reduced one of the hazards to coastal marine mammals (Bonnell and Dailey 1993). However, they are still susceptible to: (a) entanglement or by-catch in drift or gill net fisheries greater than 3 nm off shore, (b) ship strikes by cargo ships and others, and (c) gunshot wounds from frustrated fishermen, as harbor seals and sea lions are viewed as competitors and nuisances of the fishery. NMFS recently funded a grant to develop and test a nonlethal device to deter sea lions near fishing boats.

In response to a Congressional request for an evaluation, the NMFS has reported that rapidly growing populations of California sea lions and Pacific harbor seals on the west coast are causing increasing incidents of sea lions that cannot be deterred from docks and marinas, and that sea lions and harbor seals may be a threat to public safety at such locations (NMFS 1999). NMFS's goal is to reduce human interactions with nonlethal techniques, but some situations may need "more effective tools" when a few animals are threatening people and property. Lethal removal has been granted in Washington state due to sea lions predating on ESA-listed salmon species. NMFS is also working on non-lethal removal techniques, and Finnernan et al. (2003) has details of the tests (See http://swr.nmfs.noaa.gov). To implement lethal removal elsewhere would require Congress to amend the MMPA. San Diego Bay, however, is not listed on NMFS map of seal and sea lion "trouble spots," although the Channel Islands are.

Harbor seals and sea lions tolerate human contact and can become a nuisance at public places.

Tolerance of a certain level of development appears to characterize the marine mammal species presently inhabiting or visiting the bay. Harbor seals and sea lions are often seen basking on large buoys and feeding near fishing boat docks, where they may partially benefit from the artificial environment and easy food source. Densities of seals and sea lions on docks and piers have not yet reached problem levels, unlike popular tourist piers in San Francisco Bay and Monterey, but they could become so in the future.

As top predators, pinnipeds and dolphins can concentrate high levels of contaminants from the environment.

The effects of high volume boat and ship traffic, oil spills, contaminated sediments, and other disturbances on the numbers and health of marine mammal populations in San Diego Bay have not been studied. Contamination of the food chain through exposure to toxicity and bioconcentration within tissues could lead to problems of bay resident species that are top predators in the food chain, such as the pinnipeds (Fairey *et al.* 1996). Within the Bight, the highest levels of DDT in any marine animal are found in bottlenose dolphins, with elevated PCB levels (O'Shea *et al.* 1980; Schafer *et al.* 1984). The comprehensive water quality management strategy by the Bay Panel is intended to reduce contaminant levels within the bay (San Diego Bay Interagency Water Quality Panel 1998). However, efforts to mitigate the environmental impacts of projects in the bay do not always address marine mammals, perhaps because they do not have the priority of listed species and their habitats are not classified as sensitive or critical (Navy 1995).

Research on certain marine mammal species is conducted locally at Carl Hubbs/Sea World, Inc. in Mission Bay and at SDSU. Dr. R.H. Defran's lab has long-term data (since 1981) on the population numbers, dynamics, and movements of the bottlenose dolphin for an extensive area of the coast (Defran *et al.* 1986; Hansen and Defran 1990; Hanson and Defran 1993, Dudzik 1999). However, the status of this species in San Diego Bay is not known despite the awareness that bottlenose dolphin schools are regularly encountered in the bay and only 250 to 350 individuals of the coastal stock are believed to exist between Ensenada, Mexico and Monterey Bay, California. More recently, two surveys were conducted in 1994 and 1999, covering virtually the entire U.S. range of this species, from the U.S./Mexican border to just south of San Francisco, California. Using the same methods and correction factors as in Carretta *et al.* (1998), the weighted average abundance estimate for these two surveys was 169 (CV=0.11) coastal bottlenose dolphins (NMFS and USFWS, unpublished data). A more recent estimates based on mark-recapture was 323 dolphins (CV= 0.13, 95%) (Dudzik et al. 2006). This does not reflect the 35% of dolphins with no distinguishing marks. So the population size is estimated to be 400-500 animals. This has likely been stable for the last 20 years (M. DeAngelis, *pers. comm.* 2008). However, this is only appropriate for U.S. management of bottlenose dolphin stock since there are unknowns in Mexican waters. The status of coastal bottlenose dolphins in California relative to OSP is not known, and there is no evidence of a trend in abundance. They are not listed as threatened or endangered under the ESA nor as depleted under the MMPA. Because no recent fishery takes have been documented, coastal bottlenose dolphins are not classified as a "strategic" stock under the MMPA, and the total fishery mortality and serious injury for this stock can be considered to be insignificant and approaching zero.

Management Strategy—Marine Mammals

Objective: Maintain a healthy balance of marine mammal species inhabiting or visiting San Diego Bay.

I. Support the collection and analysis of information needed to better manage marine mammals in the bay.
   A. Assess the population, distribution, and time of use over a four- to five-year period for bottlenose dolphins, gray whale, Pacific harbor seal, and California sea lion.
      1. Reevaluate their status in the bay every 3 to 5 years.
   B. Identify prey species and better understand their role in the community structure.
   C. Describe haul out sites, rest areas, feeding areas, and patterns of use for pinnipeds and feeding and rest area patterns for dolphins.
   D. Determine the contribution of the bay to the abundance of the coastal bottlenose dolphin stock.

II. Support effective management of marine mammal habitat.
   A. Protect feeding areas, resting areas, and any haul out sites within the bay as necessary.
      1. Address the potential effects of proposed projects on these identified marine mammal sites through NEPA and CEQA processes.
      2. Identify and implement effective avoidance and minimization best practices where needed.
   B. Support the prompt cleanup of toxic hot spots and oil spills in San Diego Bay in areas frequented by marine mammals and their prey.
   C. Evaluate the effects that high volume boat and ship traffic, noise levels, oil spills, contaminated sediments, and other disturbances have on the numbers and health of marine mammals inhabiting the bay.

See Section 5.4.2: Oil Spill or Hazardous Substance Prevention and Clean Up.

III. Maintain a balanced marine mammal population in the bay.
   A. Identify practices to safely discourage harbor seal and sea lion use of a public area, when densities approach the level of a nuisance.
      1. Discourage the public from feeding these wild animals.
      2. Employ nonlethal deterrent devices as the preferred method, where needed.
   B. Work with NMFS and CDFG to maintain a healthy balance of marine mammals in San Diego Bay.

4.4.6 Special-Status Species Protection

4.4.6.1 Green Sea Turtle

See also Section 2.7.1.1: Eastern Pacific Green Sea Turtle—Chelonia mydas

The green sea turtle is the only species of marine reptile to inhabit San Diego Bay. Under the ESA, this species is listed as threatened wherever found, except for breeding colony populations in Florida and on the Pacific coast of Mexico, which are listed as endangered. It has experienced a decline throughout its entire geographical range. The San Diego Bay population is predominantly a part of the Mexican breeding population, and as such, is endangered (P. Dutton, NMFS, *pers. comm.*). A federal recovery plan for the species lists the following threats pertinent to San Diego Bay that jeopardize the survival or impede population recovery (NMFS and USFWS 1998).

Specific Concerns

- Limited information about the turtle's home range and foraging patterns impedes the delineation and protection of its range of habitat.
- Persistent marine debris, such as plastic and other waste, remains a concern with respect to potential mortalities through entanglement or blockage of the turtle's digestive tract.
- The reduction or fragmentation of forage habitat caused by dredging or shoreline development.
- Disturbance and behavior modification from noise attributed to various activities, most notably dredging or construction involving pile driving. Little information is available on defined thresholds or potential population impacts.
- Mortalities from vessels transiting the bay.

Current Management

The breeding population continues to decline despite international cooperation.

NMFS and the USFWS have combined efforts to protect and build sea turtle populations in the United States Pacific ocean through their March 1998 Recovery Plan for the east Pacific green sea turtle. NMFS is the lead agency on sea turtle recovery for the San Diego Bay region because the ESA delegates authority to NMFS for green sea turtles in their marine environment and to the USFWS for green sea turtles on their nesting beaches. Under the federal ESA, projects and actions must avoid impacts to this species and the project proponent must seek a formal consultation with NMFS.

Current management focuses on monitoring the status and location of the turtle population within the bay.

Photo 4-5. Monitoring transmitter on a Pacific green sea turtle shell. Photo courtesy of Eileen Maher.

Local management efforts primarily focus on monitoring the population status and the location of the turtle within the bay. This effort is presently coordinated by a NMFS sea turtle scientist. Funding within NMFS is limited, and in the past funds came from a variety of sources: San Diego County Fish and Wildlife Advisory Commission, Hubbs-Sea World Research Institute (Hubbs-Sea World Research Institute), and USFWS (McDonald and Dutton 1993). More recently, the turtles' seasonal and migratory movements within and outside the bay are being studied by using transmitters that can track them to their source nesting beaches, as well as to their foraging and resting sites (Photo 4-5). Home ranges and movement patterns are being identified through DNA analysis and transmitter data, as well as the turtles' foraging and resting areas within the bay to aid in preventing potential impacts from recreational boating and dredging.

Current investigations, coordinated with NMFS/NOAA Southwest Fisheries Service Center, funded and performed by the U.S. Navy in conjunction with the Port, have placed additional devices (hydrophones) to track transmitter tagged green turtle movements with the bay. A multitude of hydrophones are currently installed at three separate locations (regions) of San Diego Bay, providing data on movement and potential foraging patterns.

The hydrophone arrays are placed in a tandem to evaluate the direction and time individual green turtles transit specific areas. Currently three arrays are in place at: 1) across the entrance to the south bay; 2) across the bay from Coronado Island near the Convention Center; and 3) across the main south bay channel (See Map 2-21). The original array near Homeport Island was installed in winter 2007-2008 and has recorded green turtle movements both diurnally and nocturnally at various frequencies. The hydrophone arrays that cross the bay were installed in September 2008 and have provided limited reportable data to date on turtle movements seaward of the Coronado Bridge.

Adults and juveniles migrate to feeding grounds in bays along the coast of Baja all the way up to San Diego Bay and occasionally Mission Bay, areas that are vital as forage and developmental habitats (Dutton *et al.* 1994; NMFS and USFWS 1998; NFMS 2008). These warm water turtles spend much of the cooler months in the heated effluent channel of the South Bay Power Plant, dispersing further into the bay during the warmer months (McDonald *et al.* 1994). An estimated 30 to 60 mature and immature turtles currently reside in San Diego Bay. With the enhanced environment from the power plant, the San Diego Bay turtles' growth rate is significantly higher than those not using the bay (McDonald *et al.* 1994).

The warm water environment of South Bay, enhanced by the power plant's heated discharge, has created year-round habitat that accelerates the turtle's growth rate.

Evaluation of Current Management

The continued acquisition of green sea turtle habitat use and movement data is imperative to identifying valuable habitat and sensitive areas within the bay. The Navy in conjunction with NMFS/NOAA are providing the funding and scientific expertise by working collaboratively to augment existing knowledge and data sets. The Port has funded complementary turtle projects as well as physical water quality studies, through the Environmental Fund program, that should contribute to expanding existing information. Radio tracking of the green sea turtle population in San Diego Bay is ongoing in a partnership effort among the Port, Navy, and NMFS/NOAA. The existing NMFS/NOAA Green sea turtle recovery plan has identified the primary threats to green sea turtles regionally but is in need of update and revision (NMFS and USFWS 1998). Although the NMFS' Southwest Fisheries Science Center (La Jolla lab) has a sea turtle scientist (J. Seminoff) who continues to study the bay's turtles, the agency has to rely heavily on the assistance of volunteers. The green sea turtle is a high priority for the Southwest Region of NMFS, but efforts to date have focused on the central Pacific population around Hawaii and not on the eastern Pacific population found in San Diego and Mexico.

Green sea turtles are not a high priority for NMFS at the moment, though a new regional position with responsibility for turtles was recently filled.

Additional studies and funding investigating potential impacts from motor vessels need to be addressed. Boat propellers and collisions have injured turtles in the bay, causing 80% of turtle deaths reported in San Diego Bay and Mission Bay (McDonald and Dutton 1992). A posted boat speed limit of 5 mph in the south bay by the San Diego Harbor Police (Port Code 4.04) primarily intended to protect birds from harassment may also benefit sea turtles. The animals are more vulnerable during the cooler months when they congregate near the power plant. To "minimize boat collision mortalities, particularly within San Diego County" is one of the major priority actions identified to achieve species recovery (NMFS and USFWS 1998).

Boat collisions and propellers continue to cause the greatest problem for turtles within the bay. Better enforcement of the 5 mph speed limit in south bay is suggested.

Entanglement in and ingestion of marine debris is also identified in the Recovery Plan as a major problem, noting that an adult turtle was recently found dead in the bay from monofilament netting tightly packed in the esophagus. Several programs are currently in place that address debris entering the bay that could potentially reduce impacts to turtles. The Port regulates rubbish and waste disposal within its jurisdiction (Port Code 8.60), while the Navy has similar controls over wastes from its operations in the bay. The USCG is authorized to enforce federal marine pollution laws. The waste management programs currently in place by Port, Navy, and USCG could be more efficiently aligned and enforced to minimize potential impacts to the resident turtle population, especially in the south bay.

Marine debris, such as monofilament netting, also causes mortality of turtles in the bay.

The debilitating and sometimes fatal fibropapilloma tumor disease, while widespread in the Hawaiian green sea turtle population, is not prevalent in the east Pacific population. Although apparent early stages of the disease were observed on some bay turtles in 1990, the disease does not seem to have spread to more individuals or become debilitating to the original animals (McDonald and Dutton 1990; P. Dutton, *pers. comm.*). Greenblatt *et al.* 2005 recently performed genetic work on variations of fibropapilloma, noting infectious outbreaks in a specific location while adjacent locations remained unaffected. Greenblatt *et al.* 2005 concluded that it seems likely that environmental factors, particularly water pollutants, play a role in fibropapilloma pathogenesis. However, a number of characteristics of the marine turtle host complicate the differentiation of virus genetic versus environmental factors in fibropapilloma.

The turtles are considered vulnerable to dredging in the bay.

Other threats are listed in the Recovery Plan that are a known problem with "extent unknown" (and no priority given). Environmental contaminants in San Diego Bay, in particular heavy metals and PCBs, are suggested as the cause of small lesions in some turtles. Seagrass degradation and natural disasters are also mentioned. In addition, threats that are listed as "not a current problem" include marina/dock development, dredging, and power plant entrapment. However, the bay's turtles are described in the plan as being vulnerable to dredging (and noise) since juvenile and adult turtles are thought to spend most of their time motionless on the floor of dredge channels (Stinson 1984; McDonald and Dutton 1992). New findings on turtle movement suggest that resident San Diego Bay turtles may transit throughout the bay to a much greater extent than previously thought.

Management Strategy—Green Sea Turtle

The Recovery Plan lists the following relevant criteria that must be met in order to consider delisting of this species:

- All regional stocks that use U.S. waters have been identified to source beaches based on reasonable geographic parameters.
- Existing foraging areas are maintained as healthy environments.
- Foraging populations are exhibiting statistically significant increases at several key foraging grounds within each stock region.
- All priority #1 tasks have been implemented (see #1 below).

Major actions that are needed to achieve recovery were also identified. Those actions pertinent to the bay are (1) minimize boat collision mortalities, particularly within San Diego County, California; (2) determine population size and status in U.S. waters through regular surveys; (3) identify stock home range(s) using DNA analysis; and (4) identify and protect primary foraging areas in U.S. jurisdiction.

Objective: Contribute to the recovery of the listed green sea turtle population consistent with the USFWS Recovery Plan through conservation measures in San Diego Bay.

I. Maintain foraging and resting areas in the bay as a healthy and safe environment for the turtle in order to increase the local foraging population (#1).
    A. Minimize boat collision mortalities (#1).
        1. Ensure San Diego Harbor Police are aware of the need to avoid disturbing green sea turtles and the need to provide enforcement in the south bay, including the winter months when turtles congregate and are especially vulnerable.
        2. Educate the boating and water-skiing community about avoiding effects on the turtle population.
    B. Minimize persistent marine debris within San Diego Bay, that could harm the turtle through entanglement or ingestion.
        1. Educate the fishing, boating, and tourist communities about the impacts of plastics, monofilament line, and other nondegradable debris on turtles.
        2. Support regular voluntary cleanup campaigns of in-water and on-shore debris several times per year.
        3. Effectively enforce regulations prohibiting rubbish and waste disposal in the bay, and encourage all regulatory entities to provide effective enforcement.

C. Address and resolve potential impacts on turtles through the project review process.

1. Provide effective mitigation for any impacts to eelgrass beds, and discuss project implications to turtle foraging habitat, in any environmental analysis.

2. Include the potential effects of dredging projects on resting and foraging green sea turtles in environmental impact assessment documents, and propose effective practices to offset any effects.

3. Evaluate noise impacts from pile driving and dredging and implement practices to minimize potential effects.

4. Ensure thorough analysis to offset the impacts of the proposed closure of the SDG&E power plant on the turtle's status and condition within the bay.

II. Contribute to the understanding of the green sea turtle's life history needs.

A. Help determine population status in the bay through regular surveys (#1).

1. Contribute to annual population estimates of the bay's resident turtles and to the estimation of their annual growth rates.

2. Evaluate the contribution of the bay's population to the species status and recovery.

3. Determine the status of tumor disease in the resident turtle population.

B. Continue to identify the turtles' seasonal and migratory movements within and outside the bay (see Current Management).

C. Continue the cleanup of existing contaminants within the bay and the prevention of additional contamination to the bay (see Section 5.4.1: Remediation of Contaminated Sediments).

See also Section 5.4.1: Remediation of Contaminated Sediments

D. Support adequate funding within NMFS to carry out their implementation actions needed to delist this species.

III. Promote better awareness of the green sea turtle's endangered status and the identified solutions to its recovery.

A. Continue to educate users of the bay.

1. The Port should continue consulting sea turtle education through WildCoast.

2. Inform commercial and recreational fisheries operating out of the bay about the need to protect turtles from incidental mortality and harassment (#1).

B. Encourage sustained and effective international cooperative efforts to recover the green sea turtle (#1).

4.4.6.2 California Least Tern

Specific Concerns

- The USFWS recognized in its Five-Year Review that the management goals and recovery criteria identified in the 1985 Revised Recovery Plan needed to be updated (USFWS 2006). The Recovery Plan (USFWS Revised 27 September 1985) states that for delisting, the terns must have an annual breeding population of at least 1,200 pairs. The plan also sets a number of secure nesting sites (at least 20 statewide). The breeding population goal originally set in the Recovery Plan has been far surpassed; breeding pairs throughout the range are currently estimated at over 7,350 (Marschalek 2010). There are currently pairs producing fledglings at 51 documented locations.
- There is a demonstrably strong relationship between least tern success and predator management. The California least tern nests on the ground in small colonies in what is now an urbanized setting, with no protective buffer between the colony and surrounding areas, leaving it vulnerable to intense predation at unnatural levels. A single feral cat or skunk can wipe out a colony in a night,

forcing abandonment of that colony. Natural predator avoidance tactics used by the terns are no longer successful in smaller colonies. The species' inherent strategy for predator avoidance is based on their habit of nesting in large, conspicuous colonies, grouped closely together. They occasionally rise into the air as a clamorous unit, to frighten and mob would-be predators.

- There have been documented impacts to terns due to fish declines (inappropriate fish size available as forage for nesting terns during El Nino events) on a regional scale independent of management efforts. This is based on both local and regional data (Caffrey 1993; Allen 1999; Akcakaya *et al.* 2003; USFWS 1985 as cited in Appendix to USFWS 2005 Biological Opinion 3452.3 and based on intensive data sets from Venice Beach and Santa Margarita).
- Structures such as docks and piers may have a positive and negative influence on terns by acting as a fish aggregate or decreasing water surface area available for foraging.
- Streamlined regulatory processes for addressing impacts to least terns benefit all stakeholders, and details of such processes can be worked through in INRMPs such as this one.
- The abundance and availability of prey for least terns (primarily small anchovies, topsmelt, and gobies) within San Diego Bay may be limiting the productivity of least terns that nest on adjacent properties.

Background

Upon its designation as endangered, California statewide efforts to protect least tern nesting and foraging areas contributed to a breeding population increase from 623 pairs in 1969 to one that appears to be stabilizing around 7000 breeding pairs based on counts of 2005-2009 (Marschalek 2010). Generally, growth has been positive except for 2002 with a one-year loss of over 1,100 breeding pairs, and 2004, with a one-year loss of over 500 pairs (USFWS 2006c). The statewide population size has grown substantially since 1973. Fledgling production has fluctuated more widely with unknown consequences for overall population numbers. In 2009, the following were statewide statistics: fledges 1,734-2,132; fledge/pair 0.24-0.30; and 8,037-8,045 nests; at 51 documented locations (Marschalek 2010). Approximately 27% of the statewide population breeds in and around San Diego Bay, an increase from 16-17% of the population in 2000 (Marschalek 2010). These population sizes are estimates based on number of nests, and post-nesting failure can cause the numbers to be overestimates (S. Vissman, pers. comm.).

The Recovery Plan for the California least tern (USFWS 1985) identified the population size, distribution, secure nesting site numbers, and reproductive rates necessary for recovery of the species. The Plan states that for delisting, the terns must have an annual breeding population of at least 1,200 pairs. This goal has been far surpassed. The USFWS recognizes that the management goals and recovery criteria identified in the 1985 Recovery Plan are outdated and that the plan needs to be revised (USFWS 2006). Accordingly, USFWS now expects greater numbers of breeding pairs and different management measures (USFWS 2006). California least tern populations are not self-sustaining without intensive management, and probably never will be (USFWS 2006).

Efforts to model least tern population viability have been frustrated by incomplete information about the species' demography, effects from environmental stochastically, and wintering habitat location. Age at first breeding is estimated to be approximately three years (Akçakaya *et al.* 2003), with a breeding life span previously estimated at approximately 10 years (Massey *et al.* 1992). However, more recent records of a California least tern 15 years old are available (Kennard 1975), and a 20-year-old tern was trapped in 2008 (at NAB on the ocean side, originally banded at Camp Pendleton in 1988) (T. Shepherd *pers. comm.* 2008). Other least tern subspecies have been documented to survive to 24 years (Klimkiewicz and Futcher 1989).

Concurrent with fluctuations in the overall numbers of breeding pairs in San Diego Bay are fluctuations in the number of occupied sites and the number of pairs using each site. Declines at one nesting site sometimes are balanced by increases at another nearby site and are most likely a result of inter-colony movement. These shifts appear to be related to heavy predation or human disturbance event(s) which can result in poor reproductive success. The number of sites available is important to the tern population in allowing inter-colony movement in response to failure at a particular site. Of concern is the apparent trend towards fewer, larger colonies that concentrate the species into fewer areas, which may facilitate vulnerability to predation. Management actions that provide for a greater number of dispersed colonies could be beneficial to the long-term recovery of the species (USFWS 1985).

In addition to nesting areas, secure roosting areas are essential to the recovery of the species. Two kinds of roosting areas exist: pre-season nocturnal roosts and post-season dispersal sites where adults and fledglings congregate. The best documented night roost is in Long Beach, California; however, no recent surveys have been conducted to verify its continued use (Atwood 1986). In a San Diego Bay foraging study (Baird 1997), mooring areas were found to be very important as a place to rest for terns during the breeding season.

Least terns that nest at Lindbergh Field appear to have habituated to the particular noise levels and traffic patterns associated with aircraft travel to and from the runway. No explicit studies on how the noise and vibration associated with the aircraft use of the runway has been conducted, and the effect of noise may differ between sites, particularly if birds have not become habituated to noise or other potentially disturbing activities.

Current Management

The project siting approval process triggers the NEPA process for assessment of effects, CEQA, and USFWS consultation under the ESA for federally threatened and endangered species such as the California least tern. Several other laws may come into play for in-water projects that may affect terns. Both the Port and the Navy avoid, minimize, and mitigate for impacts to waters under federal jurisdiction or to Special Aquatic Sites (i.e. eelgrass) and EFH (MSA) including habitat of fish for which least terns forage. Section 401 of the CWA addresses water quality. The CZMA requires consistency with federally approved coastal zone management plans. Regulatory matters for the bay in general are described in Chapter 3. Current management of turbidity and noise that may affect the least tern and occur during in-water construction is addressed in Section Section 5.2.3: In-Water Construction. Habitat values of in-water structures as they may affect the least tern is covered in Section Section 4.3.7: Artificial Structures.

All managers of the bay's nesting sites prepare and manage the sites in preparation for the tern's arrival in spring by grading, vegetation removal, fencing, setting up a tile grid, and signing. All managers ensure predator control programs are in place, the nests are monitored, and reports on nest numbers and success are completed. Certain areas are identified as seasonal or permanent set-aside areas for tern nesting, either as a result of past consultations, or due to real estate agreements which protect these areas for natural resources in general, such as the NWR, the CVWR, and the Navy's leases to State or County park and recreation departments.

California Least Tern Management Through INRMPs

The Navy also manages impacts to least terns through its INRMPS (this one and those INRMPs for NBC, NBSD, and NBPL). All INRMPs must incorporate an ecosystem-wide approach to protect the properties and functions of natural ecosystems as a whole (OPNAVINST 5090.1C 2007 and DoDI 4715.3, the Navy's Environmental and Natural Resources Program Manual). Navy guidelines require that ecosystem-based management shall include: a shift from single species to multiple species conservation; best available science; partnerships for ecosystems that cross boundaries; and adaptive management. To this end, most of the Navy's management of listed species has been built within the framework of a larger program which is habitat- rather than species-based. However, in San Diego Bay's intense urban, industrial, and military training context, extraordinary measures have been undertaken to protect least terns, with extraordinary success to show for the effort. Some highlights of what has been undertaken by both the Navy and Port are described below.

In addition to framing and providing a mechanism to fund least tern management projects, INRMPs are a means for the USFWS and Navy to come to agreement on conservation measures for all federally listed species. The ESA was revised via the National Defense Authorization Act of 2004, PL 108-136 to recognize INRMP conservation measures and species benefit that could serve in lieu of critical habitat designation on Navy lands. Section 4(a)(3)(B) of the re-vised ESA states that: “The Secretary [of the Interior] shall not designate as critical habitat any lands or other geo-graphical areas owned or controlled by the DoD, or designated for its use, that are subject to an integrated natural resources management plan prepared under §101 of the Sikes Act (16 USC 670a) if the Secretary determines in writing that such plan provides a benefit to the species for which critical habitat is proposed for designation.”

All Navy installations with federally listed threatened or endangered species, proposed federally listed threatened or endangered species, candidate species, or unoccupied habitat for a listed species where critical habitat may be designated should structure the INRMP to serve in lieu of critical habitat designation, under the ESA 4(a)(3)(B) exemption to critical habitat designation. The INRMP may obviate the need for critical habitat if it specifically addresses both the benefit provided to the listed species and the provisions made for the long-term conservation of the species. The species benefit must be clearly identifiable in the document and should be referenced as a specific topic in the INRMP table of contents. The USFWS uses a three-point criteria test to determine if an INRMP provides a benefit to the species. An installation is strongly encouraged to use these USFWS criteria, listed below, when structuring its INRMP to avoid the need for critical habitat designation.

- The plan provides a conservation benefit to the species.
- The plan provides certainty that the management plan will be implemented.
- The plan provides certainty that the conservation effort will be effective.

California Least Tern Management Through In-water Construction MOU

Navy in-water construction that generates noise or turbidity is managed under an MOU between the USFWS and U.S. Navy concerning conservation of the endangered California least tern in San Diego Bay, California. This programmatic agreement establishes standards and conditions for in-water construction activities in San Diego Bay to prevent adverse effects to the least tern. Originally a five-year MOU, it was most recently renewed for two years in 2004, and a letter from USFWS allows for recognition of that MOU until a new one is signed (Letter from Therese O'Rourke to Capt. Anthony T. Gaiani FWS-SDG-08B0211-08I0203 December 18, 2007). The 2004 MOU provided for an additional 10 acres of tern nesting area at South Delta Beach, as well as an additional three to five acres of California least tern foraging habitat, the removal of overhead power lines at Delta Beach, predator control efforts for tern colonies, studies to determine effects of various in-water construction activities, end-of-year reports on tern population monitoring, and a list of proposed U.S. Navy projects to be conducted in San Diego Bay. In exchange, ongoing maintenance and new construction activities could be conducted by the U.S. Navy in San Diego Bay without the need for formal consultation with USFWS on each action as long as California least tern foraging areas were not affected. This MOU has provided funding consistency up front, rather than depending on project-by-project negotiations, and thus has provided a streamlined regulatory process. It also has provided personnel consistency by supporting a full-time Navy natural resource position since 1988 to manage the tern conservation program and coordinate with USFWS on U.S. Navy projects that may affect the tern.

California Least Tern Management Through ESA Project Consultation

Ongoing development and maintenance projects around the bay, as well as military training, have established a history of recurring consultation between the USFWS and project sponsors since the federal and state listings of the least tern.

Establishment of Delta Beach as Set-aside Nesting Area

The Navy's tern management program originated with the construction of a helicopter MAT facility, including a Light Airborne Multipurpose System MK III, that resulted in the loss of a nesting area and displacement of what was 13 tern nests in 1977, the year terns were first documented as nesting there. By 1979, according to the BO that was signed in 1980 (USFWS BO 1-1-80-F-18 5 March 1980), about 68 nests were located at the facility. A total of 63.45 acres were affected by the project, including 36 acres to resurface the asphalt.

In order to establish a defined site where the nests could be protected, a 21.55-acre area of the existing nesting area called the MAT site was preserved, indefinitely, for nesting terns at NASNI. An additional 29.2 acres were prepared on an annual basis as alternate nest sites, including predator and vegetation control, in the event the MAT site was not successful.

In addition to the sites at NASNI, the Navy agreed in a 1983 BO (USFWS BO 1-1-82-F-123 2 March 1983) to “exclude 75 acres of land at Delta Beach from public access by fencing for least terns under the terms of a Memorandum of Understanding between the USFWS and NAB Coronado…” The BO required that the area be “fenced and officially established as a nesting site.” The designation of the Delta beaches as a “least tern preserve” was formalized in a 1984 MOU between the U.S. Navy and USFWS (Navy and USFWS 1984) that was drawn up to provide long-term management of the 75 acres identified for least tern nesting at the Delta beaches in the 1983 BO 1-F-82-F-123. The MOU did not intend to inhibit the use of Delta beaches for military maneuvers, but it attempted to restrict these maneuvers to the north and east perimeters during the nesting season. Up until the time of this BO and MOU, Delta Beach North had been used both for Navy training and as a public boat launching facility. Installing fencing around the area eliminated the site for use as a public boat launch facility. The Navy was required to address the loss of public recreational access to the site, and under a CCC Consistency Determination (CD-4-84 22 February 1984), was required to lease 40 acres of land (Alpha Beach) to the State of California to develop for park and recreation purposes. The Navy also graded a road to Alpha Beach to facilitate public access there. In addition, a lease from the Navy to the state of California of 40 acres of NAB Coronado was promulgated to develop for park and recreation purposes.

The Navy implemented a number of measures to promote nesting at the Delta site. The Navy began controlling vegetation at the site to enhance suitability for terns which do not prefer highly vegetated areas for nesting habitat. The Navy also added sand to the site to enhancing the substrate for nesting. The Navy employed decoys at the beginning of the nesting season to attract nesting terns to the protected site. The Navy also began a program for controlling predators and a program for monitoring the site for nesting success.

Consultation on Military Training

In 1994, California least terns began nesting on oceanside beaches of the SSTC where military training takes place. Measures had to be established to protect the terns, and this began the development and evolution of a series of adaptive set of intensive impact avoidance and minimization activities, with each year bringing ever-increasing tern numbers and a new set of circumstances. As nesting on oceanside training beaches continued to increase, the Navy adapted and improved their approach as a result of information gained from monitoring and experimentation. Formal consultation between the Navy and USFWS addressing least terns on the Silver Strand was completed in 2010 with regard to all military activities on both the ocean and San Diego Bay sides of the SSTC. This consultation occurred under the umbrella of an EIS on these activities under development by the Commader, U.S. Pacific Fleet and NBC.

Based on the experience gained by the Navy and its agency partners over the years, the following measures are undertaken for both the least tern and snowy plover on training beaches.

- Beach Lane Seasonal Conservation Areas and Marking/Avoidance Measures. Certain training “lanes” are restricted through scheduling and marking on the ground from military foot and vehicle traffic during the breeding seasons of western snowy plover and California least tern. No military training is permitted within the protected areas except for designated beach crossing lanes. Since plovers nest individually or in loose groups rather than in dense colonies like the terns do, plover nest scrapes are marked with approximately 30-meter buffers for avoidance beginning approximately March 1.
- Depending on site-specific circumstances, some plover nests are covered with a mini-enclosures to protect from mammalian and avian predators.
- Due to the high predation rate from gull-billed terns, “wickets” or domes are used to offset predation by this species.
- Nests may be moved small distances, as necessary and appropriate, to reduce conflicts with training, although such moving is infrequent. The Navy reports to the USFWS any circumstance that necessitates movement of any tern or plover nest. If relocation is necessary, nests are moved the shortest distance possible into suitable habitat to increase the chance for nest success.
- Predator control of mammalian and avian predators of the least tern and snowy plover is conducted at all nesting sites. Isolated attempts by USDA Wildlife Services to discourage gull-billed terns from entering least tern nesting colonies were considered ineffective. The Navy has been using pole traps on and off since the inception of the program dependent on discussions with the USDA and the USFWS. These pole traps are designed to catch avian predators of least tern and plover chicks, such as the American kestrel.
- Predator control to manage southern fire ants, field ants, Argentine ants, and pyramid ants found on North and South Delta Beaches and NASNI is conducted prior to and during the snowy plover and least tern nesting season.
- The Navy, USFWS, and CDFG work cooperatively each season regarding the relocation of American peregrine falcons if they are determined to be impacting the least tern or snowy plover.
- Cameras are used to monitor least tern colonies on Navy property for predators. Cameras are also used as a tool for monitoring, specifically collecting status information. Cameras allow documentation of what species is predating least tern chicks.
- Sand hummocks or other substrate modification to deter nesting may occur in the certain training lanes prior to the breeding season.
- Continued Site Preparation for Maintaining Nest Site Suitability. Site preparation, in accordance with the USFWS's biological opinions is performed on North and South Delta Beach and NASNI. Site preparation includes grading or mowing to remove annual plant growth, inspection, replacement or reinstallation of the site grid poles and of chick barriers around the site perimeter, use of tern decoys, and placement of chick shelters throughout the nesting colony.
- Sand enhancement of nesting sites occurs as feasible.
- In order to provide nesting cover for chicks, minimize invasive weeds, and protect rare plants, the locations of coastal woolly-heads *(Nemacaulis denudata),* and Nuttall's lotus *(Lotus nuttallianus),* are marked for avoidance prior to grading or herbicide use. Coast woolly-heads and Nuttall's lotus are indicators of a healthy, natural habitat that is conducive to nesting by providing a mosaic of vegetation for chick shelter and escape cover.
- No kelp or other natural marine vegetation that collects on beach tidal areas is removed from the oceanside beaches. Kelp is managed at YMCA Camp Surf by relocating it to areas where it does not provide an unsafe environment for children. Marine vegetation at YMCA Camp Surf is not buried, but left on the surface for use as forage material by plovers.

- Mowing is practiced at NASNI airfield to maintain a habitat condition that is not preferred by nesting birds, in order to deter bird-related airstrikes. Areas within and adjacent to the airfield are mowed when 25 percent of the vegetation reaches eight inches or higher as measured from the soil. The mowing schedule is coordinated with the NBC Botanist and Wildlife Biologist.
- Regular beach cleanup in targeted areas continues.
- In order to provide suitable nesting substrate that does not foster weed invasion that may harm nesting or fledging success, the Navy treats invasive exotic plants.
- Signage and Education through interpretive material is used to inform the public of the need to avoid certain areas during nesting season.
- The Navy works to eliminate recreational or casual use of the beaches by military personnel and their dependents who live in the Naval housing. An annual letter is sent out to educate military housing residents about recreational use restrictions. In addition, the Navy works to eliminate nonmilitary civilian use of nesting beaches through security patrols and guards. Signage, fencing, public awareness campaigns, and/or enforcement are all necessary and implemented to achieve successful control.
- If needed, least tern eggs that have been collected are provided to Project Wildlife or Sea World, as appropriate, for hatching and rearing.
- Biological monitoring of the least tern and the snowy plover during the breeding season is performed by qualified and USFWS-permitted experts at all nesting sites.
- Banding of least tern and snowy plover adults and chicks is done in conjunction with monitoring of nests at NASNI, SSTC-N and SSTC-S.

Recently, the Navy completed consultation under the ESA on military operations along its beaches on the Silver Strand (USFWS BO FWS-SDG-08B0503-09F0517 7 July 2010).

Consultation on Airport and Naval Training Center Nesting Site Relocation

In 1993, the NTC, located adjacent to the San Diego International Airport, was identified for closure during the Base Closure and Realignment Commission process of 1993, in accordance with the Base Closure and Realignment Act of 1990. During the base closure discussion, a 25-acre site on NTC was identified for protection as a California least tern nesting site. This resulted in the need to either protect the site in place or find an acceptable replacement site that would support least tern nesting. Following extensive negotiations, an agreement was reached among the Navy, the USFWS, and the Port that would provide alternative nesting habitat. The terms and conditions of this agreement, which are described in the BO prepared by the Service on October 13, 1998, include: the NTC least tern nesting site or a replacement nesting site must be placed under federal protection in the National Wildlife Refuge System; annual least tern and snowy plover monitoring and predator management shall be provided at the salt works in perpetuity; least tern habitat enhancement measures, including expansion of tern foraging habitat and enhancement of nesting substrate within the salt works shall be implemented; overall restoration plans for the salt works shall include new least tern nesting area; public access and human disturbance shall be controlled at the salt works during the nesting season; future restoration of the salt ponds shall avoid and minimize adverse effects to least terns and snowy plovers; and habitat and management needs for least terns and snowy plovers shall be addressed in the CCP prepared for the South San Diego Bay Unit. On October 16, 1998, the USFWS and the Port (which then oversaw operations at Lindbergh Field) signed a Cooperative Agreement to protect and enhance nesting and foraging habitats for the endangered California least tern at the salt works in South San Diego Bay in accordance with the terms and conditions outlined in the Biological Opinion. This agreement, which was amended in March 1999 to clarify the terms and obligations, required that the Airport would: 1) acquire fee title most of the salt ponds owned by the Western Salt Company and then transfer the ownership of approximately 720 acres to the California SLC; 2) acquire leasehold interest from Western Salt on an additional 612 acres and transfer that interest to the SLC; 3) work with the SLC to effect transfer of those portions of the acquired property and leasehold interest to the USFWS that are within the acquisition boundary of the proposed South San Diego Bay Unit; and 4) commit $900,000 in mitigation and in-kind services for restoration and management within the acquired lands. It was through the execution of this Cooperative Agreement that a large portion of South San Diego Bay was ultimately incorporated into the South San Diego Bay Unit.

Predator Control

San Diego Bay has experienced shifts of terns among local colonies due to predation and human disturbance, which can result in reduced reproductive success. Off-road vehicle harassment at the Sweetwater site led to abandonment of that site in 1980, at which time terns began opportunistically using the newly created CVWR. Predation pressures at Chula Vista are believed to be the cause of abandonment of that site in 1985. At this point, Sweetwater experienced a return population, only to later be abandoned due to heavy predation by peregrine falcons and northern harriers (USFWS 1995). These sites have now recovered; Sweetwater and CVWR each had 132 and 48 nests, respectively, during the 2009 nesting season (Marschalek 2010).

Under specifications of the MOU designating the Delta Beach North Least Tern Preserve, the Navy intensified management of tern colonies at NASNI, NTC, and NAB by predator management and extensive biological monitoring. In an attempt to alleviate or at least minimize predator- and human-related problems, the preserve was fenced. A permanent position was funded for predator management through USDA Animal and Plant Health Inspection Service/Wildlife Services. The predator control program is required to identify mammalian and avian predators and develop methods to trap, eliminate, or relocate predators. The Navy also deploys chick shelters for least tern chicks to help protect them from predation.

There are many predators of least tern adults, young, or eggs. Examples include but are not limited to: rats *(Rattus* spp.*)*, domestic cats *(Felis cattus)*, domestic dogs *(Canis familiaris);* red-tailed hawk *(Buteo jamaicensis);* northern harrier *(Circus cyaneus)*, great blue heron *(Ardea herodias);* peregrine falcon *(Falco peregrinus);* gopher snakes *(Pituophis melanoleucus);* black-crowned night heron *(Nycticorax nycticorax);* American kestrel *(Falco sparverius);* American crow *(Corvus brachyrhynchos);* burrowing owl *(Athene cunicularia);* loggerhead shrike *(Lanius ludovicianus);* common raven *(Corvus corax);* coyote *(Canis latrans);* skunk *(Mephitis mephitis);* opossum *(Didelphis virginiana);* and gull-billed terns (USFWS 1990). The sensitive status of some predatory species requires special consideration and may reduce the predator management options available. For example the gull-billed tern, an extremely rare tern species, has recently posed a localized problem for least terns nesting on beaches around San Diego Bay. The USFWS, Migratory Bird Office has not issued depredation permits for the removal of gull-billed terns or gull-billed tern eggs due to the sensitive status of this species. However, a recent meeting was held with stakeholders (February 5, 2009), which resulted in a plan to manage gull-billed terns in 2009 by addling a percentage of gull-billed tern nests to determine whether a decreased number of viable nests will reduce predation pressure on the California least tern colonies. In 2009, NBC had 1463 breeding pairs, 1741 nests, and 42 fledglings, with most of the production at the NAB oceanside beach. This site had the most nests of any site in California in 2009; however, gull-billed tern predation resulted in the documented loss of 501 least tern eggs and 285-287 chicks (Marschalek 2010).

Up through the 2003 breeding season, predator management was conducted in all Navy nesting areas; however, an effort to deter terns from nesting on the beach entailed discontinuance of these activities on the NAB beaches in 2004. The effort was undertaken as an experiment, to see if discontinuance of predator control would deter terns and change nesting patterns, as previous deterrent efforts were costly and had been unsuccessful (Martin Kenney, *pers. comm.* 2004). The experiment was discontinued after a single year.

Foraging Terns and Structures Over Water

California least terns forage in nearshore ocean waters and in shallow estuaries or lagoons in areas with water less than 60 feet deep (Atwood 1986; Massey 1987). A study at Huntington Beach revealed that adults also forage close to shore in ocean waters, mostly within 3.2 km of the breeding area (Collins *et al.* 1979; USFWS 2006c). A recent Navy-funded study showed that bay terns forage offshore up to several miles (Baird, *in press*). Long-term data indicate that forage species for the tern occur broadly within the San Diego Bay (Allen 1999) and that the birds feed opportunistically. Terns are known to capture more than 50 species of fish and feed exclusively on small fish that frequent shallow, nearshore waters (Atwood and Kelly 1984; Atwood and Minsky 1983; Bailey 1984; Collins *et al.* 1979; Massey 1974; Minsky 1984; Thelander 1994). Prey include such schooling fish as northern anchovy, topsmelt, killifish, mosquitofish (*Gambusia affinis),* and shiner surfperch (USFWS 2006b). After their eggs hatch, breeding adults catch and deliver small fish to the flightless young. Reproductive success is, therefore, closely related to the availability of undisturbed nest sites and nearby waters with adequate supplies of appropriately sized fish.

The effect of over-water structures on least tern foraging success has been a topic of discussion for over ten years, and was memorialized in the Navy-USFWS consultation regarding development plans at the Navy Fiddler's Cove marina (USFWS 2007). The broader ecological effects of shoreline structures with respect to shading photosynthesizing organisms, altering plant or animal assemblages, and other possible impacts, is discussed comprehensively in Sections Section 4.3.7: Artificial Structures and Section 5.2.3: In-Water Construction.

Evaluation of Current Management

The number of California least tern pairs supported by San Diego Bay has increased dramatically since the late 1970s due to very significant investment and intense management by the Navy and the Port. In addition, the relative importance of San Diego Bay to least tern recovery has increased. The Navy has an annual investment and management program costing about $500,000 per year. The Port has supported tern recovery through establishment of the NWR, CVWR, and implementing conditions on the NTC site relocation.

Despite the dramatic increase in tern numbers, reproductive success in the San Diego Bay area has been extremely low since 1999. On the Silver Strand beaches, this appears to be due, in part, to increasing predation intensity by gull-bill terns during the hatching phase of reproduction. The difficulty in resolving this issue between two rare species may affect the long-term potential for least tern colonies in San Diego Bay. Of particular concern are terns nesting on Navy installations adjacent to the bay, because reproductive success has declined significantly in recent years, and is in part attributable to gull-billed tern predation. During 2009 the number of fledglings per pair produced at NBC beaches was 0.02-0.05, compared to a statewide average of 0.243. At the NASNI MAT site, the number of fledglings per pair produced was 0.21 (Marschalek 2007). Low fledge rates in recent years on NBC beaches, especially those outside of NASNI, are also due in large part to the presence of gull-billed terns (Copper 2007). While NASNI is in the same geographic area as the NBC beaches, it has not been subjected to observed depredation by foraging gull-billed terns. Gull-billed terns continue to forage and roost on nesting sites during the breeding season, and predation is worsening statewide each year (Marschalek 2010). Meanwhile, the USFWS will not allow lethal removal of gull-billed terns. The current short-term plan is to addle a percentage of gull-billed tern eggs starting in 2009; a long-term strategy is still under consideration.

Another element affecting reproductive success has been ENSO events that affect the availability of forage fish for terns to feed their young (Caffrey 1993; Allen 1999; Akcakaya *et al.* 2003; USFWS 1985 as cited in Appendix to USFWS 2005 BO3452.3 and based on intensive data sets from Venice Beach and Santa Margarita). The survival rate from hatchling to fledgling based on Venice Beach data from1981 to 1984 (Massey *et al.* 1992) and an interior site (Smith and Renken 1993) was evaluated, and the resulting productivity was 0.6237 for normal years and 0.27 for ENSO years.

The difficulty in tern productivity during ENSO years is tied to forage fish. In work conducted in San Diego Bay funded by jointly by the Port and Navy, Allen (1999) defined forage fish as those which are accessible to diving avian predators, particularly terns. Forage species are typically silvery-sided, schooling fishes which spend much of their time near the surface of the water over all depth strata. Of all the species captured during his five-year study, eleven qualified as significant forage. These species were northern anchovy, topsmelt, slough anchovy, jack smelt, Pacific sardine, shiner surfperch, Pacific mackerel, California grunion, deepbody anchovy, California halfbeaks, and striped mullet (juveniles). He found the greatest, detectable impact of the 1997-98 El Nino event on the fish assemblages of San Diego Bay to be the generally low abundance of schooling, planktivorous species, including northern anchovy, topsmelt, slough anchovy, sardine, and shiner surfperch (the five most abundant species).

In fact, the northern anchovy was virtually absent during 1997. Of the most abundant schooling fishes, topsmelt and slough anchovy seemed to be least affected by the El Nino event. Overall, the abundance of these planktivorous species was significantly and negatively correlated with summer-fall (July-October) surface water temperature over the entire 1994-1999 sampling period.

The Navy initiated a least tern foraging study to examine any effects of artificial structures, completed in 2010. This study builds on past and ongoing work conducted jointly by the Navy and Port, including regular fish, eelgrass, bathymetric, and avian surveys. One purpose of this INRMP is to streamline regulatory processes. Considering this, the proposed management strategies emphasize coming to agreement on appropriate measures that are cost-effective and support the best effort towards least tern recovery and delisting under the ESA.

Management Strategy

See Section 4.3.7. Artificial Structures for objectives regarding improving the habitat and ecological functions provided through the design of shoreline structures to benefit native species of fishes, birds, and invertebrates.

Management Strategy—California Least Tern

Objective: Contribute to the recovery of least tern numbers based on population size, distribution, and secure nesting site numbers by providing clear benefit to the species in a cost-effective manner.

Objective: Manage predators of the California least tern to maximize colony success as measured by fledgling productivity and pair numbers.

I. Continue baywide management of the California least tern to contribute to its recovery under the ESA.
    A. Continue the least tern foraging study started by the Navy in 2009. Continue evaluating management priorities based on results of this foraging study.
    B. Continue to resolve the most cost-effective and beneficial approaches to contributing to least tern recovery under conservation agreements and packages of offsetting measures agreed upon between the USFWS and resource managers, based on demonstrated success in San Diego Bay.
        1. Update the Navy-USFWS MOU on in-water construction to include broader topics of predator control.
        2. Consider USFWS Conservation Recommendations on surface coverage in concert with other measures such as predator management. They are:
            a. Conduct a foraging study (see *IA*, above) to a) determine whether primary foraging areas exist in San Diego Bay and offshore or whether the entire bay and offshore provides equal opportunity based on the behavior of foraging fishes, and b) quantify the relationship between prey availability in primary foraging areas and the reproductive success of the associated least tern colony (i.e. production of fledglings). The study should evaluate the relative usage of foraging habitat during the different stages of the breeding season, different years, and at different proximity to least tern colonies.).
            b. Fish sampling should be standardized within the expected primary foraging areas and include measures of fish density, species, and size.

c. Implement a recreational user education and enforcement program for the Navy recreational marina area, that explains seasonally restricted access to shore areas related to tern management.

C. Expand the topics covered under least tern MOUs as a mechanism to reach consensus and streamline this regulatory process. Establish a timeline for re-addressing matters covered in least tern MOUs as a result of new studies, management experience, and status of the tern.

II. Improve effectiveness and consistency in predator management by implementing a more comprehensive, baywide approach.

A. Continue proper NEPA documentation on predator management for least tern colonies by the responsible agencies.

B. Develop a set of recommended guidelines for an acceptable level of predator management effort for all colonies on the bay.

C. Develop protocols for the most common species, the ones for which a tern or plover loss is unacceptable under any circumstance.

III. Conduct monitoring and research in support of the management objective.

A. Support the development of appropriate least tern recovery criteria through population viability assessment modeling by the USFWS.

B. Develop an understanding between the fluctuation in population numbers or breeding success and prey fish and related habitat.

C. Establish a baywide, consistent approach to monitoring nesting attempts and hatching success to determine the success of predator management activities.

4.4.6.3 Light-footed Clapper Rail

Specific Concerns

- Severe depletion and fragmentation of salt marsh habitat, especially cordgrass as nesting habitat, has affected the light-footed clapper rail's ability to survive.
- The lack of high tide refugia in the high marsh or uplands may limit the rail's use of some areas.
- The successful clapper rail propagation program has abated some of the losses from predation, which is especially a problem in areas with urban borders.
- Cordgrass may be decimated by major floods and El Niño sea storms. Therefore, the clapper rail is vulnerable to El Niño and other storms that can cause it to die off.
- Constructed marshes have had difficulty growing cordgrass to sufficient height in a timely manner so it is suitable for the rail's use. Nitrogen deficiency has been problematic.

Current Management

The light-footed clapper rail is a federal and state endangered species that is a permanent resident of the salt marsh. At constructed marshes at the SWNWR, cordgrass planting was targeted towards support of the clapper rail, but nitrogen deficiency apparently stunted its growth and it took many years to meet mitigation criteria.

The Chula Vista Nature Center, in partnership with the Zoological Society of San Diego Wild Animal Park and Sea World, is managing a propagation program for the light-footed clapper rail. The first pair of clapper rails was brought into captivity in 1998 and the first chicks hatched into captivity were produced in 2001. Between 2001 and 2006, 146 rails have been released in several marshes along the southern California coast. To date (April 2008) 170 have been released.

Evaluation of Current Management

Salt marsh habitat with potential to grow cordgrass is limited and fragmented in the bay. The Port's cordgrass and annual pickleweed mitigation project has successfully grown cordgrass to three feet tall in a short amount of time. This experience needs to be built upon.

Management Strategy—Light-footed Clapper Rail

Objective: Protect the listed light-footed clapper rail population inhabiting San Diego Bay and seek to contribute to its recovery.

I. Protect nesting, foraging, and high-tide refuge areas.

  A. Protect cordgrass sites likely to be affected by erosion.

II. Continue to enhance areas with potential for growing cordgrass by building on the Port's success at the wharf extension mitigation site.

III. Conduct research and monitoring in support of the management objective.

  A. Investigate means to improve cordgrass restoration techniques.

4.4.6.4 Western Snowy Plover

Specific Concerns

- Since 1998 there has been an increase in plover nesting statewide, but with a regional decline, possibly due to an outbreak of avian botulism (USFWS 2007).
- The western snowy plover's preference for nesting on sandy beaches has led to its decline as a nesting bird along the coast.
- Foraging areas have been restricted by development, but also by the presence of human recreational activities in foraging areas.
- Increases in salt marsh vegetation may make areas less attractive for plovers because it could act as a barrier preventing chicks from foraging successfully and escaping incoming tides.
- Predation of plover young by birds and mammals is the primary cause of reproductive failure.
- Nests and chicks are hard to detect and can be damaged.
- Nonnative iceplant does not support plover nesting and may out-compete preferred plants of adjacent dunes such as *Camissonia* sp.
- Plovers can be impacted negatively by sympatric and colonial nesting colonies of the least tern (e.g. ocean beaches of NAB, Coronado).

Current Management

Western snowy plovers were added to the Navy's take permits in 1999. Silver Strand ocean-side beaches off of NRRF were added to the permit in 2003 due to plover nests detected on the beach there. Critical habitat for the western snowy plover had been designated on NBC ocean beaches in 2000; however, this designation was vacated in 2003. A new proposal for snowy plover critical habitat was published in 2004, (69 FR 75608) and included the Silver Strand beaches. However, the Navy's management, as documented in the NBC INRMP, resulted in the exclusion of designated critical habitat for the western snowy plover by the USFWS on September 29, 2005 (70 FR 56970). The final rule did include habitat D Street Fill in its critical habitat determination.

One of the historic problems at NASNI has been plover nesting on the airfield runway to the north, which may be due to inadequate availability of alternative areas for the plovers closer to the shoreline. Also, in some years the southern beaches have narrowed and have been temporarily unsuitable for nesting. NASNI operations include 112,570 annual airfield operations (based on take-offs and landings in 2004), and training and recreational activities on the beach. They include a Bird/Animal Aircraft Strike Hazard program that harasses avian species including snowy plovers to keep them off the runway where they are a danger to aircraft and pilots as well as plovers;

plover eggs are also removed from the airfield for captive rearing. Consultation between the Navy and USFWS on NASNI ongoing operations (airfield and recreational as well as military training use of the beaches) is addressed in a Biological Opinion (FWS-SDG-3908.3 2005).

The Recovery Plan criteria set a target of 95 breeding adults for Silver Strand sites (NASNI, and the Navy Silver Strand beaches) plus Silver Strand State Beach and portions of Coronado. The current method preferred by the Navy for determining breeding pairs is maximum nests at one time. If one assumes that 95 breeding adults correlates to roughly 48 pairs necessary for the Silver Strand beaches, this implies a maximum active nest at one time to be at least 48 nests across all the Silver Strand to meet recovery goals. This goal has not been met based on Navy site reports. It is unknown whether other parcels contribute sufficiently to achieving the target because the number of breeding adults is not counted elsewhere. However, 52 western snowy plovers were recorded on Silver Strand State Beach in January of 2007 during the rangewide window surveys.

Evaluation of Current Management

Because western snowy plover nesting nearly completely overlaps that of the California least tern, it has benefited by default from intensive management in these locations. For example, the western snowy plover derives coincident benefit from the protection measures afforded through the Navy-USFWS MOU on in-water construction activities that may affect the least tern, as well as other measures that enhance nesting success in the same locations where the plovers nest.

Issues of predator management for the western snowy plover (Photo 4-6) overlap those of the California least tern. Control of the common raven is an example of the results of an inconsistent predator management approach to the plover. Ravens have adapted well to human development and occur in disproportionately large numbers on tern/plover sites. There are few if any sites that support tern or plover nesting without some form of predator management. In 1998, at NAB, there was an effort to prevent plover nest loss through aggressive control of ravens, and as a consequence there were no plover nests lost to ravens either at NAB or at adjacent Silver Strand State Beach. NAB supported 34 plover nests in 1998. D Street, on the other hand, which had supported up to ten plover nests in past years had only two nests in 1998, one of which was depredated by ravens. Predator management at that site was delayed until April, while plovers typically begin nesting in late March. At Tijuana there were approximately twelve nests and some were lost to ravens until control was initiated. Past efforts to use aversive techniques failed at NAB and may have enhanced raven predation on plover nests. Aggressive management of ravens at all plover sites should increase success rates and nest numbers comparable to those at NAB (E. Copper, *pers. comm.*).

Photo 4-6. Western snowy plover. Photo courtesy of Matt Sadowski.

Since 1998 there has been an increase in plover nesting statewide, with a smaller regional decline, possibly due to an outbreak of avian botulism (USFWS 2007). NAB experienced an increase in nesting plovers to a high in 2004 of 79 nests, concurrent with the statewide high of 1,904 adults counted during the breeding season window survey. Numbers have since decreased to 32 nesting plovers on NAB in 2007.

The preference by western snowy plover for the high intertidal mudflat is not understood, so may not necessarily be protected with respect to project impacts. The same is true for its use of adjacent uplands for nesting, such as remnant dunes containing *Camissonia* sp.

Management Strategy—Western Snowy Plover

Objective: Due to a local decline in western snowy plovers, identify and correct the problem related to water quality, invertebrates, and sick or dying snowy plovers.

Objective: Protect the listed western snowy plover population inhabiting San Diego Bay and seek to contribute to its recovery.

I. Conduct a study to identify and correct the local problem related to water quality, invertebrates, and sick or dying snowy plovers.

II. Protect nesting and foraging areas.

- *A.* Support consistent and effective predator management at nest sites (see also Section Section 4.4.6.2: California Least Tern").
- *B.* Protect unvegetated areas or remnant dune sites above the high tide line which are potential nesting sites.
- *C.* Human use should be reduced during nesting season, particularly in the upper dunes, dog leashing enforced, and signs posted.
- *D.* Prohibit beach raking which can affect invertebrate populations upon which the plover depends.
- *E.* Clean up trash which attracts predators.

III. Enhance remnant dune areas as potential nest sites in areas that can be protected from human disturbance and predators during nesting season.

- *A.* Remove invasive iceplant and other nonnatives from remnant dunes.
- *B.* Support broader beaches with gentler slopes to support plover nesting.

IV. Conduct research and monitoring in support of the management objective.

- *A.* Study the plover's preference for higher mudflat, so that function may be protected or enhanced.

4.4.6.5 Salt Marsh Bird's Beak

See also Section 2.7.1.5: Salt marsh bird's beak—Cordylanthus maritimus maritimus.

Specific Concerns

- There is a severe loss of salt marsh habitat in San Diego Bay, and little means to get it back that are not excessively expensive.
- Remaining populations are isolated and subject to sudden decline due to drought.
- There is a lack of linkage between the salt marsh and upland habitat for pollinators.
- There is uncertain long-term persistence of salt marsh bird's beak populations that have been planted for mitigation projects (Zedler 1996c).

Current Management

Salt marsh bird's beak is a federal and state endangered species (Photo 4-7). It also is listed as category 1B by the CNPS, which makes it mandatory for full consideration in environmental documents related to CEQA. Salt marsh bird's beak occurs within the salt marsh and is also regulated by legislation applying to wetlands (see Section 4.2.1: Protected Sites). The USFWS adopted a recovery plan for salt marsh bird's beak in 1984, calling for the establishment and persistence of 12 populations prior to downlisting the species to a threatened status (USFWS 1984).

Photo 4-7. Salt marsh bird's beak. Photo courtesy of Eileen Maher.

In San Diego County, only the NRRF and Tijuana Estuary support a natural population of salt marsh bird's beak. Management of this plant has involved vegetation monitoring since 1979. Salt marsh bird's beak had not been observed at Sweetwater Marsh since 1987 and was reestablished there in 1990 to fulfill a Caltrans mitigation requirement. Monitoring of these plants has indicated that although seed set was almost as high as the natural population for some colonies, for others it was very poor. Concern over the ability of the Sweetwater Marsh population to become self-sustaining encouraged Caltrans to fund a study on factors affecting reproductive potential of salt marsh bird's beak. The reestablishment of salt marsh bird's beak at Sweetwater Marsh has been successful according to the mitigation criteria, with an estimated 14,000 plants in 1994. Mitigation requirements were for a three-year period with at least 100 plants (Zedler 1996c). The success of the population in terms of long-term stability are still not certain. There seems to be much variation in population size from year to year and on longer time scales, due to factors such as extreme events and the need for fresh water to germinate. The Port has also planted salt marsh bird's beak at the CVWR and D Street Fill.

Evaluation of Current Management

See Section 4.2: Mitigation and Enhancement and Section 4.3.6: Salt Marsh for more detailed discussion of this species in the context of habitat management. Mitigation requirements for salt marsh bird's beak usually require its presence for approximately three years. Although attainment of this criteria may indicate a healthy, self-sustaining population, we cannot be sure, due to the lack of data, what population size is needed for long-term persistence (Zedler 1996c).

See Section 4.2: Mitigation and Enhancement and Section 4.3.6: Salt Marsh for more detailed discussion of this species in context of habitat management.

The reestablishment of salt marsh bird's beak has occurred mostly on high marsh remnants (Zedler 1996c). The success of reestablishment on dredge material is uncertain, but will likely not be as successful (Zedler 1996c).

Management Strategy—Salt Marsh Bird's Beak

Objective: Seek the recovery of the salt marsh bird's beak population through habitat protection and enhancement.

I. Improve knowledge of the species requirements.

- *A.* Determine the population size needed for long-term persistence of salt marsh bird's beak (Zedler 1996c).

II. Promote adaptive practices to attain success in restoring population.

A. Employ techniques to establish a self-sustaining, functional population.
   1. Due to its narrow regeneration niche, very specific habitat requirements for salt marsh bird's beak must be used for successful establishment (Zedler 1993).
   2. Ensure pollination by providing adjacent uplands that include alternate hosts for salt marsh bird's beak's bee pollinator (Zedler 1993).
   3. If necessary, restore natural processes that supply nutrients to the high marsh (Zedler 1996c).
   4. Sustain the natural salinity regime (Zedler 1996c).
   5. Allow natural disturbances that create small-scale open patches in the high salt marsh canopy (Zedler 1996c).
   6. Have well separated sites available for growing salt marsh bird's beak so disturbances that might wipe out one colony would not occur throughout the transplanting location (Zedler 1996c).
   7. Mitigation performance standards should not only be based on the size of each colony, but should also include an estimate of seed production (Zedler 1996c).
   8. Colonies at the Tijuana Estuary should be used as a reference to determine if success is attained. (e.g. success = when the numbers of plants produced are at least 90% of the mean colony size at Tijuana Estuary and the numbers of seed capsules produced are statistically indistinguishable from those at Tijuana Estuary) (Zedler 1996c).
B. Implement a regional restoration plan for the species (see Section 4.2: Mitigation and Enhancement and Section 4.3.6: Salt Marsh).
C. Monitor the quality and quantity of plant sites and reevaluate practices as needed.

5.0 Sustainability and Compatible Use

This chapter summarizes natural resources management strategies from the point of view of the sustained use of those resources. It builds on the activity descriptions and regulatory framework described in Chapter 3. Landscape-level views of compatibility and sustainability are also covered in this chapter, such as processes tied to watersheds, and cumulative effects.

5.1 Toward a Sustainable Ecosystem in San Diego Bay

5.1.1 Climate Change

The San Diego region's particular and unique vulnerability to climate change has been documented in a report prepared by 40 experts for the San Diego Foundation's Regional Focus 2050 Study (San Diego Foundation 2008). In this study, the particular strategic importance of the Navy and Port's mission in San Diego Bay is identified as vulnerability of the bay to climate change.

Climate change is treated in this INRMP both as a topic in itself with its own objective and strategy and as a driving force that permeates other INRMP objectives.

Specific Concerns

- Scientific research indicates that global warming will have long-term, irreversible, adverse consequences on coastal resources, including habitat, marine life and public access, as well as impacts on all development along the coast (CCC statement).
- Climate change is now a principal driver of change along the San Diego coast line (San Diego Foundation 2008).
- San Diego Bay's low-lying shorelines and infrastructure are expected to experience inundation due to sea level rise. The strategic and economic importance of the NASNI, San Diego International Airport, and the Port are at risk from degradation by sea level rise (San Diego Foundation 2008).
- The degradation of habitats and biodiversity in San Diego Bay over the next 50 years from climate change and invasion by non-native species may overtake the Navy and Port's achievements in habitat and species protection, mitigation, and restoration. Effects of sea level rise mainly apply to intertidal habitats (Harley *et al.* 2006). Intertidal habitats provide a climate change buffering functions (Mil-

lennium Ecosystem Assessment 2005). Biodiversity is threatened in intertidal mudflats, salt marsh, sandy beaches, and rocky shores. Shorebirds and shorebird forage are particularly vulnerable (Galbraith *et al*. 2005). Rocky intertidal biodiversity is at risk even where it is currently protected at Cabrillo National Monument due to steep cliffs that prevent the landward migration of the habitat (San Diego Foundation 2008).

- Migrations of fish and avian species are expected to be altered in response to higher temperatures and increasingly fragmented natural habitat. Changes in average ocean temperatures can affect factors such as metabolism, reproduction, and predator-prey interactions, which in turn can alter species ranges and population abundances (Roessig *et al*. 2004). Warmer ocean temperatures are also expected to extend "disease seasons." Warm-water species are replacing cold water species throughout reefs in the SCB due to a climate shift (Holbrook *et al*. 1997).
- There is concern that warmer waters will facilitate the expansion of many opportunistic non-native plant and animal species whose current ranges are limited primarily by temperature.
- The dynamic and uncertain nature of information about global climate change can be overwhelming to bay managers and policy makers. The slow and deliberative process in which public agencies work can also be a barrier to swift implementation of strategic policies, especially when multiple jurisdictions are involved.
- Key questions for NEPA and CEQA analysis include whether a proposed action is expected to cause climate change effects, whether the proposed action combined with other past, present and reasonably foreseeable actions would cause such effects, and whether sufficient information is available to describe the nature and extent of the proposed action's effect. Developing mitigation for climate change is an emerging issue for project NEPA/CEQA analysis.
- Doing nothing will result in a decline to natural resources and increasing threat to infrastructure due to flooding and other impacts, and a rising cost of addressing the problem.

Current Management

Federal

The federal program has emphasized voluntary reductions in greenhouse gas emissions. Four cabinet agencies (Energy, Environmental Protection, Transportation, and Agriculture) work with 12 industrial sectors to reduce their greenhouse gas emissions. Across the federal government, partnerships and programs promote voluntary conservation of fossil fuels, improvement in energy efficiency, methane recovery, and carbon sequestration.

On 05 October 2009, an EO "Federal Leadership in Environmental, Energy, and Economic Performance" was passed. It requires each federal agency to set a 2020 greenhouse gas emissions reduction target; increase energy efficiency; reduce fleet petroleum consumption; conserve water; reduce waste; support sustainable communities; and leverage federal purchasing power to promote environmentally-responsible products and technologies.

Assessing the impacts of climate change is best approached by identifying an environmental baseline for the future that considers the differences in landscape form and function caused by climate change and other stressors on the landscape. Conducting a climate change vulnerability assessment may guide essential monitoring requirements, as well as develop appropriate adaptive management strategies. However, the abundance and distribution of species and habitats on Navy properties may be too small in scale to address comprehensive climate change vulnerabilities. Therefore, regional partnerships may be the most appropriate means to conduct such assessments and in developing and implementing adaptation strategies. In general, natural resources managers should identify natural resources management strategies that provide conservation benefits to the ecosystem, regardless of whether climate changes occur.

U.S. Navy

The recently updated guidance for Navy INRMPs (5090.1C 30 October 2007) has a new section on climate change and the need to address it in INRMPs. It states that "the evidence for climate change is extensive and has generated consensus in the scientific community. Addressing climate change poses a new challenge for natural resource managers who will need to understand changes in ecosystem structure and function anticipated from climate change, in addition to understanding ecosystems as they function now and as they have in the past." The guidance continues with a framework for addressing climate change issues, and this is incorporated in the strategy outline below.

State of California

Many actions have been undertaken by California agencies as climate change is an emerging priority of the governor and in the Legislature. Some examples include:

- Governor Schwarzenegger issued an EO S-13-08 directing state agencies to plan for sea level rise and climate impacts such as increased temperatures, shifting precipitation and extreme weather events (November 14, 2008).
- With the passage and implementation of the Global Warming Solutions Act (AB 32), California is planning to mitigate climate change through reductions in greenhouse gas emissions.
- The California Climate Change Portal contains information on the impacts of climate change on California and the state's policies relating to global warming. It is also the home of the California Climate Change Center, a "virtual" research and information website operated by the California Energy Commission. Information on the portal is coordinated by the California EPA and the Climate Action Team. California is developing a Climate Adaptation Strategy in concert with efforts targeting greenhouse gas mitigation policies. The Climate Adaptation Strategy has six different Climate Adaptation Working Groups that identify and prioritize climate adaptation strategies on a per-sector basis, including: Biodiversity and Habitat, Infrastructure (roads, levees, buildings, etc.), Oceans and Coastal Resources, Public Health, Water, and Working Landscapes (forestry and agriculture).
- CEQA guidelines now include greenhouse gas mitigation and adaptation.
- The CCC is developing a planning manual for how stakeholders should address climate change within the CCA. The Commission receives Climate Change Task Force (staff) advice on climate change adaptation; green building; local governments and local coastal programs; smart growth; public education and information; interagency coordination; carbon footprint scoring systems; carbon offsets/cap and trade/sequestration, and tools under the Coastal Act that might be employed to address climate change. These include requiring applicants to consider a range of potential future changes in water level and high tides.
- The California Coastal Conservancy is developing Climate Change Grant Assessment Criteria for project design for wetland restoration or public access. The Conservancy's 2007 Strategic Plan states the climate change "will affect many Conservancy projects, such as the design elevation for restored wetlands and the location and materials for public accessways near the ocean or waterways." The Strategic Plan stated that "Climate change will have dramatic physical, ecological, economic, and social impacts on coastal, marine, and inland resources. As a result...expenditures for infrastructure and projects need to include projected climate changes in project designs and siting, and need to incorporate appropriate mitigation measures."
- CDFG's WAP identifies climate change as one of four primary stressors affecting wildlife, along with growth and development, water management conflicts, and invasive species, and makes recommendations to include climate change science in restoration work.

Port of San Diego

The Port's Green Port Program contributes to mitigating the effects of climate change with annual goals for reducing greenhouse gas contributions and other air emissions from Port operations. The Port's Environmental Fund has funded a high percentage of projects that reduce the carbon footprint of its activities. In progress or in the planning stages are: incorporating energy efficiency technology within a development at Broadway Pier; conducting energy audits of Port buildings through a SDG&E partnership; identifying energy efficiency retrofit opportunities for Port buildings; conducting an energy efficiency demonstration project; developing a voluntary incentive truck program with mandatory tracking and compliance elements; evaluating options for a vessel speed reduction program; pursuing grant funding for cold ironing at the Cruise Ship Terminal and Tenth Avenue Marine Terminal; conducting feasibility studies for cold ironing at National City Marine Terminal; retrofitting and replacing cargo handling equipment at Port maritime facilities; and defining the carbon footprint of Port operations.

Evaluation of Current Management

Impacts on San Diego Bay's resources are positioned to lead those of other bays on the west coast; therefore statewide and national leadership in mitigating and adapting to sea level rise can occur locally. Generally, management of climate change is in very early stages locally.

Objective for Climate Change

Objective: Offset the adverse impacts of climate change through annual goal setting based on science-based scenarios, targets, collaborative planning, adaptive management, and joint pilot projects.

I. Improve the depiction of the potential impacts of sea level rise scenarios for San Diego Bay based on science-based models and the best data sets (IPCC 2007; Delta Vision Blue Ribbon Task Force 2008).

- *A.* Estimate the cost of doing nothing, by combining infrastructure, social costs, and habitat/species loss potential.
- *B.* Use NOAA 2002 coastal lidar data to improve mapping of adjacent uplands to 2-meter resolution, or a better data set as available.
- *C.* Since the most damage potential from flooding comes from the coincidence of sea level rise with waves from storm surge, ensure depictions include wave modeling as shown in the San Diego Foundation's Focus 2050 Study (2008).
- *D.* Incorporate sea level rise and habitat/species loss into Navy encroachment planning.

II. Adapt to and offset stresses on shoreline infrastructure, flooding, beach erosion, and loss of intertidal habitats.

- *A.* Ensure that species/community conservation priorities and investments are adjusted for climate change vulnerabilities.
- *B.* Identify restoration projects to provide habitat elements for specific species which may be most vulnerable to climate change.
- *C.* Include BMPs related to climate change (see also Section 5.1.2: Sustainable Resource Use and Development).
- *D.* Provide for the management of threatened and endangered species such that changes in distribution and abundance may be understood in the context of climate change versus effects from other sources.
- *E.* Identify intertidal habitat subsets and species that are most vulnerable to the sea level rise or changes in water temperature or chemistry, so that they may be targeted for restoration and adaptive planning.
  - *1.* Characterize the most vulnerable intertidal communities and location in the bay.
  - *2.* Characterize the invertebrates and physical substrates that are least and most at risk.

F. Make San Diego an innovation leader for shoreline structures adapted and planned to accommodate sea level rise while providing habitat value.

1. Institute pilot and demonstration projects and showcase their results.

2. Disseminate information and showcase examples of habitat enhancing marine structures.

3. Identify habitat and species objectives for structures (Dyson 2010).

G. Plan for shoreline stabilization using biotechnical or hybrid approaches to erosion control, where possible. See, for example:

http://plant-materials.nrcs.usda.gov/technical/coastal.html

http://www.habitat.noaa.gov/restoration/techniques/lsimplementation.html

http://www.greenshores.ca/sites/greenshores/documents/media/108.pdf

III. Address the anticipated increase in extreme events by emphasizing preventative technologies.

A. Improve stormwater management through LID technologies.

B. Provide a rapid response to invasive species threats and disease outbreaks triggered through close monitoring of, for example, water temperature.

IV. Address higher ocean temperatures and anticipated shifts in species ranges and population abundances.

A. Witness these changes through monitoring.

B. Lessen the impacts of higher ocean temperatures by increasing the overall resiliency of the bay ecosystem to resist or recover from disturbance such as invasions (Grimsditch and Salm 2005).

V. Address the expected increase in ocean acidification.

A. Continue the progress in controlling greenhouse gas emissions, the pollution that causes global warming, through baywide, interagency annual targets.

B. Support water resources planning.

VI. Improve coordination and collaboration that responds to the consequences and costs of climate change.

A. Identify and implement regional conservation designs that provide stepping stones for species to move (use existing programs such as borderlands and potentially new ones) to sites with suitable climates.

B. Incorporate climate change in Navy Encroachment Action Plan, especially for San Diego Bay.

C. Develop science-based agency coordination to protect, maintain, and restore at-risk bay habitats.

D. Disseminate contributions regarding climate change in a baywide symposium.

VII. Identify data and research needs for ensuring an effective response to the consequences of climate change.

A. Develop electronic databases of demographic information from Navy and Port studies in order to provide witness to the local consequences of climate change.

B. Improve the application of models through data collection and validation (as feasible and needed) in environmental and natural resources planning.

C. Fund a website and other dissemination tools for info on best practices for reducing greenhouse gases, construction materials, design templates for use by landscape architects, landscape contractors, coastal engineers, and private organizations such as homeowner groups or garden clubs.

VIII. Improve and strengthen investment in adapting to sea level rise.

A. Establish partnerships for collaboratively addressing the expected impacts of climate change on infrastructure, habitats, and species.

B. Analyze project impacts and cumulative effects through CEQA/NEPA in a consistent way.

IX. Ensure public education and outreach to help minimize the most dire forecasts for global warming through modification of behavior and lifestyle patterns that contribute to a changing climate.

A. Form a San Diego Bay climate change interagency forum.

B. Partner with the San Diego Foundation Climate Change Initiative (http://www.sdfoundation.org/communityimpact/environment/Initiative-ClimateChange.html).

5.1.2 Sustainable Resource Use and Development

Background

Broadly speaking, sustainability planning takes a long-term view of natural resources stewardship, Navy/Port mission accomplishment, social responsibility, and economic prosperity into the future. The conventional application of the term sustainability focuses on energy efficiency and how pollution and wastes are prevented and processed in the built environment. For this INRMP, sustainability is defined to include the Port's and the Navy's strategic economic and national security missions and sustainability of the natural habitats and communities of the bay.

For this INRMP, the topic of sustainability encompasses:

- Sustainability of the institutional missions of the Navy and the Port (also discussed in Chapters 1 and 7).
- Best practices for the use of renewable and non-renewable resources and how pollution and wastes are prevented and processed (see "The Daly Rules for Sustainability" [Womersley 2002]). The practices may address energy, water, water and sediment quality, air quality, greenhouse gas management, reducing threats to shorelines both natural and developed, securing habitat for special status and indicator species into the future, and preparing for sea level rise and global warming. This topic is also integrated into other INRMP sections including: Water Quality, Storm Water Management, Artificial Shoreline Structures, Cumulative Effects, Monitoring and Research, Climate Change, and INRMP Annual Review and Metrics.
- Indicators that help monitor progress toward sustainability objectives (covered in more detail in Chapter 6).

Specific Concerns

- Local metrics for sustaining the institutional missions of the Navy and Port should include global warming as a primary driver of change. Each agency requires access to its land and waters. The concept of sustainability in the military and under the Sikes Act (under which this INRMP is a mandate) requires this INRMP to document "no net loss" to the military mission to comply with the Sikes Act.
- To date, sustainability has been applied in San Diego Bay somewhat narrowly to the built environment and focused mostly on energy and recycling. It is beginning to be applied to stormwater management such as with LID approaches, and to ecological sustainability of habitats, species, and functions for San Diego Bay. Sustainability in siting and resource use is only beginning to be considered a metric of successful project design.
- The work of professional societies from various disciplines (such as wildlife, water, soils, energy, coastal ecology, restoration ecology, economics, development, or business) has insufficiently incorporated into management.

- The true long-term cost of choices, trade-offs, and synergies are not as visible to leadership as they should be (Millennium Ecosystem Assessment 2005) because natural resources assets are not assigned a value, and thresholds or tipping-points of change in their value are not known.
- Many of those involved in executing sustainable development projects are not sufficiently educated about costs and technologies to understand the difference in approach and choices. This uncertainty hampers the adoption of more projects that meet sustainability criteria.

Current Management

Agency Missions

The Sikes Act and DoD guidance require that INRMPs ensure no net loss of available land and operational carrying capacity for military support occurs while pursuing environmental protection needs (DOD 4715.DD-R 1996). This “no net loss” policy is broadly accomplished by:

- Balancing short-term projects with long-term goals for maintaining a healthy bay using principles of ecosystem management and sustainability.
- Ensuring access to the bay’s natural values for infrastructure and uses that sustain the strategic missions of the Port and Navy, and working with neighbors and partner agencies to plan for encroachment.
- Integrating infrastructure with the environment with proper siting and sustainability practices.
- Continuing to use NEPA documentation, including cumulative effects and climate change analyses, to guide specific projects and document choices.

The Commander of each installation must report annually on metrics regarding the relationship between the military mission and natural resources. The military mission of the Navy in San Diego Bay is as follows:

It is the mission of the U.S. Navy in San Diego Bay and its environs to equip, maintain, train and support Naval surface and aviation units of the Pacific Fleet in order to conduct military operations in support of the Fleet’s operational commanders. Additionally, the U.S. Navy in San Diego Bay will conduct Naval operations in the eastern and northern Pacific Ocean, protecting the western sea approaches to the United States.

Each year the Commanding Officer must answer as part of the INRMP metrics review the following questions:

- Does the natural resources team consult with operators when making changes to the INRMP in order to keep it current? Coordination examples include: maps, signage, pamphlets, other communications, orientations, meetings, training, etc.
- To what level do natural resources compliance requirements support the installation’s ability to sustain the operational mission?
- Has there been a net loss of training lands?
- Does the INRMP process effectively consider current mission requirements?

The Port’s mission integrates development and natural resources stewardship responsibilities. Through the Port policy on Sustainability and the Green Port program, the Port gives “equal weight to environmental, economic and social concerns in the decision-making process.”

Sustainability Through Stormwater Management and Landscaping Standards

LID practices offer an additional benefit in that they can be integrated into the infrastructure and are more cost effective and aesthetically pleasing than traditional, structural stormwater conveyance systems.

Opportunities for enhancing buffer areas for habitat value have only begun to take shape along bay margins that are integrated with the management of water resources including stormwater. For example, throughout the Chesapeake Bay, water quality- and wildlife-friendly landscaping designs called "Living Shorelines" have been adopted to reduce chemical runoff, conserve water, and enhance the wildlife value of properties adjacent to that bay (http://www.cbf.org/Page.aspx?pid=923). The designs minimize the use of pesticides and fertilizers that may run off into adjacent waters. Such an approach could also help prevent invasive introductions. Locally, water providers and managers are gradually placing an emphasis on native plants and xeriscaping as a way to manage water use and quality in communities and by individual property owners. For example, native plant demonstration gardens may be viewed at Chula Vista Nature Interpretive Center, the Tijuana Estuary, and Cuyumaca College. The San Diego County Water Authority offers a downloadable water-smart landscaping "How-To" guide. The Port provides "Healthy Garden Healthy Home" brochure downloads off its website, as well as stormwater and integrated pest management guides. The Navy (the NRSW Botanist and NAVFAC Southwest Landscape Architect) has developed a preferred plant list as well as a "Do Not Plant" list for horticultural plants that are invasive in the wildland environment.

Sustainability in the Built Environment

Topics related to built interiors are not addressed in this INRMP, such as: building systems, energy efficiency, building materials, waste and services, transportation, and use of historic properties. Air quality is treated briefly and only as a sub-theme under this topic of sustainability for this INRMP.

Sustainable development is intended to foster high performing buildings in terms of energy efficiency and that reduce the use of natural resources, decrease pollution, and provide a healthier indoor environment. Such development takes into account the full life cycle cost of a project, including broader concerns such as its effect on the environment and the community, not just the financial cost.

A federal task force agreed to the following set of federally accepted principles for sustainability in the built environment (adapted from the Whole Building Design Guide, National Institute of Building Sciences http://www.wbdg.org):

1. Optimize siting potential. Avoid using undeveloped land, open space, water and soil conservation areas, existing natural ecosystems, endangered species habitats, and floodplains.
2. Promote socio-economic development by involving local community residents in setting the vision for and developing plans and actions for their communities and regions, and making optimum use of existing assets in the adjacent communities.
3. Reduce the concentrations of carbon dioxide and other greenhouse gases in the atmosphere by encouraging alternatives to the use of gas-powered vehicles.
4. Optimize operations and maintenance practices to maintain specified performance levels. Minimize energy consumption while maximizing use of renewable energy sources. Encourage pollution prevention by specifying land uses that minimize or eliminate the use of extracted underground substances; and by encouraging methods of landscape design and maintenance that use native vegetation and reduce or eliminate the use of pesticides, herbicides, and synthetic fertilizers.
5. Reduce the use of water through water conservation and recycling; re-use gray water on-site and employing innovative wastewater treatment.
6. Use environmentally preferable products.
7. Enhance indoor environmental quality.

The most recent EO 13423 (January 2007) issued in order to "strengthen the environmental, energy, and transportation management of federal agencies in the United States" built on previous EOs. Those included EOs on waste prevention and recycling (EO 13101), locating federal facilities on historic urban properties (EO 13006), energy efficiency (EO13123), bio-products and -fuels (EO 13134), environmental management

(EO 13148), and fleet and transportation efficiency (EO 13149). To support implementation of this policy, goals to guide energy and water conservation, building design and construction, waste and recycling, and procurement procedures were established.

The U.S. Green Building Council (http://www.usgbc.org) developed the LEED Green Building Rating System to evaluate sustainability for a project. The LEED rating system is a checklist of various "green" options for building design and construction developed through a consensus by a consortium of industry groups. It evaluates environmental performance from a "whole building" perspective over a building's life-cycle, providing a definitive standard for what constitutes a "green building." The LEED rating system covers all phases of a building's design over its entire life cycle, from planning to commissioning and maintenance. Its six credit areas for new construction in business and industrial buildings are: Sustainable Sites (includes site selection, site resource protection, landscaping, and stormwater management); Water Efficiency (water efficient landscaping, water conservation, and innovative technologies); Energy and Atmosphere; Materials and Resources; Indoor Environmental Quality; and Innovation and Design Process (includes exceptional performance beyond the LEED requirements).

Many federal and state initiatives are in place for LEED certification that cover new construction and renovation, including most federal departments. California's EO #S-20-04 (December 2004) requires the design, construction, and operation of all new and renovated state-owned facilities to be LEED Silver.

For sustainable water management, the EPA (http://www.epa.gov/nps/lid.pdf), maintains a web site for LID resources including design and guidance manuals, videos, and other multi-media information sources and links; and it is starting to be a requirement in stormwater permits (See also Section 5.3.2: Stormwater Management). On January 20, 2005, the SWRCB adopted sustainability as a core value for all California Water Boards' activities and programs, and directed California Water Boards' staff to consider sustainability in all future policies, guidelines, and regulatory actions. Locally, the Navy has a LID manual (http://www.lowimpactdevelopment.org/lid%20articles/ufc_3_210_10.pdf) as does the County of San Diego (www.co.san-diego.ca.us/dplu/docs/LID-Handbook.pdf) (County of San Diego 2007).

The Joint Ocean Commission Initiative (2009) recommended that local leaders "Make the land-sea connection" by reducing the impacts of land uses and development on water quality. The White House (EO 19 July 2010) adopted this as a national priority.

LID is a site design strategy with a goal of maintaining or replicating the pre-development hydrologic regime through the use of designs to create a functionally equivalent hydrologic landscape. Hydrologic functions of storage, infiltration, and groundwater recharge, as well as the volume and frequency of discharges are maintained through the use of integrated and distributed micro-scale stormwater retention and detention areas, reduction of impervious surfaces, and the lengthening of flow paths and runoff time (Coffman 2002). This contrasts with conventional approaches that typically convey and manage runoff in large facilities located at the base of drainage areas. Although traditional stormwater control measures have been documented to effectively remove pollutants, the natural hydrology is still negatively affected (inadequate base flow, thermal fluxes or flashy hydrology), which can have detrimental effects on ecosystems, even when water quality is not compromised (Coffman 2002). LID practices offer an additional benefit in that they can be integrated into the infrastructure and are more cost effective and aesthetically pleasing than traditional, structural stormwater conveyance systems.

The recent White House EO (19 July 2010) that established a national policy for coastal stewardship identified a national priority to "Enhance water quality in the ocean, along our coasts, and in the Great Lakes by promoting and implementing sustainable practices on land."

The LID Urban Design Tools website (http://www.lid-stormwater.net/index.html), developed cooperatively with the EPA Office of Water program, and offers tools and techniques for retrofits and new design projects. Several examples of LID designs for different applications are offered; and through an interactive screen, the user can access various techniques for LID solutions, as well as examples of the techniques. The the Whole Building Design Guide (http://wbdg.org/design/index.php) provides projects managers and designers of many disciplines an extensive set of LID information. Building attributes, emerging issues, and relevant codes and standards highlight a small portion of what this website presents.

Current Management: U.S. Navy

As stated in NAVFAC Instruction 11010.45, "Sustainable development is required by law and policy, and is a requirement for the Navy."

As stated in NAVFACINST 11010.45, "Sustainable development is required by law and policy, and is a requirement for the Navy." The Navy was the first federal agency to participate in the LEED program. In 2005, apart from the Government Services Administration, the Navy had the highest number of LEED certified structures of any federal agency at 17.

Locally, the Navy recently implemented energy conservation measures totaling $35 million on NASNI, NAB, and Naval Station. These include upgrades in irrigation, lighting, and refrigeration. The flagship of this project is the 750 kilowatt solar power array installed atop a parking structure on NASNI reducing carbon dioxide (CO_2) emissions by 309 tons per year. A second solar power array was recently installed at Naval Station.

In the Navy much of sustainability planning occurs within the RSIP process because this is when facility needs are evaluated and siting options are examined for fulfilling them. One of the stated Navy goals of the RSIP process pertaining to natural resources sustainability is (as stated in NAVFACINST 11010.45): "Recognizing the environmental association of all planning recommendations and providing ecologically sustainable solutions that support and enhance the regional shore establishment." Properly following the RSIP process means that a planner is taking a longer-term approach (NAVFACINST 11010.45). NAVFACINST 11010.45 adds the LEED and National Governors Association (NGA) New Community Design checklist requirement to the RSIP process. The Navy's LEED checklist has the scoring shown in Table 5-1 (only elements related to natural resources are shown).

Table 5-1. Partial checklist (portion relating to natural resources) and scoring system for Navy LEED projects.

Erosion and Stormwater Control
Construction site sediment and erosion control plan that conforms to BMPs.
No net increase in the rate or quantity of stormwater runoff from existing to developed conditions, OR, if existing imperviousness is greater than 50%, new development will result in a 25% decrease in the rate and quantity of stormwater runoff.
Stormwater treatment systems designed to remove 80% of the average annual post development TSS, and 40% total phosphorous.
Site Selection
If the site is FREE from the following unfavorable conditions.
Land whose elevation is lower than 5 feet above the elevation of the 100-year flood as defined by Federal Emergency Management Agency. Within 100 feet of any federal, state, or local wetland.
Land that provides habitat for any species on the federal or state threatened or endangered list.
If the site has any of these problems, strongly consider using another area.
Urban Redevelopment
Develop on a site classified as a brownfield and provide remediation.
Conserve water use through xeriscaping with native plants.
Reduced Site Disturbance/Reduced Heat Islands.
Post development landscaping uses native plants that improve habitat for native species.
Light Pollution Reduction
Do not exceed Illuminating Engineering Society of North America footcandle level requirements, AND design interior and exterior lighting such that zero direct-beam illumination leaves the building site.
Water Use Reduction
Use only captured rain, graywater, or trenched wastewater to water landscape.
Install non-potable water system for toilets, cooling towers, boilers, landscaping, vehicle washing, and other non-potable water needs.
Employ strategies that in aggregate use 20% less water than the water use baseline after meeting Energy Policy Act of 1992 fixture performance requirements.
Exceed the potable water use reduction by an additional 10%.
Comply with the Department of Energy Performance Measured Protocol.

The NGA Checklist for better land use "smart growth" approaches includes one criterion that addresses protection of open space, farmland, natural beauty, and critical environmental areas:

- Does the project avoid fragmenting existing green space, especially natural habitats and forests?

- Does the project design protect the local watershed? Water runoff and other factors should be examined to determine whether the development is harming the watershed. To minimize water runoff, the fraction of land paved over for streets and parking typically should not exceed 20 percent to 30 percent.
- Does the project location avoid increasing the risk or negative impacts of natural disasters? Consideration should be given to what kinds of periodic natural hazards exist for the site and whether a specific location is vulnerable, for example, to flooding, wildfires, mudslides, beach erosion, or high winds.

Current Management: Port of San Diego

The Port's Environmental Sustainability Policy (BPC Policy No. 736 11 December 2007) is directed towards improving the environmental condition of the bay and bay tidelands by integrating sustainability principles into business decisions, development, and operations within the Port's jurisdiction. The Port does this by leadership in:

- Minimizing environmental impacts
- Conserving energy and resources
- Preventing pollution and improving personal, community, and environmental health
- When possible, exceeding applicable environmental laws, regulations, and industry standards
- Balancing environmental, social, and economic concerns
- Defining and establishing performance-based sustainability objectives, targets, and programs
- Monitoring key environmental indicators and consistently improving performance
- Fostering socially and environmentally responsible behavior through communications
- Collaborating with tenants to develop an integrated, measurable, baywide sustainability effort

The Green Port Program unifies the Port's environmental sustainability goals in six key areas. As part of the Green Port Program, the Port sets measurable goals and evaluates progress in each area on an annual basis. The Green Port Program both continues the Port's existing environmental efforts and expands these efforts through new programs and initiatives. The goals of the Green Port Program within the six key areas are as follows:

- Water: Improve water quality in San Diego Bay. Reduce the Port's water usage to preserve San Diego's water supply.
- Air: Reduce greenhouse gas contributions and other air emissions from Port operations.
- Waste Management: Reduce waste from Port operations through material reuse, recycling and composting.
- Sustainable Development: Enhance the environment of Port buildings while maximizing long-term economic benefits.
- Sustainable Business Practices: Give equal weight to environmental, economic and social concerns in the decision-making process.

Other priorities are to grow the Green Port Program every year as new projects are added and existing ones refined. The Port has established an annual review process to measure results and establish new priorities. This process will include input from a variety of departments within the Port and from Port stakeholders.

As of 2008, the Port is making headway with its program to replace and retrofit older model trucks and is now moving forward with plans to install shore power at the B Street Cruise Ship Terminal with the help of grant funds from the Carl Moyer Grant Program. The Port was awarded $2.4 million from this grant by the San Diego Air Pollution Control District in August 2008. This is the second shore power project awarded under the Carl Moyer Program in the state of California. The estimated cost for this project is

$6 million. This includes approximately $1.9 to power the terminal, $2.4 million for the electrical equipment and $1.7 million for public works infrastructure. To comply with the Carl Moyer Grant Program regulations, the system must be operating by May 31, 2010, more than three years prior to state regulatory requirements. Once the project is operational, it is expected to remove 151 tons of air emissions.

Sustainability Indicators

Specific resource subsets, such as water, energy, fisheries, wildlife, rangeland, soils, etc. are undergoing research and scrutiny for criteria and indicators of sustainability. Professional societies collaborate in each specialized topic area to develop BMPs, conceptual approaches at a hierarchy of scales, and position statements. Examples are "roundtable discussion forums" for water, energy, and soils. The resource roundtables, blogs, and discussion groups focus on each criterion, a category of conditions or processes that can be assessed nationally to determine if the current level of management will ensure sustainability. The indicators are developed through the expert opinions of scientists, management agency personnel, non-governmental organization representatives, practitioners, and other stakeholders. A suite of variables, when complemented with other sustainability indicators, produce a viable system to monitor at the national level the biophysical, social, and economic characteristics indicating trends of sustainability.

Evaluation of Current Management

Many opportunities exist for the construction of infrastructure in a way that promotes the achievement of the Navy's and Port's mission in an environmentally integrated way. For example, the use of permeable surfaces and bioswales reduces storm-water runoff and reduces COCs in stormwater runoff. Re-engineering of the intertidal can promote favored wildlife while excluding undesirable species, such as rats that are known to predate upon endangered species. It is less expensive to design to prevent such impacts rather than to fix them after the fact.

Across nearly all sectors of environmental concern, there is unfulfilled potential to conduct operations that affect San Diego Bay in a more sustainable manner. In addition, there are few yet emerging examples of projects that meet criteria as sustainable.

Information sharing between agency practitioners with the work of professional societies in a range of resource areas are only beginning. LEEDs is the best integrated into agency work due to the application of EO 13423 (January 2007).

San Diego Bay managers continue to have difficulty implementing the concept of enhancing the habitat value of needed shoreline structures. Similar programs are better institutionalized by the states of Virginia and Maryland, and the Chesapeake Bay Program. The "Living Shorelines" programs on the east coast are defined as restored shorelines that, in addition to protecting property from erosion, provide habitat for fish, birds and other wildlife. Similar to undisturbed natural shorelines, they also protect water quality by trapping excess nutrients and sediment. See the state of Virginia's Coastal Zone Management Program Living Shorelines Factsheet as an example (http://www.deq.virginia.gov/coastal/documents/lsfactsheet.pdf). In Virginia, workshops are held for marine contractors, permitting agents, environmental consultants, local government and state agency staff, advisory board members, and others interested in learning how to apply the living shoreline approach for shoreline structure benefits to preserve, create, or maintain habitat; restore critical feeding and nursery habitat for adult and juvenile fish; provide wildlife access to the shoreline for nesting species of birds and terrapins; maintain natural shoreline dynamics; create a natural buffer that absorbs wave energy and reduces coastal erosion; trap and retain land runoff containing nutrients and pollutants; and provide aesthetic value, enhanced views, a sense of place, and privacy to the property owner.

A National Academy of Science study, "Mitigating Shore Erosion Along Sheltered Coasts", backed up the need for improving the functionality of shoreline structures. According to this 2006 study by the National Research Council, erosion will destroy many of the nation's estuaries, bays, lagoons and mudflats unless there are major land-use regulations along sheltered coasts in the United States. The report concluded "that local regulatory regimes must be replaced with approaches for larger regions that are carried out with an eye to long-term effects and that property owners and regulators must think beyond rock and concrete and consider new protection methods for coast areas, such as artificial marshes."

The following strategies are designed to improve sustainability of both projects and habitat. Many are adapted from EO 13423.

Objective for Sustainable Resources Use and Development

Objective: Sustain natural resources and Port and Navy institutional missions into the future without decline to natural resource assets or compromising the ability to grow those assets, by enabling innovation in planning, design, project management, and implementation.

I. Ensure Navy and Port leadership have visibility with respect to the total cost of mission sustainment, day-to-day operations, infrastructure and building development, and redevelopment. This should incorporate sea level rise scenarios and the projected value of the loss of habitat associated with the decision for no action.
    A. Balance short-term mission accomplishments with long-term environmental, social, and economic assets that sustain the mission in the long-term.
    B. Write a sustainable operations policy statement at an organizational level meaningful to the implementation of practices. Consider how to affect practices at the individual agency, joint agency for San Diego Bay, tenant (both Port and Navy), or installation level.

II. Use the RSIP/master planning/site approval/NEPA/CEQA processes to bring in interdisciplinary support to decisions early in the project planning phase that includes water, engineering, and natural resources professionals.
    A. Improve the integration of [Navy and Port] natural resources professionals into the sustainability planning through RSIPs, NEPA, site approval, and sustainability action plans. Facilitate early, advance project review for stormwater management, landscaping, shoreline and in-water structures.
    B. Improve the integration of Navy water resources and water quality professionals into sustainability planning.
        1. Anticipate future water quality permit requirements with sustainability planning early in the site process.
    C. Expand the incorporation of sustainability principles into project scope and cost estimates, such as that reflected in the DD Form 1391.

III. Apply sustainability principles to the management of habitats, species, and ecological functions within San Diego Bay by identifying resource-specific best practices similar to what has been done for energy and water in the built environment using LEED and LID approaches.
    A. Continue to comply with EO 13123, which tasked federal agencies with defining principles for implementing sustainable development in construction.
        1. Promote sustainable land use - planners should avoid using undeveloped land, open space, water and soil conservation areas, existing natural ecosystems, endangered species habitats, and floodplains (NAVFACINST 11010.45).
            a. Select a site that preserves natural resources (Credit 1 under LEED Green Building Rating System).
            b. Clean up and redevelop polluted sites (Credit 3).
            c. Choose the project site to protect natural resources (NAVFACINST 11010.45).
                1. Consider the vegetation and topography of available sites and identify which would require the least amount of disruption in order to accommodate the project. Protect ecologically sensitive areas such as endangered species habitats, forests, meadows, wetlands, and waterfronts. Preserve culturally sensitive areas such as historic

and archaeological sites. Increase urban density rather than developing untouched green spaces. Maintain or increase the amount of green space, including planting trees, especially in dense urban areas where open parkland may not be possible.

2. Evaluate the topography of the possible sites. Accommodate topographically difficult terrain, avoiding disturbance of steep slopes where development could cause erosion. Avoid development of sites that would adversely affect watersheds. Accommodate natural watershed drainage patterns, and take advantage of water on a site in land use planning.
3. Plan for efficient use of water through use of natural drainage, drought tolerant landscaping, and recycling.
4. Reduce and manage stormwater runoff from the site. This involves consideration of a stormwater system layout and integration with existing utilities.
5. Minimize paved areas and maximize green space and use of native vegetation.
6. Align proposed structures on the site to take advantage of positive, or minimize negative, climatic and weather factors such as sun angle and wind direction, thereby using passive measures to reduce energy consumption.
7. Minimize the footprint of the building and associated facilities on the site to retain open space. Bring the outside in, and the inside out, thereby connecting building occupants with nature.
8. Improve energy efficiency and reduce greenhouse gas emissions through a reduction of energy use.
9. Encourage methods of landscape design and maintenance that uses native vegetation and reduces or eliminates the use of pesticides, herbicides, and synthetic fertilizers as well as encouraging the use of compost and recycled rain or gray water (NAVFACINST 11010.45).
10. Reduce the consumption of petroleum fueled transportation and operations. When ships are in port, use 'cold iron' powering for on board power supply whenever possible.
11. Prevent waste and encourage recycling to reduce the amount of trash in San Diego Bay and along its shorelines, consistent with EO 13101.

B. Implement LID practices for protecting water quality (covered under sections on stormwater and others).

C. Adopt a baywide or regional approach, as appropriate, to the placement and design of shoreline armor (National Academy of Science 2007).

D. Use construction siting, materials, and methods that promote biotic communities to the fullest extent possible.

1. Ensure for design review by engineers, water quality specialists, and marine biologists at all major phases of intertidal and subtidal construction project development.
2. Design substrates that are amenable to occupation by intertidal and subtidal biota during the refurbishment and construction of new armored shorelines as implemented in the Military Construction project P-793 Navy Lighterage Project, and as similarly described in Section 4.3.7: Artificial Structures.
3. Design against the occupation of shoreline stabilizing structures by terrestrial predators that can negatively impact the success of endangered species programs.

IV. Go beyond government and industry standards "beyond compliance" when possible (BPC Policy No. 736).

V. Use baywide metrics (indicators) of sustainability that integrate environmental stewardship, social responsibility, economic prosperity, and mission accomplishment. (See also Chapter 6 for Indicator Species and other Monitoring and Research strategies.)

A. Define and adopt standards, rating systems, and metrics. [BPC Policy No. 736: Defining and establishing performance-based sustainability objectives, targets, and programs. Monitoring key environmental indicators and consistently improving performance.]

B. Collaborate with tenants to develop an integrated, measurable, baywide sustainability effort (BPC Policy 736).

C. Incorporate metrics and standards of success meaningful to San Diego Bay (INRMP Sustainability Committee).

1. Expand Port sustainability policy to incorporate LEED or other appropriate metrics and build on it. Seek a requirement for LEED certification or other sustainability metric for energy use.

2. Navy should seek LEED certification for all Military Construction projects starting in a fiscal year in the future.

3. NGA Checklist for New Community Design (http://www.nga.org/cda/files/072001NCDFULL.pdf).

4. Habitat Value Indicators support.

5. Global warming threat reduction through reduced carbon footprint and project design that incorporate planning for climate change.

VI. To develop sustainability indicators and best practices, monitor and integrate into San Diego Bay planning the work of professional societies, academic institutions, managers, business and government entities on the topic of sustainability with regard to specific disciplines and resource subsets. Examples are:

- Statements of professional societies such as the Ecological Society of America's Sustainability Science Initiative that looks at sustainability through the integration of ecological and social sciences. Policy statements of professional organizations such as The Wildlife Society on environmental quality and watershed planning.
- Natural Resources Roundtable networks such as http://RoundtableNetwork.cnr.colostate.edu/, Sustainable Water Resources Roundtable; Sustainable Rangelands Roundtable (http://sustainablerangelands.cnr.colostate.edu/); Roundtable on Sustainable Forests (http://www.sustainableforests.net/); National Report on Sustainable Forests (http://www.fs.fed.us/research/sustain/index.html); Sustainable Minerals Roundtable (http://www.unr.edu/mines/smr).
- Journals on sustainability science such as Sustainability: Science, Practice, & Policy (ejournal.nbii.org).
- Forums on sustainability science (such as www.sustainabilityscience.org).
- Government offices on sustainability of specific resources, such as the Office of Sustainable Fisheries implementing the Sustainable Fisheries Act.(http://www.nmfs.noaa.gov/sfa/reports.htm).
- Industry forums, such as the Sustainable Tuna Roundtable.
- Policy forums such as the International Institute for Sustainable Development; University of California Sustainability Policies and Best Practices.
- University research efforts such as the UC sustainability initiatives and the University of Southern California Center for Sustainable Cities.

- Business forums such as the World Business Council for Sustainable Development which argues that "sustainable development is good for business and business is good for sustainable development." Others are the Center for Sustainable Global Enterprise at Cornell University; the Erb Institute at the Ross School of Business at The University of Michigan; the Center for Sustainable Enterprise at the University of North Carolina, Chapel-Hill; and the Stern Review on the Economics of Climate Change.
- Sustainable Livelihoods application as used by Food and Agriculture Organization as well as non-governmental organizations such as CARE, OXFAM and the African Institute for Community-Driven Development, Khanya-aicdd.

A. Select sustainability indicators that have the potential to turn the generic concept of sustainability into action.

   1. Select indicators that improve the quality, regularity of dissemination and accessibility to the public of sustainability achievement.

   2. Identify appropriate spatial and temporal resolutions for reporting.

   3. Consider Life Cycle Assessment as a "composite measure of sustainability." It analyzes the environmental performance of products and services through all phases of their life cycle: extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling, and final disposal.

   4. Consider Ecological Footprint Analysis as an estimate of the amount of land area a human population, given prevailing technology, would need if the current resource consumption and pollution by the population is matched by the sustainable (renewable) resource production and waste assimilation by such a land area. Such measures have been combined with an index of quality of life (Marks *et al.* 2006), and the outcome christened the "(Un)Happy Planet Index" shows data for 178 nations.

   5. Consider an Environmental Sustainability Index (e.g. Yale Center for Environmental Law and Policy, Center for International Earth Science Information Network of Columbia University and World Economic Forum, Millennium Ecosystem Assessment of the United Nations (2005), and the Directorate-General Joint Research Centre [European Commission] 2004).

VII. Develop a sustainability action plan at an organizational level meaningful to on-the-ground practice.

A. Rank projects based on metrics that will help meet sustainability objectives.

B. Place top-tier projects in the Implementation Table (Chapter 7) for action.

C. Assign natural resources valuation to support life-cycle cost analysis.

D. Integrate anti-terrorism considerations (NAVFACINST 10110.45).

VIII. Involve community stakeholders (Navy commands, Port tenants, etc.) to support local action plans and socio-economic development, and to avoid disadvantaging communities through poor siting and unattractive views.

IX. Conduct training in sustainable design criteria cooperatively between the Port and the Navy for engineers, construction and design specialists, water quality specialists, and marine biologists. This could be web-based training.

X. Foster a functioning and innovative culture of sustainability through communications, outreach, and recognition. [BPC Policy 736: Fostering socially and environmentally responsible behavior through communications].

A. Conduct training in environmental sustainability.

B. Establish sustainability leadership awards for excellence in environmental, transportation, and energy management.

5.2 Within-Bay Project Management

5.2.1 Dredge and Fill Projects

This section describes the continuing need for dredging projects, the permitting environment in which these operations are conducted, the environmental issues associated with dredging, and finally, opportunities to use necessary dredging work for environmental enhancement.

Specific Concerns

The following specific concerns address both dredging and dredge material disposal.

- There is a need for predictability, timeliness, and stability in the decision-making process so that the Port can remain competitive in a world market and the Navy's use of the bay for a major homeporting facility can be sustained. With the unique nature of each project and over 30 major environmental statutes and regulations governing dredging projects, consistency in their application is difficult if not impossible.
- There are uncertainties regarding the scientific ability to evaluate risks from metallic or organic contaminants to human and ecological health from dredging contaminated sediments and their disposal.
- Resuspension of bioaccumulative contaminated sediments may have effects on biota, but there are not data on background levels of turbidity to separate the ambient from disturbed condition.
- There are air quality compliance concerns due to dredging and transport of dredged materials.
- While hydrodynamic models for the bay have been developed to help predict the fate of contaminants and oil spills based on predicted changes in the current profile, these two-dimensional and three-dimensional models lack ground truthing and are too coarse to be site specific. The ecological implications of a change in current, salinity, or dissolved oxygen in the most sensitive habitats, such as intertidal areas, are unresolved.
- The need to dredge, especially close to the shoreline, leads to a need to stabilize the shoreline with non-native hard substrate due to unnaturally steep slopes that erode with wave and current action. It also leads to a loss of sandy beach areas from erosion, and potentially a loss of eelgrass.
- Opportunities for beneficial reuse of dredged material for work in the bay may be lost without a regional plan that addresses both beach nourishment and habitat enhancement projects. The current SANDAG-sponsored plan addresses beach nourishment only.
- The core sampling methodology used to characterize sediment in advance of dredging in order to anticipate disposal requirements does not detect anomalies, such as the presence of ordnance, which makes sand unsuitable for beach nourishment. To date, there is no satisfactory technology to operate dredges with screens or grates that is 100% effective at removing ordnance.
- Habitat enhancement within the bay can be more costly than ocean dumping. There is a need to address funding issues associated with habitat enhancement using dredge spoils that fulfill objectives of this Plan.
- There is a shortage of upland and nearshore confined disposal sites for sediment unsuitable for aquatic disposal.
- There is uncertainty about the capacity of the LA-5 ocean disposal site. Also, there has been public concern about toxic sediments dredged from San Diego Bay on their way to LA-5 that are dumped short of the actual dump site, a process called short hauling.
- There is a lack of prioritization of beneficial use sites for dredge disposal in the bay, in contrast to beach nourishment sites outside the bay.

Background

The dredging and dredge disposal requirements for maintaining San Diego Bay as a vital, economically successful port will not lessen in the foreseeable future. The trend is for deeper draft, power-intensive vessels in both the shipping industry and the Navy. Dredging is conducted by the U.S. Navy, USACE, the Port, and some commercial marina operators. Major dredging first occurred in the early 1900s. See Map 2-2 for the history of dredge and fill in San Diego Bay.

Dredging is conducted by the U.S. Navy, USACE, the Port of San Diego, and some commercial marina operators.

Bay users have both new and maintenance dredging needs to be met. Maintenance dredging is required because of new material entering the bay, and existing material becoming suspended and displaced by currents and wave action. Relatively minor amounts of new material enter San Diego Bay compared to other bays because of low rainfall and the damming and diversion of river waters that would naturally provide intermittent sediment supply. As a result, maintenance dredging has never been conducted in the life of some projects. In the case of some Naval Station piers it has occurred about every five years. A long-term estimate of the volume involved with maintenance dredging from interior channels is about 3.4 x $10^5 m^3$ over 29 years; at least one unmaintained channel has persisted for more than 30 years (Smith 1976).

Most material dredged from San Diego Bay was removed, prior to 1970, and used to fill wetlands and to develop the bayfront.

Table 5-2 shows some recent and proposed dredge projects. The historical volume of material dredged from San Diego Bay over the years is estimated to be between 180 and 190 million cubic yards (Smith 1976). Most of the material was dredged prior to 1970 (See Map 2-2). The volume of recent or proposed dredging within San Diego Bay cumulatively totals approximately 24.3 million cubic yards. Historically, most of this material was used for filling wetlands and developing the bayfront. A small percentage has been disposed of at the LA-5 Ocean Disposal Site (about 5 to 8 million cubic yards historically, and less than 0.5 million cubic yards recently or proposed). About 35 million cubic yards were placed along Silver Strand Beach, in nearshore waters on the ocean side and in-bay waters at NAB Coronado. Approximately 147 million cubic yards were used around the bay as fill. A fraction of this has been used for habitat enhancement.

Current Management

Authority over dredging and dredge disposal in the ocean, the bay, or on land is implemented through a variety of federal and state permit processes. The USACE is responsible for any fill, construction, or modification of navigable waters and wetlands by authority of the Rivers and Harbors Act (33 USC.A. §401 et seq.); §404 of the CWA, and the Marine Protection, Research, and Sanctuaries Act or “Ocean Dumping” Act; 16 USC.A. §§1431 and 1447 et seq.; and 33 USC.A. §§1401 and 2801 et seq.). NEPA and CEQA documentation must also be fulfilled for dredging and dredge disposal.

Although USACE actually issues the permits, the EPA participates in the entire permit process and can object to permit issuance under certain conditions.

The EPA provides regulatory oversight authority over dredging, to ensure that it does not have significant adverse effects on marine and estuarine resources. They establish the environmental criteria and guidelines that must be applied by USACE and met by dredging projects, and EPA reviews all project proposals based on these criteria and guidelines. The USACE is prohibited from issuing a permit if the EPA finds the proposed disposal does not meet criteria for disposal site selection (§102 of the Marine Protection, Research, and Sanctuaries Act). USACE, under CWA §404(e)(1), must also provide notice and opportunity for public hearings. While the EPA itself does not issue permits, it participates in the entire permit process, including preapplication consultation, technical assistance, commenting, recommending special permit conditions, and postproject enforcement. The EPA can object to permit issuance under certain conditions.

A federal permit for dredge disposal cannot be issued unless it is in compliance with California WQS, or federal water quality criteria.

Under §401 of the CWA, a federal permit for dredge disposal, or any other activity under §401, cannot be issued unless the SWRCB issues or waives a certification that disposal in California waters is in compliance with California WQS, or federal water quality criteria for offshore waters. The SWRCB also regulates disposal into state waters through its Waste Discharge Requirements and specifies what must be considered in regulating dischargers (CWC §13263). Specific regulations for disposal of waste (dredged spoils) are contained in California Code of Regulations Title 27 (the former Chapter 15 regulations).

Table 5-2. Summary of existing and potential dredging projects and disposal methods since 1988[a] .

Project	Type[b]	Total cubic yards	Beach Nourishment	Ocean Disposal (LA-5)	Upland Landfill	Habitat Enhancement (eelgrass)	New Fill Fastland Construction	Left in Place
Navy Bravo Pier (M1-90) 1995	M	123,000		123,000				
Navy Fuel Pier 180 1998		21,000			21,000			
Naval Amphibious Base (P-187)1992	N	9,000				9,000		
Naval Amphibious Base (P-211) Pier 21	N	40,500			17,800	22,700		
Naval Station San Diego (M10-90) (various sites) 1993	M			116,000	390,000			33,255 Paleta Cr.
Naval Station San Diego (P-332S) 1995		180,000		+	+			
Naval Station San Diego (P-338S) 1994	N	300,000		172,000	+			158,000
Naval Station San Diego Pier 3 for Deep Draft Power Intensive (DDPI) ships 2000	N	184,500		85,500	99,000			
Navy Magnetic Silencing Ranges 1992	N	14,000						14,000 entrance channel
USCG Pier at Ballast Point 1995		40,000	+40,000					
Carrier Homeporting I	N	9,200,000		920,000				
Carrier Homeporting II	N	582,466				30,000		
Chollas Creek 1997	M	100,000		42,000	58,000			
San Diego Bay Harbor Maintenance 1996	M	175,000	175,000 Nearshore Silver Strand					
SDG&E South Bay Channel 1992–1993	M	1,000,000	+	+1,000,000				
Port of San Diego/USACE Central Bay Channel Deepening 10th Ave.	N	500,000	500,000					
Scripps Inst. of Oceanography, Nimitz 1995	M	47,000	47,000					
National City Marine Terminal	N	150,000			150,000			
Commercial Ship Repair Yards (ongoing)	M	15,000			15,000			
Dredged Material Sand Bar Feeder Berm 1988		150,000						
Cleanup Contaminated Sites (hot spots)	M	50,000/yr						
City of SD Point Loma Outfall Extension								
Berths 10-1 and 10-2					20,000			
Campbell Shipyard					45,000			
Berths 10-3 to 10-6				25,200				
Berths 24-10 and 24-11				25,000				
B Street Pier - sidecast								
Misc. undefined dredge projects		100,000/yr						

a. Data courtesy of P. McCay, M. Perdue and G. Rogers, U.S. Navy Southwest Division; SANDAG; Port of San Diego.
b. N= new; M = maintenance.
Addendum to the Environmental Assessment for Pier 3 Dredging and Ocean/ Upland Disposal, Naval Station San Diego, California.

The RWQCB waives establishment of Waste Discharge Requirements for dredging projects of 5,000 cubic yards or less that are not expected to have an adverse effect on the environment, and the disposal is at an upland site or at LA-5. Determination of environmental effect is made on a case by case basis considering the protection of beneficial uses, with mitigation requirements evaluated in consideration of other regulatory agency and public comment. The dredging operation itself has been waived pursuant to the San Diego Basin Plan. For upland disposal, the project proponent must still request authorization to discharge under a Regional Board waiver; for disposal at LA-5, the Regional Board defers to USACE decisions. RWQCB can issue a waiver of its certification consistent with the Basin Plan, Bays and Estuaries Plan, Ocean Plan, and California Drinking Water Standards. Criteria for the waiver are disposal is outside of the 100 year flood zone, capped with construction materials or 2 feet (0.6 m) of “noncontaminated clean” fill, 100 feet (30 m) away from any surface water, 5 feet (2 m) above highest anticipated groundwater level, and outside of basins designated for municipal and domestic drinking water supply.

If disposal is at an upland site or LA-5, the RWQCB waives establishment of Waste Discharge Requirements for dredging projects that are not expected to have an adverse effect on the environment and consist of 5,000 cubic yards or less.

Dredging operations must comply with RWQCB water quality objective for turbidity in San Diego Bay: Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses.

Dredging operations must comply with RWQCB water quality objective for turbidity in San Diego Bay: Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses.

The CCC exercises its authority over dredged material disposal by way of federal consistency and certification provisions of the CZMA, its Reauthorization Amendments (see also Section 3.6: Overview of Government Regulation of Bay Activities), and the CCA. Federal agencies must make consistency *determinations* for activities, while applicants for federal permits make consistency *certifications*. To be consistent with the CZMA, every effort must be made to use sandy material for beach nourishment or habitat restoration or enhancement. For beach nourishment, the material must meet USACE criteria, which require that particles be mostly greater than 74 microns (i.e. sand, gravel, or rock), compatible with sediments at the receiving site; and substantially the same as the disposal site. Provisions of the CCA relevant to dredge disposal are summarized in Table 5-3.

Table 5-3. Provisions of the California Coastal Act relevant to dredge disposal.

In-Bay Habitat Enhancement/Restoration
Section 30230. Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.
Section 3023l. The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of groundwater supplies and substantial interference with surface water flow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.
Section 30233. (a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects, and shall be limited to the following:...(7) Restoration purposes.
Beach Nourishment
Section 30233. (b) Dredge spoils suitable for beach replenishment should be transported for such purposes to appropriate beaches or into suitable long shore current systems.

For the Port, Chapter 8 of the CCA requires that the Port's Master Plan identify acceptable development uses. Under the master plan, dredge and fill operations cannot occur without establishing:

1. a demonstrated need for the dredge or fill operation;
2. the severity of impacts from dredge or fill on marine life and other activities within the port; and
3. a consensus between state and federal regulatory agencies regarding the adequacy of potential mitigation options (California Resources Agency 1997).

Through SANDAG, local, state, and federal resources are being used to develop a shoreline preservation strategy using dredge material.

Attempts to resolve dredging and disposal issues in advance take place in the NEPA- and CEQA-driven environmental review process. Standard mitigations for the environmental effects of dredging itself are employed: silt curtains, avoidance of the California least tern season, hooded shields, match boxes, antiturbidity overflow systems, or closed bucket or clamshell. Maintenance dredging is usually issued a Finding of No Significant Impact, such as dredging by the Navy at Chollas Creek, even though this site was shoaled up to near-zero water level. New dredging, however, will require at least an EA.

Potential alternatives for San Diego Bay's dredged material disposal include beach replenishment, habitat restoration/enhancement, ocean disposal, incineration, upland disposal without treatment, upland disposal with treatment, confined aquatic disposal, and capping at reuse sites. Some of these alternatives can have significant environmental benefit. Starting in 1977, sediment testing was required for aquatic disposal of dredge material under EPA guidelines developed under the Ocean Dumping regulations (40 CFR Part 227). The sediment must be characterized prior to dredging in order to determine the appropriate disposal alternative. Disposal protocols for the ocean and compliance with CWA, Marine Protection, Research, and Sanctuaries Act, and NEPA are defined in the "green book" (EPA Ocean Disposal and Inland Testing Manual, which can be found at the Corps Dredging Operations Technical Support home page at: http://www.wes.army.mil/el/dots/, or at EPA web site http://www.epa.gov/waterscience/itm/). The Inland Testing Manual provides a national testing framework which comprises one element of an overall decision-making process for determining whether dredged material can be discharged into CWA §404 waters. In recognition of the importance of site- and situation-specific concerns, regional flexibility in implementation and application is allowed within this national framework. The EPA/USACE also has published a "gold book" national testing manual for disposal in inland areas of Waters of the U.S. (Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S.—Inland Testing Manual [EPA and USACE EPA 823-B-98-004 1998]). Both manuals adopt a similar testing framework, including a tiered testing approach, multispecies benthic and water column testing of appropriately sensitive organisms, 28 day bioaccumulation testing, and comparison of benthic test results with those of offsite reference sediment. Tiered testing promotes cost effectiveness by focusing the least effort on the disposal operations where the potential (or lack thereof) for unacceptable adverse environmental impact is clear, and expending the most effort on those operations requiring more extensive investigation to understand the potential impacts. For example, during the first CVN homeporting project, Tier 1 (existing information and chemical data only) testing and Tier 2 (Tier 1 with some water quality modeling) testing were performed in the channel areas because they were away from a contaminant source. Tier 3 testing (including bioassays) was performed at the turning basin that was close to existing berthing areas and known potential contaminant sources (P. McCay, *pers. comm.*).

To determine the appropriate disposal alternative, sediment must be characterized. Both "green book" and "gold book" testing manuals include a similar tiered-testing approach and compare sediment test results to those of off-site reference sediment. This helps avoid potential adverse environmental impact.

Upland disposal of dredged material is treated as a solid waste. Concerns are centered around contaminants becoming soluble and mobilizing into surface or groundwater. Data from in-water testing programs are often inadequate for determining the suitability of dredged material for upland or landfill disposal because of differences in solubility of the contaminants and different exposure pathways. Generally, project sponsors must work individually with the agencies involved to develop site-specific testing protocols and waste discharge requirements for each project, largely due to differences in the engineering characteristics of each site, proximity to ground or surface water, and other factors. Typical testing requirements include total and soluble metals, and total organics such as benzene, toluene, ethylbenzene, and xylenes, PCBs, pesticides, chlorinated solvents, and total recoverable petroleum hydrocarbons, such as waste oil or diesel.

Due to different characteristics of each site, project sponsors and agencies must work to develop site-specific testing protocols and waste discharge requirements.

Contaminant testing for disposal in wetlands is not standardized on a national level. Because these sites have exposure pathways similar to both in-water and upland sites, appropriate testing may involve some in-water and some upland approaches. These decisions are made on a site-specific, case by case basis.

The Navy dredging operation for homeporting a new aircraft carrier is an example of the many issues that can arise with a large dredging project, including the need to mitigate for socioeconomic impacts, air quality compliance, adequate sediment testing, complications in meeting CZMA consistency obligations, and the public voice in obtaining the maximum value of the dredge material as a resource. The project was viewed as a "once in a generation" source of beach nourishment for the region's eroding coastline (SANDAG 1997). The CZMA and the Shoreline Erosion Committee's (elected officials of all coastal cities and the City of San Diego, the SDUPD Commissioner, and a U.S. Navy representative) viewed the beach nourishment as required mitigation due to the socioeconomic impacts of the homeporting project. The CCC filed suit against the Navy for

The Navy dredging operation for homeporting an aircraft carrier is an example of the many issues that can arise with a large dredging project.

not meeting its CZMA consistency obligations after difficulties ensued with the dredging with regard to testing and screening for ordnance in bay sediments. The Navy delivered dredged material from San Diego Bay to LA-5 and committed to dredging clean sand from ocean sources to meet its beach nourishment obligations. This required Congressional funding to accomplish. In addition, the Navy agreed to investigate alternatives for beach nourishment in the future, ranging from using ocean borrow pits as sand sources to improved ordnance detection during dredging.

SANDAG has spearheaded effective use of community, local, state, and federal resources to develop a consensus-based beach nourishment strategy for the region. The Shoreline Preservation Committee has made a regional priority of beach nourishment, tailoring to local needs the CZMA statewide policy for the reuse of dredged material that gives priority to beach nourishment and enhancement/restoration projects. Since 1993, at least ten opportunistic sand dredging projects have resulted in the replenishment of four million cubic yards of sand to the region's beaches.

Human activities over the last 150 years have altered the natural supplies of sediment (e.g. gravel, sand, silt, clay/mud) to the coast, as well as the transport of sediments along the coast. Dams block the transport of sediment through coastal streams and rivers and reduce peak stream flows, both of which reduce downstream transport of sediment. Land development and fires release volumes of sediment much larger than that produced from unaltered land. If the cleared land is subsequently covered by roads, buildings or other impermeable surfaces, the volume of sediment available for beaches drops far below the unaltered condition. Coastal structures, such as groins and breakwaters, alter the transport of sediment along the coast. Harbors and harbor maintenance activities trap sediment and modify the transport patterns through dredging and disposal practices.

The historical approach by federal, state, and local agencies toward these sediment imbalance and deficit/supply problems has been project by project which focuses solely on solving site specific problems. Consequently, federal, state, and local agencies have historically implemented many projects to optimize cost benefit per individual project, rather than attempting to resolve the regional sediment imbalances. This inability to consider excess sediment at one location as beneficial use at another has contributed significantly to the perception that sediment is a waste. This California Coastal Sediment Management Workgroup is developing the California Coastal Sediment Master Plan (www.dbw.ca.gov/csmw/csmwhome.htm). The Master Plan is set up to facilitate the implementation of "Regional Sediment Management" throughout the entire California Coast. SANDAG's Shoreline Preservation Working Group is now working on a Coastal Regional Sediment Management Plan, as well as a Sand Compatibility and Opportunistic Use Program, and potential regional infrastructure investments. The following Sediment Master Plan tools are under development.

- Analysis of Impacts and Recommended Mitigation for Critical Species and Habitats: provides standardized references for environmental documentation, and assists sediment managers in pre-project planning by science-based identification of impact to critical species and appropriate mitigation measures.
- Development of Sand Budgets for California's Major Littoral Cells: Comprehensive review and compilation of dredging records and other relevant sediment source/sink information on a littoral cell basis; calculates regional sand budgets based on port/harbor dredging records.
- Mud Budget Final Report- Fine Grained Sediment Sources, Transport and Sinks: Examines the natural fate and transport of fine-grained materials for comparison against sediment management projects; provides a mega-regional analysis of this potentially major impediment to regional sediment management.

Evaluation of Current Management

Opportunities exist to use dredge material as a valuable resource with a substantial net benefit to the environment.

Dredging is necessary for safe navigation of commercial, navigational, and recreational vessels in channels, turning basins, docking slips, and marinas. While the process of dredging itself and disposal of dredge material may have adverse environmental effects, opportunities exist to use dredge material as a valuable resource with a substantial *net* benefit to the environment, rather than disposing of it as a waste. Most of the short-term environmental effects of dredging can be offset. The following is a discussion of potential environmental effects and benefits of dredging and dredge disposal.

Contaminated Dredge Material

Dredging and disposal of dredged material may redistribute toxic pollutants and increase their availability to aquatic organisms (Marine Board Commission 1985; Anchor Environmental 2003). Generally, the greatest potential for environmental effects from the disposal of dredged material is related to the benthic exposure pathway. Benthic organisms, those living or feeding on or in deposited material, are the most likely pathways for adverse environmental effects from contaminated sediment. Acute toxicity to various benthic species is used as a measure of the potential for direct effects to exposed organisms. Tissue bioaccumulation is a measure of bioavailability, and thereby the potential for chronic or food web effects (including human health effects from eating contaminated seafood) of sediment contaminants in longer-term exposures (USACE *et al.* 1998)**.**

On the other hand, dredging can reduce contaminant levels in the bay by removing contaminated sediment. This is evident by the general trend of increasing toxicity, ammonia, and fine sediment with distance away from the bay's opening, except where dredging has occurred.

Disturbance and Recolonization of Benthic Species

Recolonization of benthic organisms after disturbance depends upon the degree of disturbance, life span of the organism, and proximity of the seed source.

Effects on benthic invertebrates at the dredge site are apparently temporary, and the potential for persistent environmental effects due to maintenance dredging is very small (Marine Board Commission 1985, Anchor Environmental/Los Angeles Coastal Sediment Task Force 2003), unless maintenance dredging is so frequent that the area never has a chance to completely recolonize. The effects are believed to be similar to that caused by storms, which can cause locally catastrophic mortality and change in community structure. Recolonization of benthic organisms after their removal by dredging depends upon the extent of disturbance, life span of the organism, and proximity of the seed source. Soule and Oguri (1976) looked at recolonization of infaunal species after dredging, compared to a reference site. Colonizing populations were less diverse than established populations; they were dominated by opportunistic, stress-tolerant species. Two to three years were required for the community to stabilize (Rhoads *et al.* 1978). This time requirement was similar to the one Reish (1961) found for the initial colonization of the benthos in newly established marinas. A wide range of studies from many regions report a range of time to reestablish a stable community at between 1-1/2 and 12 years. A study is currently underway (funded by Ports of Los Angeles, Long Beach, San Diego and NMFS) to look at recolonization of dredged areas; preliminary results indicate within two years the community is stable (Merkel & Associates, in draft).

Despite the above conclusions regarding community stability, questions remain unanswered regarding whether the recolonized areas are also recovered in terms of function (such as food provided to higher-level organisms), compared to undisturbed areas. While some areas are exposed to wave turbulence and naturally experience disturbance, others are more sheltered and can develop a more diverse and structured community.

Turbidity

Dredging and disposal increase turbidity. Filter feeding organisms that live on the surface, such as mussels, are the most sensitive.

Dredging and disposal activity can affect marine life, both favorably and unfavorably, through increased suspended sediment (turbidity) (e.g. Higgins et al. 2004; Wu *et al.* 2007) or the release of organic matter, nutrients or contaminants depending upon the nature of the affected material. Turbidity can be a management concern because increases in suspended material in the water column limits photosynthesis which in turn impacts eelgrass (Erftemeijera and Lewis 2007) and phytoplankton viability. In this way it can temporarily affect the bay's primary productivity. Turbidity also affects fish and other aquatic life by: 1) limiting photosynthesis and increasing respiration, which increases oxygen use, and the amount of carbon dioxide produced; 2) clogging fish gills and the feeding apparatus of bottom-dwelling animals by suspended particles; or 3) blocking the vision of fish or other animals that rely on their sight to locate and capture their prey. Turbidity itself is not a major health concern, but high turbidity can provide a medium for microbial growth, or indicate the presence of microbes. Settlement of these suspended sediments can result in the smothering or blanketing of subtidal communities or adjacent intertidal communities, although this can also be used beneficially to raise the level of select areas to offset sea level rise or erosion (short-term impact versus long-term gain).

Filter feeding organisms that live on the surface, such as mussels, are the most sensitive to disturbance due to turbidity. While a variety of studies have shown them to tolerate short periods of turbidity up to 1,000 mg/l or even benefit from it due to increased pumping and nutrient supply (Marine Board Commission 1985), data still suggest that effects can be lethal at persistent high concentrations greater than 750 mg/l, such as in the immediate vicinity of the dredge, or with shallow burial (<0.4 inch [1 cm]) (Marine Board Commission 1985). Because of this, some ports around the country limit dredging activity during the spawn-and-set period of commercially valuable species of shellfish.

A southern California comparison of dredging-induced suspended sediment concentrations observed in the field and physical effects concentrations reported in the literature indicated that dredging is not likely to cause acute lethal effects in aquatic organisms (Anchor Environmental/Los Angeles Coastal Sediment Task Force 2003). Because of the transient nature of dredging induced sediment plumes, more long-term chronic and sublethal effects from resuspended clean sediments are not expected to occur around most dredging operations. Further, chronic and sublethal effects reported for clean sediments in the literature appear to overlap with naturally occurring background suspended sediment concentrations in the Los Angeles region indicating that regional aquatic life may be adapted to occasional exceedances of these chronic and sublethal effects levels. Very high levels of resuspended sediments and turbidity do have the potential to affect marine organisms; however, most of those impacts occur at resuspension levels and durations that are typically not present during dredging operations. Potential impacts from dredging of contaminated sediments are more difficult to assess.

Hydrologic Changes

The potential for persistent environmental effects associated with dredging new locations may be more significant than for maintenance dredging. It is a function of the quality of materials dredged, the changes in channel geometry, and the local hydrologic regime. Such changes can affect the fate of sediment and contaminants, as well as biota sensitive to changes in current, salinity, and dissolved oxygen. This is one of the questions being addressed in a model of Ecological Risk Assessment by SPAWAR Systems Center (K. Richter, *pers. comm.*).

Dredging Method

Four types of dredges are currently used in the bay. See Table 5-4.

Table 5-4 is an evaluation of the comparative biological effects of four types of dredges currently used in the bay. While there are distinct differences, project sponsors do not always have a choice as to which dredge system is employed. Cutter head dredges are preferred for excavating hard, rocky material or alluvium in relatively protected areas. Hopper dredges would be favored in the main channel where dredge materials are not hard, rocky, or indurated. Suction dredges would be selected for dredging under and around piers and adjacent to other structures where a hopper is difficult to operate, and where a cutterhead may damage structures. The choice of dredge depends upon these factors and the *availability* of a particular dredge, environmental sensitivity, volume of the material to be dredged, physical and chemical characteristics of the material, dredging depth, method of disposal, production rate required, distance of dredging from disposal sites, contamination level of sediments, expected waves and currents, and cost (U.S. Navy 1992; USACE *et al.* 1998).

Table 5-4. Biological effects of various dredging methods available in San Diego Bay.[a]

Dredging System (mechanism and transport method)	Description	Biological Effects
Stuyvesant (cutter head and hopper)	The Stuyvesant is a self-contained hydraulic unit. It dredges and disposes in pulses. Dredging occurs for about three to four hours, then the unit moves offsite for about five hours to dispose of the dredged material. Usually for maintenance dredging.	Cutter-head dredges reportedly cause less turbidity than hoppers and clamshells (USACE1986), but at least some operation of the Stuyvesant in the bay has resulted in more turbidity both from the head itself and from the overflow slurry (M. Perdue, U.S. Navy, *pers. comm.*). However, the intermittent operation allows turbidity to settle and appears to have increased foraging opportunities for the California least tern, brown pelican, and other fish-foraging species that congregate around the dredge apparently awaiting periods when the turbidity plume dissipates (M. Perdue, *pers. comm.*). Also, turbidity from a cutter-head-type dredge appears to contain material to within the immediate vicinity of the dredge compared to other dredge types (USACE 1986). However, overflow of the hopper can cause a large increase in the turbidity plume, suggesting that some restriction on overflow may be necessary if a hopper is used to remove contaminated sediment (USACE 1986). Observations in several locations indicate concentrations adjacent to the hopper overflow to the port at more than five orders of magnitude above background (Marine Board Commission 1985).
Florida (cutter head and scow)	The Florida operates continuously with scows coming and going to dispose of the dredged material. It does not move far from its location, which occupies about a 656 feet (200 m) diameter site. Use is limited by distance from an electrical source.	The combination of continuous operation and use of a cutter head results in increased turbidity. The Florida is an electric dredge, so it has more reduced air emissions than other types.
Dutra (clamshell and scow)	Used to dredge the turning basin for the CVN project, the Dutra mechanical dredge operates continuously with scows coming and going to dispose of the dredged material. A clamshell dredge is typically used in areas where hydraulic dredges cannot work because of proximity to docks, piers, etc. Can be used for maintenance and new work dredging.	Continuous operation does not provide an opportunity for turbidity to settle and avian foraging to resume. Resuspension of solids (turbidity) from a clamshell is typically higher than for most cutterheads, especially when the scow is allowed to overflow (USACE 1986). During dredging for the carrier Stennis CVN, the clamshell turbidity plume to 12 inches (30 cm) depth (believed to be the depth of importance to the foraging California least tern) never persisted more than one hour and never extended more than a 98 feet (30 m) circumference from the dredge point during Navy operations (M. Perdue, *pers. comm.*). The clam shell produces more localized turbidity nearer the water surface than the cutter head (Raymond 1984).
Suction (cutter head and hydraulic pump to fill site)	This method uses continuous, self-contained dredging and pumping by way of a hydraulic pipe to the disposal site. Currently used to move material from the north end of NAB to the disposal site. It is only useful for smaller projects.	The primary effects are temporary increases in turbidity and destruction of benthic infaunal community at the dredge and fill sites.

a. The extent of effects depends upon variables such as sediment characteristics, dredging methods, and hydrodynamic characteristics of the dredging site.

Dredge Disposal for Beneficial Use

When properly designed and sited, dredge disposal can be designed to benefit habitat and water quality by improving sediment retention, filtration of pollutants, and shoreline stabilization. Innovative dredge disposal for habitat restoration or enhancement has benefited the bay. Nevertheless, some degree of functional trade-off for particular fish and wildlife species is inevitable with almost any restoration project using dredged material to modify habitat substrates and depths. Decisions are required about the relative value of existing habitat types compared to the habitat targeted for restoration or enhancement by dredge disposal. Mitigation for impacted resources may, in fact, be required by regulatory agencies despite the resulting net benefit for another habitat type. This has been the case in San Diego Bay when intertidal habitat is created from vegetated or unvegetated shallow subtidal habitat. Whether restoration intended to support sensitive species or a certain habitat will result in a net benefit is a case-by-case decision involving specific project impacts and objectives. In other locations, such decisions are made in the context of a regional Plan such as this INRMP (e.g. San Francisco Bay's Long-term Management Strategy for dredging requires that such decisions be consistent with comprehensive regional plans of the area). The challenge of using dredge material for habitat enhancement is to maximize environmental benefits while minimizing the related losses of other, competing habitat values (USACE *et al.* 1998).

San Diego Bay project sponsors are developing some experience with habitat enhancement using dredge material. Dredge spoil has been used successfully to build up medium-depth habitat to shallower depths appropriate for eelgrass planting. This has occurred at NEMS 1, 4, and 6. Fill deposited at NAB has now become prime habitat for the California least tern and western snowy plover, as well as subtidal eelgrass. The CVWR is a 32-acre island that was created from placing dredge spoil in subtidal habitat to mitigate for development of the Chula Vista Marina. Homeport Island was constructed from dredge spoil from the wharf improvement project at NASNI in 2001, and now supports 15 acres of fish structures, eelgrass, and an intertidal flat. The Port filled a borrow pit to change from deep subtidal to shallow subtidal in 2003.

In San Diego Bay dredge material has been used successfully for habitat enhancement. Medium-depth habitat has been built up to shallower-depth habitat so that eelgrass could be planted.

Photo 5-1. Dredging at the wharf. Photo courtesy of Dale Frost.

To fulfill salt pond modification and restoration at the South Bay NWR approximately 181,000 acres of fill would need to be imported.

Other mitigation projects using dredge spoil have been proposed within the bay for many years, some of which are described in Section 5.2.1: Dredge and Fill Projects. For example, the South Bay Enhancement Plan (MBA 1990) proposed a number of projects for general enhancement of productivity, some of which could be supported with dredge material. An example is expanding intertidal, salt marsh and shallow subtidal eelgrass habitats such as at Emory Cove, or Grand Caribe Isle South. Least tern nesting sites at D-Street Fill (33 acres), NASNI (two sites), Delta Beach North (about 18 acres) and Delta Beach South (about 60 acres) occasionally benefit from dredge material to enhance the substrate and expand the site for least tern nesting, and this need will continue. Islands for colonial nesting birds could be created with dredge material, such as at or near the NWR salt ponds. The CVWR could benefit from sediment enhancement, as it is settling. Proposals in the Refuge CCP for Sweetwater Marsh Unit include excavating intertidal at D Street Fill, and enhancing the salt marsh at F&G Street Marsh. To fulfill salt pond modification and restoration at the South Bay NWR, approximately 181,000 cubic yards of fill would need to be imported (USFWS 2006).

Management Strategy—Dredge and Fill Projects

Objective: Conduct necessary dredging and dredge disposal in an environmentally and economically sound manner.

I. Avoid and minimize impacts to portions of the bay ecosystem that may be sensitive to dredging and dredge disposal.
   A. Ensure sediment is adequately characterized chemically, physically, and biologically based on the exposure pathways of concern at a particular site. Do as much as possible of this work in advance of projects.
      1. Ensure that current regulations adequately identify appropriate design or operational features necessary to control all contaminant pathways of concern at a disposal site using worst-case scenarios.
      2. Identify constraints, including potential contaminant exposure pathways, in advance of potential projects. Use information from the Ecological Risk Assessment currently being developed for the bay by Navy SSC (K. Richter, *pers. comm.*) to identify key susceptible organisms in each habitat/ecosystem, and the critical exposure pathway.
      3. Identify and seek to correct gaps in existing sediment testing criteria, such as the need to detect ordnance in advance. Expand on current work being conducted by the Navy to predict the likelihood of ordnance encounters during dredging.

B. Synthesize existing and develop new criteria, practices, and measures for successful dredge and fill in a bay ecosystem context, using existing regulations and practices to start. The criteria should include timeliness, maximizing scheduling outside of breeding season for the California least tern and perhaps other organisms at risk, minimizing periods of turbidity, minimizing contaminant exposure, etc.

   1. Investigate the possibility of other organisms having seasonal vulnerabilities to turbidity in certain locations or habitats in the bay, such as migratory birds or the larval stages of susceptible fish or filter-feeding invertebrates. Review and schedule dredging with this information.

   2. Consider the use of target management species that may be affected by the short-term or cumulative effects of dredging practices. Consider effects on such species in environmental documentation. For example, any visual predator may be affected by an increase in turbidity.

C. Define habitat values and vulnerable species in sufficient detail at both the site of impact and the mitigation site to ensure impacted values are adequately mitigated.

   1. Delineate intertidal habitat values for fishes, invertebrates, and shorebirds so that all are addressed.

D. First avoid, and then minimize, the need for dredging close to shore, which can contribute to the loss of intertidal habitats and the need to armor the shoreline.

   1. Maximize use of existing channels rather than creating new ones.

   2. Consider restricting new dredging to locations where the shoreline is already armored.

   3. Locate or design new dredge channels to minimize the need for shoreline protection.

E. Minimize air quality emissions during large dredging operations.

   1. Evaluate project emissions and obtain permits well in advance of implementation to stay within air quality thresholds.

   2. Where air emissions are of concern and use of an electric dredge is feasible, use this approach to minimizing emissions.

F. Establish means for project sponsors to routinely learn about and incorporate the latest research and practices.

II. Maximize the use of dredge material for beneficial reuse / habitat enhancement in the bay consistent with the habitat objectives and strategies of this Plan and other comprehensive, regional planning efforts.

A. Habitat enhancement tradeoffs should be guided by priorities of this Plan or other regional plans, and on a case by case basis depending on resource values at the site.

   1. Priorities and strategies for beneficial reuse within the bay should be based on habitat scarcity in relation to historic proportions (see Table 2-3) until research provides a more functional understanding of habitat values and interconnections.

   2. When mitigation for filling in bay waters is required, consideration should be given to habitat values of the site impacted compared to the resulting fill. This should include an evaluation of the relative scarcity of the habitats affected and created.

   3. Beneficial reuse projects should, where possible, be developed specifically for proactive habitat enhancement and restoration aimed at a net gain in current habitat values in the bay, rather than arise solely from reactive mitigation projects aimed at avoiding a net loss of habitat values.

B. Develop a comprehensive inventory of projects for the beneficial reuse of dredged material around the bay.

1. Identify areas of the bay for which dredged material could be used for habitat restoration and enhancement, Table 4-4 in this Plan.
2. Establish criteria for material suitable to use for restoration at each site.
   a. Any dredged material used for habitat enhancement or restoration should remain water-saturated, reduced, and near-neutral in pH, since these characteristics have a great influence on the environmental activity of any chemical contaminants that may be present (RWQCB 1994).
   b. Identify what characteristics constitute sediment that would be suitable for least tern nesting substrate enhancement.
   c. Characterize sediment suitable for enhancing habitat for target species and communities.
   d. Identify which sites would benefit from habitat enhancement using fine sediment mud, since this particle size is considered a waste in beach replenishment projects (See also IIE, below).
3. Identify and seek funding source since enhancement can be more expensive than other disposal alternatives.

C. Identify a multi-user beneficial reuse site for habitat restoration or enhancement in the bay (e.g. 'LA-5-type' site for the bay, such as abandoned channels in south bay).
   1. Develop a site plan.
   2. Develop sediment criteria for reuse at specific sites in advance of dredging projects.
   3. Allow for public comment on the site.

D. Investigate new locations for both upland and nearshore confined disposal sites. Seek a means to combine habitat enhancement with nearshore confined disposal sites.

E. Coordinate with SANDAG's Regional Sediment Management Plan. Investigate the use of fine sediments in material collected near shore for beach nourishment, that exceeds EPA standards for beaches but may be desired for south bay mudflat enhancement, or to raise elevations of habitats in anticipation of climate change. Collaborate with SANDAG on results of the Mud Budget Final Report, a tool under development for the Sediment Master Plan.

III. Obtain consistency, predictability, and timeliness in decisions involving dredging regulation and implementation.

A. Improve coordination and integration of agency policies by establishing a comprehensive dredging plan for the bay or region, which ties into the Shoreline Preservation Committee's regional symposium on beach nourishment and would seek to:
   1. Maximize the use of dredged material as a resource.
   2. Ensure that dredging and disposal is conducted in the most environmentally sound fashion.
   3. Reduce the need for some studies and tests associated with the Environmental Assessment process. Use the State's Sediment Master Plan tools for standardized impact analysis (such as Anchor Environmental 2003; Higgins *et al.* 2004). Make these locally relevant through local studies.
   4. Reduce the need for separate EAs for each project, using the same approach as in 3) above.

B. Develop a biological effects database for bioaccumulative contaminants (Maritime Administration Recommendation, Report to Congress). Identify opportunities to "streamline" testing needs by accomplishing some work in advance on a comprehensive basis.

1. Use the tools developed under the Sediment Master Plan such as "Analysis of Impacts and Recommended Mitigation for Critical Species and Habitats" to provide standardized references for environmental documentation, and assists sediment managers in pre-project planning by science-based identification of impact to critical species and appropriate mitigation measures.
2. Improve the bay-appropriate application of such tools.

IV. Sponsor research on dredging, dredge disposal, and their environmental effects in support of the regulatory process and impact analysis.

A. Support studies that help establish criteria for successful implementation of dredging projects, especially beneficial reuse of dredge material.

B. Establish the effects of a change in channel configuration that may result in changes in salinity, sediment accumulation, or erosion of sensitive intertidal habitats, or affect aquatic organisms.

1. Seek better understanding of the behavior and fate of sediment in the bay.
2. Determine if alteration of substrate and changes in circulation and sedimentation patterns due to dredge and fill activities are affecting the salt marsh and intertidal habitats of south bay.

C. Use existing and develop new information on background, ambient turbidity to help assess turbidity effects of dredge/fill and other human actions on biological resources. This should include spatial patterns across the bay ecoregions and differences with depth in the water column. It should also depict differences related to tides, seasons, and storms. Understanding the natural/background turbidity in a mudflat will affect the location of equipment that may cause turbidity and the placement of silt fences.

1. The above would build on the project studies conducted by the Navy for locating their second new nuclear carrier (CVN II), and include studies for Homeport Island and a Navy Eelgrass Mitigation Site (NEMS V). Protocols would generally build on those of the RHMP and SCCWRP's Bight-wide monitoring. These need to be supplemented by a more continuous program that integrates the mandatory TMDL requirements and NPDES permit requirements for water quality.
2. Placement of continuous turbidity monitoring devices should be based on modeling of spatial patterns combined with jurisdictional needs for information.

D. Research methods for detecting anomalies in the site to be dredged, such as the presence of ordnance, that would facilitate beneficial reuse without excessive cost to the project sponsor.

E. Develop designs for shoreline protection close to deep channels that provide more shallow subtidal or intertidal habitat.

F. Identify alternative dredging practices and general design considerations for new projects to reduce dredge material volumes.

V. Support the Port's and Navy's need to find environmentally beneficial mitigation solutions. Promote implementation of the Coastal Conservancy's recommendations in their reporting (required under Assembly Bill 2356 [Chapter 751, Statute 1989]) on issues with ports and mitigation needs, timeliness, acceptability, and effectiveness.

A. As recommended in AB 2356, the Coastal Conservancy should prepare restoration plans for candidate Port mitigation sites.

B. The State of California Resources Agency and Coastal Conservancy should continue supporting appropriate banking mechanisms that would enable ports to satisfy their mitigation requirement.

C. Resource agencies should form joint ventures with ports for habitat enhancement and mitigation.

D. Procedures should be developed to avoid future delays associated with the use of funds generated on public trust lands to implement mitigation projects outside the boundaries of port jurisdictions.

E. Navy, Port and agency directors should participate consistently and productively in regional mitigation working groups.

F. The Coastal Conservancy and CDFG should take the lead in completing projects to help develop the mitigation credit appropriate for developing artificial reefs. Determine if this is appropriate for San Diego Bay. Also, consider mitigation credit for improvement in habitat values of armored shorelines. (This latter item was not part of Coastal Conservancy recommendations.)

5.2.2 Receiving Water Monitoring and Trend Analysis

This section addresses water and sediment quality concerns related to ship and boat maintenance practices performed at Navy installations, commercial shipyards, and boatyards. It also covers marinas (including yacht clubs) that are leased from the Port for public and private uses, as well as Navy marinas.

Specific Concerns

- Antifouling coatings, or biocidal paints, on boats and ships are significant contributors of copper and other metal contaminants due to leaching and cleaning of hulls where boats are concentrated.
- Legacy pollutants from former practices at these facilities can remain in the nearby sediment.
- Monitoring indicates these sites to have some of the highest levels of certain pollutants in the bay. Toxic conditions from contaminated water and sediment can adversely affect biotic communities.
- PCBs, PAHs, and legacy pollutants are sediment quality issues for San Diego Bay. Costs of regulatory compliance, achieving recently-adopted state sediment quality objectives (SQOs), and contaminated sediment cleanup are a serious concern for the boating industry and military, as well as a feasible means to accomplish the compliance.

See also Sections 2.3 Water and Sediment Quality, 5.2.1 Dredge & Fill Projects, 5.3.2 Storm Water management, 5.4.1 Remediation of Contaminated Sediments, and 4.3.1 Exotic Species.

Background

Water quality issues are the main ongoing concern with boat and ship maintenance practices. While shipyards and boatyards perform maintenance activities with potential for water pollution discharge, areas such as marinas where boats are simply docked can also passively contribute pollutants through the underwater leaching of hull paints. Sediment quality is also a concern at all these facilities, with PCBs, PAHs, and legacy pollutants the sediment quality issues for San Diego Bay.

Ship maintenance occurs at Naval installations and commercial shipyards in the bay. While aircraft carriers dock at NASNI, major repairs and maintenance of carriers are performed outside of San Diego Bay. Repair and maintenance of most other Navy ships occurs at NBSD, located at the foot of 32nd Street. While the NBSD was home to 87 surface ships in 1991, it presently is home to 50 surface ships (U.S. Navy 2007). NBPL services five submarines at two dry docks.

Navy dry docks are used for performing certain repairs and maintenance, such as paint removal and repainting with an anti-fouling coating. While in port, wastes are transferred from carriers and other ships to tanker trucks and transported to the Navy onshore industrial waste treatment facility for processing. These wastes include bilge water, boiler blowdown, equipment cooling water, and evaporator brine (U.S. Department of the Navy 1995).

Discharges from the hull and exterior of docked ships were an issue addressed in the Navy's Homeporting EIS (U.S. Department of the Navy1995). The underwater hull surface of Navy ships has copper anti-fouling coatings to control the build up of marine fouling organisms and other organic matter. Copper unfortunately leaches into the marine environment at a rate of about 10 microgramsper square centimeter per day. In 1995, the 72 Navy ships then homeported in San Diego Bay had a maximum potential copper leaching of about 60 pounds (lbs) (27 kilograms [kg]) per year. As the number of Navy ships in the bay continues to decline, the amount of newly contributed copper at ship docks and yards accumulates at a slower rate. Copper is a heavy metal that is toxic to many marine organisms in large concentrations. Existing copper in marine sediments can continue to be removed through dredging of the contaminated sites and sediment remediation technology, as discussed in Section 5.2.1: Dredge and Fill Projects and Section 5.4.1: Remediation of Contaminated Sediments.

Commercial shipyards are located along the east side of the bay (north of NBSD): NASSCO, BAE Systems San Diego Ship Repair (formerly Southwest Marine), and Continental Maritime. Maintenance and construction of ships, such as tankers and container ships, also occur at the yards. A detailed description of shipyard activities and their water quality issues can be found in several Regional Board staff reports (RWQCB 1994; 2007a).

Natural leaching from hull paint is the greatest source of copper, followed by in-water hull cleaning during ship and boat maintenance.

In 1996, the annual copper load to San Diego Bay from all sources was estimated at almost 83,000 lbs (38,000 kg) (PRC Environmental Management 1996). The same report estimated that leaching of copper from anti-fouling hull paint, which includes copper from leaching, hull cleaning, private marinas, and ship and boat yards, accounts for about 82% of this load, or 68,000 lbs (31,000 kg). These estimates contrast sharply with the estimated contribution of Navy ships to annual copper loads discussed above. Marinas tend to have the highest copper inputs due to the very dense berthing of boats and the calm waters preventing natural mixing and dispersal (Schiff *et al.* 2006). For just the Shelter Island Yacht Basin, the RWQCB estimated in its 2005 TMDL that dissolved copper sources contributed 4,715 lbs (2,163 kg) per year: 93% from the passive leaching of copper from antifouling paint on boat hulls and 5% from the underwater hull cleaning of such paint (RWQCB 2005). This finding is very similar to the SCCWRP finding of 95% of copper emitted from passive leaching on recreational vessels versus hull cleaning activities (Schiff *et al.* 2003).

In-water hull cleaning has been or is still being carried on at Naval installations boatyards, and marinas. Underwater hull cleaning of ships is usually performed by a diver-operated brush (using a Scamp or a Brush Kart) to remove the slime layer of diatoms and algae. If a hull has gone too long without cleaning, then barnacles and other fouling organisms can accumulate on the surface roughened by the slime layer. At this stage, hull cleaning by a Scamp can also remove anti-fouling paint, which releases copper into the water and sediments. At boatyards and marinas, incidental underwater cleaning by divers is an activity conducted by an estimated 75 divers. Presently, no underwater hull cleaning is occurring in civilian shipyards in the bay (P. Michael, *pers. comm.*). However, Navy installations continue the practice as well as marinas. The Navy uses large diving operators under contract who operate with a workboat and hoses. The Navy follows Naval Sea Systems Command guidelines for underwater hull cleaning of Navy vessels to reduce the amount of anti-fouling paint that could be removed during the cleaning process. Underwater hull husbandry is an incidental discharge regulated under the Uniform National Discharge Standards being developed by the EPA. Specific Marine Pollution Control Devices are implemented for all of the Uniform National Discharge Standards discharges including the discharge from hull coatings and from hull cleaning (Rob Chichester, Navy, *pers. comm.*). Boatyard and shipyard sites also perform out-of-water hull cleaning and painting, an activity that can be more closely controlled but which is subject to stormwater runoff problems eliminated by collecting.

TBT levels have significantly declined in many areas of the bay since its use was severely limited.

TBT was once commonly used as an anti-fouling paint on boats, although not by the Navy. It is known to be extremely toxic to aquatic life while being very stable and resistant to natural degradation in water (EPA 2002). By 1986, high concentrations of TBT were detected in the surface waters and in the tissues of bay mussels at yacht harbors and marinas within San Diego Bay (Valkirs 1986). Due to TBT's water quality and ecological impacts, the federal government restricted the use of TBT in 1988 to only aluminum vessel hulls, vessel hulls over 82 feet (25 m) in length, or to the outboard motor or lower drive unit of a boat of any size (Richard and Lillebo 1988; U.S. Congress 1988; CDBW 1993). By 1991, TBT surface water and mussel tissue concentrations had significantly decreased in San Diego Bay marinas (Valkirs *et al.* 1991). A 1996 study also showed an overall decline in TBT sediment concentrations at commercial and Naval basin areas, although the concentrations were still higher than other areas in the bay (Fairey *et al.* 1996). Pollution from TBT remained a serious concern in the mid-1990s in areas of high vessel density and low hydrologic flushing (RWQCB 1994).

Water quality regulation and enforcement have been ongoing for shipyards, boatyards, and marinas. In 1986, the monitoring of these facilities led to eight Cease and Desist orders from the RWQCB San Diego. Seven boatyards were also issued Cleanup and Abatement Orders for violating allowable levels of copper, mercury, and TBT in their NPDES Permits (RWQCB 1990a). These sites were cleaned up in 1995.

Management of invasive species introductions from ship ballast water is discussed in Section 4.4.1: Invasive Species.

Besides water quality issues, the potential is high for the continued introduction of AIS when ship ballast tanks are emptied at dry dock. This ballast water problem and a management strategy are described in detail in Chapter 4, under Section 4.4.1: Invasive Species. However, a related invasive species issue has arisen over the effectiveness of anti-fouling paints on boats in preventing new exotic introductions through fouling growth on the external boat surface (Johnson and Gonzalez 2006). If the current biocides are restricted or prohibited due to their toxic effects in waterways, concern is raised that water quality could improve while AIS could increase.

Current Management

A combination of regulatory action, water quality monitoring, and voluntary efforts is continuing to help improve boat and ship maintenance practices in San Diego Bay. Industrial alliances, such as the Clean Marinas California Program, voluntarily work together to inform their members of BMPs that will improve their facilities. Meanwhile citizen advocacy groups, such as the Environmental Health Coalition and San Diego Coastkeeper, monitor the actions of the regulatory agencies.

All commercial boatyards and shipyards in the bay are regulated by NPDES permits that require implementation of BMPs.

Industrial stormwater discharges are regulated for each of the ten boatyards in the bay through regularly updated NPDES Permits (pursuant to §402 of the CWA), most recently issued in 2005 by the Regional Board (e.g. RWQCB 2005b). All three shipyards and the three Naval facilities are regulated under individual Waste Discharge Requirements (SDUPD 2007). For example, shipyard NPDES Permits were most recently issued for NASSCO in 2003 and BAE Systems in 2002 (see RWQCB 2007). Each permit requires specific discharge prohibitions, monitoring requirements, a BMP Plan, and a Storm Water Pollution Prevention Plan (SWPPP), among other requirements. The "first-flush" stormwater runoff (>0.1 inch) from each facility is required to be eliminated, since this initial rainfall event of each season tends to contain the highest concentration of pollutants. Drainage from each boatyard and shipyard site is usually collected, treated, and discharged to the city sanitary sewer system managed by the City of San Diego.

For each of the sites in the bay listed as impaired for water quality by the Regional Board (see Table 2-3), the state's strategy is to prepare a TMDL plan to address the allowable loading for each listed pollutant. Many of these sites are at marinas or at the mouths of creeks where shipyards are located (e.g. NASSCO pier and NBSD at the mouth of Chollas Creek). Complicating the picture is the determination of the relative contribution of pollutant loadings from these facilities versus the creek, which drains upstream sites in the watershed. Chollas Creek's copper, lead, and zinc loadings were separately addressed in a 2005 TMDL while another TMDL for bacteria pollutants at the Chollas Creek mouth is recently completed. Watershed sources of pollutants are also addressed through the urban runoff control requirements of the Municipal Storm Water NPDES Permit that covers all municipalities (county, cities, Port) in the bay's watershed, but not the federal jurisdiction of the Navy.

A TMDL for dissolved copper in the Shelter Island Yacht Basin was adopted by the Board in 2005 and may represent the approach for future TMDLs in the bay for copper (RWQCB 2005). Shelter Island Basin berths about 2,200 vessels. This large concentration of hulls with copper-based antifouling paint, combined with reduced tidal flushing in the artificially enclosed basin, has created conditions for the passive leaching of copper, found at levels as high as 8 to 12 ug/L in this marina. The water quality objective and numeric target for the TMDL, as defined by the California Toxics Rule, is 3.1 ug/L of copper over a chronic (four-day average) exposure and 4.8 ug/L over a maximum (one-hour average) exposure. Copper load reductions are required by the Board over a 17-year staged compliance schedule period, with a target of 76% reduction by the year 2022.

Complicating the picture for addressing areas of impaired water quality is the determination of the relative contribution of pollutant loadings from shipyards versus the watershed draining into the impaired site.

Both the EPA and the California Department of Pesticide Regulation regulate the application of anti-fouling paints. TBT coating applications were banned in 2003 by the International Maritime Organization and are to be eliminated by 2008 (Ingle in: Zirino and Seligman 2002).

Boat discharge of sewage also remains a management issue. The entire bay is a "No Discharge" Zone for treated or untreated sewage, as declared by the EPA (RWQCB 1994).

Educational Efforts and Experiment

Major educational efforts of the boating community are underway to address pollution problems. The Port recently produced the "San Diego Bay Boater's Guide" that suggests wildlife-friendly boating practices related to: sewage, bilge water and grey water, safe fueling, engine and topside maintenance, boat cleaning and maintenance, and hazardous waste (SDUPD 2006). Its website also offers clean boating information (portofsandiego.org). The UCCE Sea Grant Program (San Diego) has prepared "Clean Boating Tips 2007" and a "Clean Boating Guide 2007" as water pollution prevention aides for boaters, marina, yacht club and harbor managers, and boat maintenance workers (Johnson *et al.* 2006). Sea Grant continues to hold boater education seminars around the bay and suggests BMPs for underwater hull cleaners (UCCE 2007). The Port distributes the Sea Grant informational materials to the boating community during quarterly inspections at marinas as part of the Municipal Storm Water Program (SDUPD 1995b, 2006). Commercial and environmental representatives have also produced useful clean water materials for marinas and boaters in San Diego Bay (Bear 1989; Environmental Health Coalition 1991; USCG Auxilliary 1998). The Environmental Health Coalition has also led a 'Clean and Safe Shipyards Campaign' that seeks to make the bay's shipyards good employers and safe neighbors through toxic use reduction and other means (http://environmentalhealth.org).

Informative pamphlets and boater education seminars are part of the local pollution prevention program by the Port and UC Sea Grant for the boating community.

The voluntary Clean Marinas California Program is a special Clean Marina Program - San Diego Region that was agreed upon by the San Diego RWQCB's staff and board members to be an acceptable method to help address water quality in the area's marinas and yacht clubs (Clean Marinas California Program 2007). This effort is driven by a partnership of private and government marina owners and yacht club members, with close ties to the San Diego Port Tenants Association and UC Sea Grant (as a key advisor). Its BMPs are designed to provide environmentally clean facilities that will protect waterways from pollution. Compliance with the BMPs is part of the criteria for certification under the program, which allows the certified marina to display the 'Clean Marina' logo (see inset) and certificate. Since the program's inception in 2004, at least 15 marinas and yacht clubs in San Diego Bay have become certified. One of the values of their self-regulation approach is the natural incentive for the private sector to derive marketing benefits from this positive certification: flying the 'Clean Marina' flag helps boost occupancy rates and may help operators attract better clients (Innis 2007).

Fifteen bay marinas participate in the 'Clean Marinas' program, identified by this logo.

Evaluation of Current Management

Water and Sediment Quality Conditions

While many improvements have been made in management practices and in water quality conditions, the bay continues to have pollution problems at shipyards, boatyards, and marinas. The current water and sediment quality conditions are described in

Section 2.3.2: Hydrology, and need not be repeated in detail here. In summary, chemical contaminants found in the water column and sediment of most of the bay's harbors, ports, and marinas have led to these areas being listed by the RWQCB, SWRCB, and EPA as impaired water bodies (under §303(d) of the CWA). As noted in Chapter 2, Table 2-3, the predominant pollutants are dissolved copper in the marinas (e.g. Chula Vista Marina) as well as other heavy metals in the sediments at shipyard areas (e.g. Shoreline between Sampson and 28th Streets). Sediment toxicity and degraded benthic communities were other indicators of the relative pollution of these sites.

While one study found 86% of the surface water in 20 bay marinas having dissolved copper levels in the water column exceeding the state water quality threshold, toxicity was found in only 21% of the marinas' area (Schiff et al. 2006). The Bight '03 monitoring results indicated harbor/marina sites in the bay with higher levels of sediment contamination, but the severity of adverse biological effects could be interpreted differently, depending on which evaluation approach was used (Schiff et al. 2006).

No study has yet attempted to separate the relative contribution of historic sources and practices from current ones, although most would acknowledge that today's practices are better and a considerable amount of the contaminants in the bay's sediments are a legacy of over a century of intensive ship and boat use and maintenance (RWQCB 1994).

Enforcement Efforts

Enforcement of the CWA's provisions for shipyards, boatyards, and marinas is ongoing by the RWQCB. A Cleanup and Abatement Order was issued in 1995 to the former Campbell Shipyard, which operated from 1910 to 1999 near the corner of 8th and Harbor Drive, to remediate contaminated sediment; the Port remediated this site in 2007 (Photo 5-3). Two NPDES permits for shipyards were challenged in 1998 by the permittees for being unreasonable and not achievable, but the permits were later upheld by the State Board and the courts.

For the 55 acres of contaminated shoreline between Sampson and 28th Streets, the Regional Board has recently proceeded with preparing a Cleanup and Abatement Order in lieu of a TMDL program as the “appropriate regulatory tool” for correcting the impairment of this “Shipyard Sediment Site” (RWQCB 2007). The Tentative Order claims that certain shipyard operations have caused, or permitted, waste to be discharged to the bay in violation of waste discharge requirements over several decades, in addition to other dischargers at the site. Legacy pollutants possibly generated from past Navy operations at a former boatyard are also listed. Corrective actions are expected to clean up contaminated bay sediment to attain specific sediment quality levels for nine metals and three organics, based on a Remedial Action Plan. Dredging of almost 900,000 cubic yards of contaminated sediment at a possible cost of about $100 million is the identified feasible technology, which the Order acknowledges can be difficult to implement at a working shipyard. See also Section 5.4.1: Remediation of Contaminated Sediments.

This cleanup mandate, drafted and announced in 2005 and revised after much public comment, is currently in mediation with all the involved parties. The magnitude of the cleanup project is one factor, as well as (until recent progress) the lack of statewide guidelines for sediment quality. Public pressure to take immediate action is being placed on the Board by the SLC (with jurisdiction on state bays and tidelands), legislators, state officials, and environmentalists (Lee 2007a). The staff Technical Report, at 715 pages (and referencing thousands of pages of supporting documents), was recently released to provide the rationale and factual information for each finding in the Order (RWQCB 2007).

For the Shelter Island Yacht Basin Copper TMDL, the Regional Board proposes to implement it through the issuance of Waste Discharge Requirements, Waivers of Waste Discharge Requirements, or adoption of Waste Discharge Prohibitions. These methods could build upon pollution control programs developed by discharger organizations or the Port (RWQCB 2005). To help ensure environmental compliance, the Port incorporates environmental clauses into tenant lease agreements, assists tenants with environmental compliance issues, maps known contamination sites, and provides permit assistance (SDUPD 1995b).

In June 2007, the Navy and the DoD were charged in an environmental group's lawsuit with a violation of the NBSD's stormwater permit by illegally discharging into the bay stormwater carrying toxic pollutants (Lee 2007b). Some of these stormwater outfalls drain Naval operations that include ship repair and painting on the eastern shoreline. Questions were raised in the San Diego Coastkeeper's litigation about the implementation and effectiveness of the BMPs being applied and how quickly improvements were becoming evident. Expectations appear to differ between this organization and the Regional Board over what constitutes reasonable progress.

Boat Sewage Discharge

Boaters caught discharging sewage into the bay can be fined up to $2,000 (see Port's “Clean Boating” webpage). In practice, the discharge of sewage or other pollutants from foreign vessels or small boats is difficult to regulate. The RWQCB has no enforcement arm active in the bay (except the imposition of fines). The USCG is limited to dealing mainly with oil spills. The San Diego Harbor Police help to enforce the Port's ordinances. The CDFG can enforce Fish and Game Code §5650 on water pollution, but detection and proof are problematic. Since detected sewage pollution cannot be readily traced to an individual boat, an eyewitness is usually needed who is willing to go to court and testify. Clean boating brochures for the public, prepared by the Port and UCCE Sea Grant Program (among others), warn that state and federal laws prohibit the dumping of plastic, garbage, oil, and sewage (SDUPD 2006; Johnson *et al.* 2006).

The cumulative effect of sewage from boats in combination with bacteria from stormwater runoff can produce sufficient contamination to cause a short-term beach closure to human water contact in the bay (Gonaver *et al.* 1990). Sewage discharges in recreational marinas are considered to be more significant than at Naval berthing areas (RWQCB 1994). The Navy collects sewage on board and pumps it to shore-side sewage facilities. At present, 15 sewage pump-out stations are available to boaters in the bay (SDUPD 2006). However, boat users sometimes do not know how to use the pump-out equipment, are intimidated by it, are unaware of the facilities, or do not care. Besides marinas, anchorages can also be important sources of human pathogens from vessel sewage releases (RWQCB 1994). Regular sewage pump-out from liveaboard boats is an obvious area for education and enforcement.

Monitoring and Research

Monitoring needs to be designed to answer several different management needs related to water quality trends, BMP implementation and effectiveness, and compliance with WQS.

The monitoring of water and sediment quality in the marinas, boatyards, and shipyards of the bay has improved in recent years. To answer the many management questions, monitoring needs to focus on several different types and functions: (a) Trend (e.g. measurements at regular intervals to determine long-term trend in certain conditions), (b) Effectiveness (e.g. determination if a BMP had desired effect), (c) Compliance (e.g. determination if specified water quality criteria are being met), (d) Project (e.g. for construction or remediation project's effect evaluation), (e) Assessment or Study (e.g. for specific purpose) and (f) Implementation (e.g. whether activities, such as BMPs, were carried out as planned). Funding to support monitoring is always critical (e.g. a consistent funding mechanism) but is usually paid for by the bay's stakeholders (see Port's 'State of the bay 2007' report for more detailed summary of ongoing monitoring efforts).

Certain baseline monitoring (pre-BMP efforts) began in the 1980s and '90s, such as the State's Bay Protection and Toxic Cleanup Program (Fairey *et al.* 1996). Trend monitoring of water and sediment quality is ongoing in the bay, with the Bight '98, '03, and '08 regional monitoring program by SCCWRP, and in harbors, with the RHMP that is designed to integrate existing monitoring programs in the area. This latter program originated from a directive issued by the RWQCB. During its 3 year pilot phase ending in 2008, the RHMP will collect trend data on surface and sediment parameters and test the validity of its statistical design and needed frequency (SDUPD 2007).

Assessment monitoring is being performed by stakeholders for each of the ongoing TMDL processes, partly to better identify pollutant sources for source load reductions. Additionally, the SWRCB has the SWAMP performing periodic trend monitoring of water and sediments.

As a condition of the NPDES permits for all of the boatyards and shipyards, the RWQCB has required compliance monitoring of the water and sediment for each site. Cleanup and Abatement Orders also require monitoring as an indicator of success. However, these sampling stations are not necessarily the same as those used for previous monitoring programs or sites and the data may not be comparable or useful as a means to assess the effectiveness of the Board's permit conditions (e.g. BMP Plan). It is unclear whether Effectiveness or Implementation monitoring is systematically carried out for BMPs related to shipyards, boatyards, and marinas. Self-monitoring reports to the Regional Board for permits and TMDLs could be a tool to measure effectiveness of BMPs.

The 'State of the Bay 2007 Report' concluded that stakeholders are limited in their ability to accurately report on many matters that concern the public, such as bay health or Key Management Questions outlined in the INRMP, because of a lack of long-term, time series data specific to San Diego Bay and its harbors. Site-specific or focused studies, such as sediment characterization and TMDL investigations, will continue to be conducted as needed. More frequently repeated regional studies would aid trend analysis by increasing its statistical confidence. In particular, science-based copper criterion and SQO need to be implemented using widely accepted and peer-reviewed risk assessment protocols.

A science-based copper criterion and Sediment Quality Objective need to be developed using widely accepted and peer-reviewed risk assessment protocols.

Sediment quality objectives have recently been officially approved by California's SWRCB. Until SQOs were established, assessments of sites at shipyards, boatyards, and marinas were subject to interpretation. The SWRCB and its advisors developed these objectives for many years through a complex and technically difficult process. The SQOs use multiple lines of evidence that integrate the chemistry, toxicity, and condition of the benthic community to determine the health of the sediment.

Research into developing more scientifically relevant copper criteria is advocated by Navy scientists (Zirino and Seligman 2002). Water-effects ratios, for example, are one tool becoming more widely accepted for understanding what levels of copper create toxic effects on aquatic biota. While one of the best indicators of overall environmental toxicity is the available (noncomplexed) copper, this quantity is not being routinely measured in water quality monitoring and assessment programs though it can be readily measured. Navy managers also believe that a San Diego Bay-specific copper criterion is needed (B. Gordon, Navy, *pers. comm.*).

Promising nontoxic alternatives to copper-based hull coatings are now in the demonstration phase.

Research is underway for nontoxic alternatives to copper, TBT, and other biocides as anti-fouling coatings through a program under Naval Sea Systems Command (Zirino and Seligman 2002). One promising new method is called “foul-release coatings” because their unique surface chemistry creates a physical surface to which fouling organisms cannot readily adhere (e.g., silicone-based coatings) (U.S. Department of the Navy 1998). The bonding and durability of the new coatings are being tested in field demonstrations on a few Navy and USCG boat hulls. The drive to extend the interval between drydock maintenance periods (ideally greater than 20 years) and to reduce operating costs (e.g., removal of old paint) is setting the desired performance level of the antifouling coatings. Meeting stringent environmental requirements is another criterion. Navy vessels have higher antifouling requirements than commercial vessels since they are kept at pierside longer, where the majority of fouling occurs. If antifouling coatings are not effective, ships suffer through increased drag and fuel consumption, which can cause a significant increase in the Navy's fuel bill.

Alternative hull paints on recreational boats are also being studied by the Port and the UC Sea Grant Extension Program (see Port's 'Clean Boating' webpage). At least six different nontoxic coatings, such as epoxy, ceramic-epoxy and silicone-rubber, are part of the demonstration study on powerboats and sailboats. Initial results after at least four years experience by boaters with these paints were recently reported and appeared promising (UCCE 2006). To help convert recreational boaters to the new coatings, Sea Grant has a publication, “Transitioning to Non-Metal Antifouling Paints” (UCCE 2002).

The Port matched this grant for $190,000 to work with tenants on experimenting with alternative hull paints that do not leach copper in the bay and thus contribute to water quality problems. The Port was recently awarded a two-year grant by the EPA for evaluating and identifying "Safer Alternatives to Copper Antifouling Paints for Marine Vessels." The project incorporates a stakeholder advisory group to help identify viable alternatives to copper antifoulant and initiate the transition to these paints.

Management Strategy Introduction—Ship and Boat Maintenance

See also Implementation under Section 5.6: Outdoor Recreation and Environmental Education.

Much progress has been made in identifying and addressing the water quality problems related to shipyards, boatyards, and marinas. The regulatory tools have increased in application, scope, and enforcement. It will take time and probably considerable money to remedy the water quality effects of past practices that have released pollutants from these facilities into the bay, particularly sediments adjacent to or beneath these sites. Persistence and good science are key, along with adequate funding. The Navy has found that, as copper WQS and permit limits are lowered, it is becoming increasingly difficult and cost prohibitive for Navy facilities to achieve regulatory compliance (Zirino and Seligman 2002). They and other dischargers want to ensure that WQS for sediment and dissolved copper are scientifically based to ensure a focused investment in cleanup, and that the toxicity criteria that they are expected to achieve actually represent relevant environmental benefits.

Since the Regional Board is legally constrained in telling how dischargers must comply, an alternative approach would be for both the Navy and the Port to internally establish and enforce water quality procedures for their shipyards, boatyards, marinas, and anchorages. BMPs for stormwater runoff are implemented and promoted by all jurisdictions at this time; consistency in application and effectiveness in pollution control may be areas that need pursuing. The reasonableness of their cost will always be an issue. Perhaps a bay-wide partnership can help public entities obtain the needed funding, especially for being proactive rather than reactive to compliance issues (e.g. a Notice of Violation). Feedback is also needed on the effectiveness of voluntary programs, such as Clean Marinas, in reducing pollutant loads.

Finding nontoxic antifouling paint alternatives to the prevalent toxic coatings for boats and ships appears to be essential for the reduction of copper in the bay's water and sediment. Banning copper-based paints alone without an antifouling alternative is not realistic. Nontoxic coatings currently evaluated are known to create significant additional costs for boat owners. Such alternative coatings must also sufficiently repel AIS to prevent an unintended consequence (Johnson and Gonzalez 2006).

Management Strategy—Ship and Boat Maintenance

Objective: Manage the maintenance of boats and ships in San Diego Bay in a manner that achieves significantly improved water and sediment quality, healthier marine organisms, and economic good sense.

I. Promote opportunities for the prevention of pollution from shipyards, boatyards, marinas, and anchorage areas.

Pollution prevention through education and other voluntary means should continue to be promoted.

- *A.* Encourage education about each boater's clean water responsibility.
    1. Ensure that each boater is clearly educated about BMPs for proper boat maintenance through educational materials and presentations.
    2. Target boat dealers as a source for distributing information about BMPs in association with boat sales.
    3. Fully promote the recent voluntary compliance program of the boating community. Reevaluate in two years to determine its effectiveness in getting full participation and in reducing pollutant loading.
    4. Support the regular scheduling of UC Sea Grant sponsored seminars and workshops for the boating community throughout the bay.
    5. Prepare and distribute bay-specific radio and TV spots to educate about boating pollution, along with written handouts.

6. Work closely with nonregulatory, educational organizations such as the USCG Auxilliary, UC Sea Grant, and boating organizations in the promotion of pollution prevention.

B. Advance the concept to marina operators that clean marinas are good for business, such as through the Clean Marina program.

1. Ensure the continued provision of necessary facilities at sufficient bayfront sites for sewage pumpouts and waste oil receptacles for all boats
2. Actively promote BMPs for standard fueling, waste oil handling, bottom cleaning, repair, preservation, and painting procedures that must be followed by boaters.
3. Encourage marina operators to develop and practice BMPs that are beyond the minimum practices often expected, such as:
   a. Add green vegetated buffers at marina sites where possible for runoff control.
   b. Move power wash pads for boat hulls away from the bulkhead and adding filters to capture paint chips.
4. Emphasize cost savings of preventative actions in comparison to remedial, cleanup actions (following spills and chronic discharges).
5. Ensure frequent independent inspections of marinas for BMP compliance.
6. Promote better practices by recognizing significant efforts at marinas through an annual Better Bay Award program.

C. Promote pollution prevention as a major priority to boatyards and shipyards.

1. Support continuing education and training programs in stormwater BMPs for all managers and workers at these facilities.
2. Encourage the use of self-monitoring reports in BMP implementation and effectiveness at each facility. Develop lists of Lessons Learned based on experience with BMPs to help with improved practices.
3. Seek funding to help carry out these tasks, if needed.

Regulatory efforts must be supported when voluntary efforts are not adequate.

II. Support the application and enforcement of regulations when educational and voluntary practices are not sufficient.

A. Promote needed pollution control enforcement for boaters, marinas, and yacht clubs.

1. Encourage enforcement of marine debris regulations and the certificate of adequacy requirement of trash receptacles at all marinas and yacht clubs.
2. Encourage enforcement of marine sanitation device/holding tank regulations, and maintenance of sewage pumpout facilities for boaters and marinas throughout the bay.
3. Based upon a study of the levels of sewage-related bacteria originating from vessel discharges, the RWQCB should advise the vessel operator, County health officer, the Port, and the USCG so appropriate actions could be taken to abate the effects of sewage discharges from vessels.
4. Ensure that regular, legal sewage pump-out occurs from live-aboard boats as a condition of their use. Enforce for noncompliance when necessary.
5. Continue the use of the Port's Harbor Police to help enforce these requirements.

B. Ensure that BMPs are effective and diligently implemented. (See also: *IIIA* for effectiveness monitoring.)

1. Promote compliance of commercial boatyards and shipyards with existing NPDES permit conditions for BMP Plans and implementation.

2. Incorporate internal pollution prevention plan requirements by the Navy for Navy installations through specific instructions and by the Port for Port ship and boat maintenance facilities through lease conditions, to include specific components:
   a. An audit of all pollutants generated by the facility and their sources within the operation.
   b. An analysis of appropriate pollution prevention methods to address each pollutant.
   c. A strategy to prevent pollution, including specific objectives to be accomplished.
   d. Anticipated short- and long-term costs and savings.
   e. A detailed description of tasks and time schedules for the above.

C. Promote coordination among all local, state, and federal regulatory agencies on conditions and measures for managing boat and ship maintenance areas.
   1. Encourage local governments and the Port to address the water quality issues in their updated local coastal plans.
   2. Seek regulatory consistency among conditions and measures to simplify compliance for the permittees.

D. Support an active, on-water presence for enforcement, investigation, assistance, early warning sampling, and deterrence.

E. Support and seek adequate Congressional funding to help the DoD's shipyard facilities achieve water quality compliance through both proactive and remedial actions.

III. Foster an improved, coordinated monitoring and research program for marinas, boatyards, and shipyards.

Monitoring and research must be better coordinated to aid management decisions.

A. Develop the quality and quantity of information needed to better aid management decisions.
   1. Ensure standard monitoring stations and methods among the various monitoring programs to perform trend, effectiveness, and compliance monitoring for boat and ship maintenance areas.
      a. Support the adaptive implementation of science-based SQOs and a copper criterion by the SWRCB in order to have consistent and supportable compliance targets.
      b. Coordinate the development of consistent monitoring sites and protocols for the bay, such as through the RHMP.
   2. Evaluate the effectiveness of BMPs for shipyards, boatyards, and marinas through effectiveness monitoring (e.g. does the BMP work?) and BMP implementation/monitoring (e.g. was the BMP applied correctly?).
   3. Continue to evaluate the relative contribution of these facilities to water and sediment contaminant levels through trend monitoring, such as through the RHMP and the periodic Bight Regional Monitoring Program.
   4. Continue measuring the levels of sewage-related bacteria originating from vessel discharges in order to allow the Regional Board to make decisions based on measured levels, such as through current efforts by the County Environmental Health Division.

B. Promote research into methods and materials to reduce or eliminate pollution from boat and ship maintenance.
   1. Strongly promote the development of less toxic and non-biocidal antifouling paints for boat hulls.
   2. Ensure testing of new paints is thorough and adequate to protect the environment but not to a point that creates expensive disincentives for researchers. Ensure that alternative coatings are also effective against AIS.

3. Continue field demonstrations of promising nontoxic coatings on ships and boats in San Diego Bay to help evaluate effectiveness of durability, bonding, and repellency (of fouling organisms) under local conditions such as currently sponsored by the Port, Sea Grant, and EPA.

5.2.3 In-Water Construction

This section addresses construction activity and other disturbance in the water and the shoreline environment of the bay. Habitat values intrinsic to these structures are discussed in *Section 4.3.7: Artificial Structures*. The types of activities addressed include disturbance related to construction and maintenance of structures such as piers, docks, and wharves in the tidal zone, and roads, bridges, and buildings in the supratidal zone.

Specific Concerns

- Current engineering of shoreline structures does not always effectively consider habitat values of alternative designs. Current "rule of thumb" for construction buffer zones from the CCC may be inadequate for ensuring habitat impacts are avoided, especially for salt marshes. A need exists for optimal sizes and types of buffers that prevent disturbance to different species of birds at critical time periods. For example, increased lighting may make otherwise high value habitat unusable for some species. Night lighting may increase vulnerability of nesting birds to predation. Plants of the salt marsh may be affected by night lighting as it may disrupt photosynthetic processes. Effects of night lighting on wildlife are difficult to study and to prove cause-and-effect, but the sensitivity of the resource merits further study and that a cautionary approach be taken.
- While regulation protects in-water habitats from their direct impacts, shoreline structures may have incidental effects on adjacent habitats by modifying sediment transport currents. Road, bridge, and building construction or maintenance practices adjacent to the bay can produce sediment and contaminants that may enter bay waters or wetlands, or can interfere with tidal action or drainage patterns needed to sustain wetlands.
- While CWA Sections 404 and 401 offset many impacts of dredge/fill and water quality concerns, there are currently no regulatory or financial incentives to improve the habitat value of permitted shoreline structures.
- Shoreline areas have natural resource values that need characterization and quantification in order to assure proper avoidance and minimization measures are taken: (1) high tide refuge for birds, (2) habitat for species of upland transition areas, (3) buffer zone between bay habitats and the developed environment, and (4) sources of prey and juvenile nursery habitat for subtidal species.

Current Management

In cases where shoreline construction may affect listed species, offsetting measures are required under the ESA.

Shoreline construction or maintenance activity in Waters of the U.S. is permitted under the CWA and also must comply with EFH conservation requirements under the MSA, CZMA consistency, as well as NEPA and CEQA environmental assessment. In cases where listed species may be affected, an effects analysis is required under the ESA, such as that found in the Navy-USFWS Least Tern MOU on In-water Construction (renewal letter from Therese O'Rourke to Capt. Anthony T. Gaiani FWS-SDG-08B0211-08I0203 December 18, 2007). Other BMPs are implemented through the CWA Section 401/404 and EFH permitting process and address construction activities that generates turbidity, sedimentation, erosion, vibration, noise, and lighting that may hinder successful fish and wildlife use of the bay. In this way impacts are first avoided, then minimized, then mitigated consistent with permit requirements. Above the MHHW line, construction activities must comply with provisions of the CCA and ESA. The Navy, for example, has a General Consistency Determination for periodic replacement of piers and shoreline structures dated 1998 (CD-070-98).

Permitting for riprap and other structures that result in a complete fill to upland habitat is primarily reviewed for the requirement for no net loss of jurisdictional Waters of the U.S. (a balanced cut and fill must be part of the site plan). Mitigation for fill is required, as well as for impacts to marine resources or listed species. Per the Navy/USFWS least tern MOU, construction activities that generate noise or turbidity are restricted during the California least tern season to avoid impairing their foraging activities. The CCC may impose setback buffer requirements for construction not related to erosion control or vessel access. Current precedent for construction permitted by the CCC for buffer distances is 50 feet (15 m) in freshwater areas, and 100 feet (30 m) for the salt marsh. The CCC could adjust this requirement based on requests from commenting resource agencies.

Previous consultations with resources agencies such as NOAA have discussed in the NEPA and CEQA documents the addition of any kind of rock as a net benefit on a case-by-case basis because it can be more productive for fishes than soft-bottom habitat. The hard substrate provides for the attachment of algal and invertebrate communities that leads to enhanced fish populations. No mitigation would be required for this activity—for example, pier demolition normally does not require mitigation because of the assumed benefits of adding an "artificial reef" type of enhancement (the pier remains) to the bay's generally soft-bottom habitat. Alternative consideration is that the technique needs testing and monitoring to understand any negative effects, such as loss of soft-bottom prey.

In environmental assessments for bay projects the addition of rock has been considered a net benefit.

Standard materials used for piers and pilings vary. Waterfront structures such as piers and wharves are normally concrete decks with pre-stressed concrete piles. Fender systems depend on ship berthing requirements. The Navy currently uses the following systems in San Diego Bay:

In-water structures are constructed of material selected to protect water and sediment quality.

- Foam-filled rubber fenders backed by concrete reaction piles.
- Pneumatic rubber fenders backed by concrete reaction piles for submarines.
- Recycled plastic piles, with plastic "camels" in the water spanning over three piles.
- Plastic pile clusters for corner protection, with rubber buckling fenders.
- Fiberglass piles filled with concrete, again with the plastic camels.
- Pre-stressed concrete piles.

The choice of systems is based on the berthing energy of the ship(s) using the system as well as the type of materials. The Port, Naval Station and SUBASE are no longer using treated timber within the tidal range; the Navy ships use foam-filled fenders on concrete reaction piles. In between the ship berths, there are plastic piles used as a secondary system for small craft, and to keep debris from accumulating under the pier and damaging the structural piles or utility systems. At the corners of the piers, there is a system of plastic piles with rubber buckling fenders (out of the water) to prevent damage to the ship and pier in case of accidental impact. On the quaywall, concrete piles with rubber cylindrical fenders (out of the water) are generally used, since larger vessels pull up there. On a couple of piers, the Navy is trying the concrete-filled fiberglass piles for berthing barges, since they need stronger fenders than the plastic system. At SUBASE, the primary system for submarines is pneumatic fenders (similar to foam-filled, except that they are filled with air and configured vertically rather than horizontally). The Navy completed a project to install plastic pier pilings (made from recycled plastic) as a replacement for chemically treated timber pilings at SUBASE. A three-year demonstration and study of steel-reinforced plastic pilings was completed at NASNI Pier Bravo, where the pilings were evaluated primarily for durability, strength, cost, and environmental integrity. The Naval Station is using untreated wood pilings on an interim basis and is experimenting with plastic, concrete, and fiberglass pilings. NASNI is also using untreated wood piling on a temporary basis. NAB obtained approval for a one- time use of arsenic-zinc treated wood pilings and is seeking funding to use composite plastic piling in the future. The plastic composite pilings are triple the cost of wood pilings, but according to manufacturer claims, last three times longer than conventional wood pilings.

Choice of systems is based on the berthing energy of the ship(s) using the system, and type of materials. Plastic composite pilings are expensive; however, they last longer than wood pilings.

See also Section 4.3.7: Artificial Structures.

Evaluation of Current Management

Many examples exist around the bay of structures with clear differences in habitat value. For example, Shelter Island has better low tide habitat than Harbor Island where the structures and slope are too steep (R. Ford, SDSU, *pers. comm.*). Some rip-rap niches have been filled in with concrete, while others are filled with invertebrate fauna. Man-made structures need "gradual slope with lots of relief, places to retain water at low tides, some protection from wave attack, and a recruitment source." Three dimensional habitat complexity has been shown to enhance biodiversity in many marine habitats (J. Meigs, NOAA, *pers. comm.*).

Plastic pilings have apparently been functioning well at the Naval Station and other locations where they have replaced creosote pilings. They are expected to have a very long life. Levels of PAH (petroleum hydrocarbon residues), a contaminant tied primarily to weathered creosote pilings, has decreased around the Naval Station where the plastic pilings were installed, and there has been a slight decrease baywide since the 1990s (Katz 1995). From a regulatory standpoint, nearly all PAH measurements are below proposed EPA water quality criteria for California.

Management Strategy—Shoreline Construction

Objective: Seek improved habitat value of developed shorelines and marine structures and their functional contribution to the ecosystem.

I. Conserve existing habitat values.

- *A.* Encourage and promote construction of habitat friendly structures. Use data produced from Shoreline Structure project to support habitat friendly designs that meet the requirements of the construction activity.
- *B.* Recommend setbacks for CCC permits for new construction to effectively avoid impacts to habitat values, especially of sensitive habitats such as salt marsh/tidal flats.
- *C.* Ensure that the Navy's Regional Shoreline Infrastructure Planning integrates the goal and objectives of this INRMP.

As a top priority, initiate demonstration projects that provide data on habitat friendly shoreline structures that meet engineering requirements.

II. As a top priority, initiate demonstration projects that provide data on habitat friendly shoreline structures that meet engineering requirements.

- *A.* Convene the natural resources agencies, coastal engineers, hydrodynamic specialists, natural resources specialists, and Navy and Port project managers to develop habitat-friendly shoreline structure requirements for a range of shoreline wave energy conditions in San Diego Bay. The outcome would be structural designs to become part of Requests For Proposal when a need arises.
- *B.* Seek an agreement among regulators to support improvement in habitat value of shoreline structures.
- *C.* Seek mitigation credit for enhancing the habitat value of shoreline structures.
- *D.* Develop a consensus among regulators about the effects of placing artificial hard substrates in intertidal and shallow subtidal habitat.

III. Encourage the refitting of developed shorelines and existing structures to enhance habitat values.

- *A.* Besides providing their engineered function, design shoreline structures to mimic the original habitat structure and function (this refers to situations where the native substrate is a hard one). Maximize benefit to native bay species of fishes, birds, and invertebrates.
- *B.* Incorporate estuarine habitat attributes as elements of modified habitats in urbanized areas of the bay.

IV. Promote experimentation and application of alternative shoreline and underwater habitat structures.

- *A.* Develop objective design criteria.
  - *1.* Incorporate the best understanding about the attributes of the target habitat that promote the desired function.

2. Designs should incorporate several options or variations of a particular attribute to constitute a legitimate test of the concept, and to provide an adaptive direction towards design modification.
3. Incorporate contingency plans for each design element.

B. Promote the replacement program for all chemically treated wood pilings within the bay, which are no longer installed in the bay. The replacement of creosote pilings with those made from plastic should continue. The Navy and Port should produce a report on the effectiveness of removing creosote-soaked pilings in San Diego Bay.
1. Set a reasonable schedule for replacement.
2. Consider designating the PAH “hot spots” as high priority for experimental use of plastic pilings.
3. Promote evaluation monitoring in pier replacement sites to evaluate change.

C. Follow the success of the fish enhancement structures installed as part of the Navy CVN permit and the Port’s success with the installation of fish structures in a former underwater borrow pit in June 2006. The Port also installed more fish structures in the borrow pit in 2008 and at the Coronado Marriott and S. Embarcado fishing pier.

D. Monitor changes in invertebrate and algae populations that can result from alternative structural designs.

E. Identify and prioritize desired ecological function of artificial structures, including 1) trophic support for native fishes and birds, 2) habitat for migratory birds, 3) nursery/refugia for subtidal species, and 4) habitat for endangered and other special status species.

V. Promote experimentation and application of alternative LID and habitat-friendly landscaped areas adjacent to San Diego Bay.

A. Encourage appropriate native and water-conserving landscaping designs (“bayscaping”, “green shores” or “living shorelines”). The Port has an integrated pest management policy to minimize the use of pesticides and fertilizers on properties adjacent to the bay to enhance habitat value, prevent pollution, conserve water, and control invasive introductions.

B. Promote an award system for the best use of appropriate landscape designs.

C. Continue to update brochures, such as the Port’s Healthy Garden Healthy Home brochure, and web tools on appropriate landscaping for bayside properties using existing materials and demonstration gardens as a start (San Diego County Water Authority, National City’s native plant “palette” for landscape design, the NAVFAC Landscape Architect’s plant list, local Resource Conservation District guidelines, local nurseries that specialize in native plants, demonstration gardens at Chula Vista Nature Interpretive Center, Cuyumaca College, and the Tijuana Estuary).

5.2.4 Water Surface Use and Shoreline Disturbances

Specific Concerns

- Federal law, enforced by the USCG, protects the right of navigation in waters of the U.S. Commercial and military traffic is expected to increase in the bay area.
- Boating is an important and growing recreational use of the bay and boating trends are toward smaller, faster watercraft, which tend to be the most disruptive class of boats to wildlife. Pressure from boating on bay birds is not well known.
- Special recreational boating events, permitted by the USCG, can significantly affect bird populations if not properly planned.
- Disturbance by human activities such as boating can result in direct mortality, cause displacement from habitats and excess energy expenditure, disrupt feeding and nesting or roosting, and expose sensitive bird species to predation.

Photo 5-2. East Pacific green sea turtle in San Diego Bay. Photo courtesy of E. Maher.

Background

Birds are affected by disturbances to varying degrees and with often poorly understood consequences to their long-term well-being at local and regional scales. Disturbance of birds can result from excessive noise on the open water or at the shoreline, landings by boaters at sensitive areas protected from the landward side but not at the water, and excessive levels of night lighting from associated commercial and industrial areas. It is known with some certainty that anthropogenic disturbances on open water or at the shoreline can change activity budgets of birds and reduce their production and survival in several ways (See also *Section 4.4.4: Birds* and references in Dahlgren and Korschgen 1992; York 1994; Cywinski 2004). Characterizing the local nature of these disturbance factors—and relating them to the current regulatory environment—are necessary to developing practical management strategies aimed at addressing local conservation priorities for birds in the San Diego Bay area.

In general, waterbirds use all regions of the bay, although there may be some differences in habitat values among the regions.

Abundance and distribution of waterbirds in the San Diego Bay area are summarized in detail in Section 2.6.5: Birds. In general, waterbirds such as diving ducks, geese, and brant use all regions of the bay although there may be some differences in habitat values among the regions. The south bay and central bay are especially important to shorebirds, dabbling ducks, and sea birds. Almost certainly, regions of the bay that have experienced excessive habitat losses—for example, intertidal areas in the north bay—were used considerably more by birds than is seen today. Conversely, sites such as the Salt Works in south bay have become important secondary habitats compensating to some degree for the loss of primary habitats and preventing further development in the far south bay.

Larger, slow-moving ships have not been identified as a major disturbance to birds on the bay.

Current Management

On the open water of San Diego Bay, boating is the primary surface use that may disturb birds. Being a relatively small bay, conflicts between watercraft and birds may occur more often than in bays where uses are not so compressed, such as San Francisco Bay (M. Kenney, *pers. comm.*). Disturbances may be from commercial ship traffic, military ships, recreational water vessels, and low-flying aircraft associated with the military bases and the San Diego airport. For the latter, there is no information about effects on birds. Map 3-5 shows boat traffic patterns on San Diego Bay based on 1995–1996 data from several sources. In general for boating, the large military and commercial vessels are confined to the deep channel in the central and north bay (with the exception of some cross-bay ferry excursions in north bay). These larger, slow-moving ships have not been identified as a major disturbance to birds on the bay. Their direct impact might be expected to be primarily from displacement of rafting birds.

At this time, the management measure with the most direct implications to boating disturbance of birds is the 5 mph speed limit in south bay. This speed limit is effective in minimizing disturbance to birds if it is adhered to by boaters and if used in concert with other management measures that minimize close proximity contact between birds and boaters.

In addition, there are restrictions on public access to the channels entering the Sweetwater Refuge and to the salt ponds. Finally, a fisherman's quick reference guide to sea bird protection was developed as an interagency project to inform the fishing and boating public about ways to minimize disturbance and harm to sea birds.

Multiple development plan recommendations could significantly alter the current land-use patterns of the south Bay and lead to increased disturbance at nesting and roosting sites.

Future developments may increase use by boaters. Included in the boundaries of the City of National City's Harbor District Specific Area Plan (City of National City 1998) is an approved land use designation for tourist commercial use of the 8.3 acres located on the bluff immediately to the north of Paradise Marsh, as well as a limited area of medium industrial use to the west. This Specific Area Plan, which encompasses both the General Plan recommendations for the area and Local Coastal Program requirements, covers the lands located between 24th Street in National City south to the Sweetwater Channel and west from I-5 to the Burlington Northern Santa Fe Railroad. The City of Chula Vista and the Port are currently developing plans for the Bayfront Redevelopment area that could change current use of the area east of the South San Diego Bay Unit of the NWR. This redevelopment area extends from near the F&G Street Marsh in the Sweetwater Marsh Unit to the south end of the South Bay Power Plant site. Proposals envision a significant increase in the intensity of uses occurring in the vicinity of the Chula Vista Marina, to the east of the J Street Marsh, and within the existing power plant property. The plans also propose to improve public access to the bay and could result in the development of residential uses adjacent to some portions of the Refuge. The property currently occupied by Ponds 50 through 54 in south bay is currently being considered for development as part of another redevelopment planning effort to the south of the bayfront. Another potential future redevelopment site is the 17-acre portion of the salt works owned by the Airport Authority. The Airport Authority had leased this property to the South Bay Salt Works, but that lease expired in 2007.

Evaluation of Current Management

Recreational surface uses of the bay in the form of jet skis, powerboating, waterskiing, sailing, and kayaking likely represent greater sources of disturbance to birds than military and commercial craft. This disturbance would be both on the open water and at the shoreline where people embark and disembark from their boats. Because of their mobility, most of the bay regions could are accessible to recreational boats and boaters. Based on earlier surveys, activities and locations of especially concentrated use include sailing in the north bay, jet skis in and around Glorietta Bay in the central bay and points north, and powerboating and waterskiing along the Silver Strand in the central and south bay regions. Canoes and kayaks are not known to be a substantial disturbance source for birds, although this has not been specifically investigated.

Human disturbance, including lights, noise, boats, the presence of people, free-running pets and feral animals, may determine levels of bird habitat use more than the biological suitability of the habitat. Waterfowl sensitized to boating disturbance will often flush when a boat motor approaches within 0.6 mile or more (Kahl 1991). Migratory birds stopping in an area for rest and replenishment have been shown to be especially susceptible to disturbance (Figley and Vandruff 1982). Migrating birds do not accustom themselves to boat movements as resident birds do (Figley and Vandruff 1982). Effects on foraging birds attempting to build energy reserves before continuing their migration can be significant enough at a physiologically vulnerable time to affect their productivity. And a high level of disturbance can decrease the carrying capacity of an area (Dahlgren and Korschgen 1992).

Overall, human activities can cause displacement, excess energy expenditure, disruption of feeding, nesting, and roosting, and increased predation exposure. The timing and frequency of disturbance events, as well as the species involved, can result in very different impacts.

Cywinski (2004) summarized the effects of motorized watercraft on waterfowl. When approached by powerboats or jet skis, waterfowl generally take flight, though the distance flushed and the amount of time spent in flight varies. Flushing can significantly reduce feeding time, deplete energy resources, cause avoidance of prime feeding sites and decrease reproductive success. Boats also enable humans to enter remote areas such as small islands and wetlands that are essential foraging and breeding sites for waterfowl. The energy cost of flight is high, 12 times the basic metabolic rate of waterfowl (Ward and Andrews 1993). Therefore, waterfowl must increase their food intake to make up for the lost energy, which can be difficult when food supplies are limited (Ward and Andrews 1993).

Cywinski (2004) also compared watercraft types in relation to disturbance of birds. Personal watercraft have the ability to operate at high speed in shallow areas, such as wetlands and near shorelines, where waterfowl feed and breed. They produce a large vertical and horizontal spray due to their deep, V-shaped hull. Rodgers and Schwikert (2002) studied 23 species of waterfowl on the east and west coasts of Florida and observed that the great blue heron flushed farther when approached by personal watercraft than by boat, while little blue heron, willet, and osprey exhibited significantly larger flush distances in response to the outboard powered boat. A study by Havera *et al.* (1992) showed waterfowl took flight in response to hunting and fishing craft, while few flushed because of barges. Korschgen *et al.* (1985) found that birds were more sensitive to boats with outboard motors. In a study of management options to reduce boat disturbance on foraging black guillemots *(Cepphus grylle)*, a seabird, in Canada (Ronconi and St. Clair 2002), it was found that smaller boats had more tendency to flush than medium ones. That species is considered particularly sensitive to flushing because it forages close to its breeding colony.

The rate or frequency of disturbance may be the most important factor influencing the severity of flushing effects to birds, possibly more so than the simple magnitude of a temporary disturbance. Speight (1973) noted that the frequency of human presence seemed to have a larger impact on waterbirds than the number of people involved in creating any particular disturbance. Observations on Silver Strand beaches of western snowy plover and other shorebird response to the presence of unmanned aerial vehicle testing and recreational beach users also showed a stronger response to human presence on the beach than to vehicle use (in this case overhead) (E. Copper and B. Foster *pers. comm.* to T. Conkle 2006). Repeated disturbance at nesting and roosting sites may disrupt pair and family bonds, force birds into sub-optimal habitats, cause birds to repeatedly flush or permanently abandon nests, and expose birds and eggs to higher predation rates (for example, MacInnes 1962; Cooch 1965; Choate 1967; Mickelson 1975; Bartelt 1987; Purdy *et al.* 1987; Pomerantz *et al.* 1988). Frequent disturbance may also exact substantial energetic consequences to staging birds by repeatedly forcing them into lower quality feeding areas and reducing time spent foraging and building up fat reserves necessary for successful migration (Belanger and Bedard 1989, 1990). Dahlgren and Korschgen (1992) equated the effects of excessive disturbance of birds to loss of habitat where both diminish the availability of preferred habitat to birds.

Timing of disturbance can also contribute to the magnitude of effects. For example, energetic consequences of disturbance may be greater for some species in the spring than in the fall (Kahl 1991). Birds may also be more wary and sensitive to disturbance seasonally or coinciding with important physiological cycles, such as while nesting or during seasonal molts when birds are temporarily rendered flightless (Speight 1973; Anderson 1978). Finally, the frequency and severity of disturbance may be greatest on weekends, simply because more people are coming into contact with birds than during the week (Hartman 1972; Evenson *et al.* 1974).

The severity of disturbance may also be related to the type of bird and the habitat in which birds experience the disturbance. For example, as a group, diving ducks may be more sensitive to disturbance than dabbling ducks (Sincock 1966), shorebirds more than waterfowl (Purdy *et al.* 1987), and migratory birds more than resident ones (Figley and VanDruff 1982). Speight (1973) believed that birds of open habitats, like waterbirds exposed in deep water, are especially susceptible to disturbance. Bratton (1990) found that birds of the Ciconiiformes order (herons, egrets, bitterns) were more likely to flush in estuaries than from shores. Birds that are reportedly especially sensitive to disturbance include goldeneye, scoter, gadwall, merganser, ring-necked duck, green-winged teal, northern shoveler, scaup, and black brant (especially by low-flying aircraft) (see reviews in Dahlgren and Korschgen 1992 and York 1994).

Boating can also directly damage habitat by removing vegetation and reducing submerged vegetation (Liddle and Scorgie 1980; Bouffard 1982). Eelgrass scour boats has occurred on bay beds, and as boats enter salt marsh areas at high tide in south bay. This can be either a direct result of propeller and boat contact with substrates or vegetation loss at the shoreline from repeated wakes caused by boats and water skiers. Recovery of the marsh vegetation may be very slow. The impacts of propeller and collision injuries to sea turtles is an additional concern in the bay (see Section 4.4.6.1: Green Sea Turtle).

The impacts of propeller and collision injuries to sea turtles is an additional concern in the bay (see Section 4.4.6.1: Green Sea Turtle).

Huffman (1999) studied the effect of boating disturbance in south bay. This study consisted of 25 days (6 hours per day for a total of 150 hr) of observations between mid-January and the end of March 1998. The study examined specific disturbance types, number of boats per day, hour and month; differences among subareas of south bay; and differences between high and low tides. Bird reactions were recorded for both flush length and flush time. Flush length refers to the total distance the bird traveled from when first flushed to resting location. Flush time was the total duration the bird was in flight. Average and total disturbances by month and by type are presented in Table 5-5. During surveys of central bay in 1994, Ogden (1995) summarized 637 observations on bird flushing distances from a 23 feet (7 m) survey boat, shown in Table 5-6. These numbers suggest at least some energetic loss of these species.

Table 5-5. Totals and averages for specific disturbance types for the entire South Bay Study Area.[a]

Disturbance Type	Totals			
	January	February	March	Totals
Pedestrians	123	297	142	562
Speed boats	22	50	68	140
Sailboats	22	91	21	134
Dogs	24	50	28	102
Kayaks	4	39	38	81
Wind surfers	1	39	31	71
Fishing boats	9	29	18	56
Cabin cruisers	21	25	8	54
Helicopters	16	23	8	47
Jet skis		14	18	32
Canoes			14	14
Dinghies	2	4	8	14
Planes	10	2		12
Blimps	3	6		9
Catamarans		3	2	5
Long boats		1	4	5
Harbor patrol	2		2	4
Speed boats w/skier			5	5
Row boats	1	2	1	4
Tug boats	2	1		3
Trucks		1		1
Schooners		1		1
Pontoons			1	1
Barges			1	1
TOTALS	262	678	417	1,357
Total days/month	5	10	10	25
Total hours/month	30	60	60	150
Disturbance/day	52.4	67.8	41.7	54.3
Disturbance/hour	8.7	11.3	6.95	9
Water craft/day	17.2	29.9	23.9	25
Water craft/hour	2.9	5	4	4.2

a. Huffman 1999

Table 5-6. Percentage of Birds Sampled Avoiding Survey Boat by Distance Category in Central San Diego Bay[a].

	Flushing Distance Interval (feet)			
Species	0 to 10	11 to 100	More than 100	Sample Size
Bufflehead	1.0%	66.5%	32.5%	197
Surf scoter	1.3%	43.3%	55.3%	150
Double-crested cormorant	0.0%	64.6%	35.4%	79
California brown pelican	1.6%	67.2%	31.1%	61
Eared grebe	11.9%	74.6%	13.6%	59
Great blue heron	0.0%	75.0%	25.0%	52
Brant's cormorant	0.0%	69.2%	30.8%	39

a. Numbers in bold indicate the highest proportion of avoidance behaviors.

Huffman noted that the speed limits in the south bay were rarely adhered to. She developed several recommendations for managing boating and non-boating human disturbances of birds in the south bay region during the months of January through March: (1) restrict access of the far south bay to non-motorized boats, (2) strict enforcement of the 5 miles-per-hour speed limit that was routinely violated by boaters during her study, (3) restricting all human access to the extreme end of the south bay including all of the salt ponds, marshes, and intertidal mudflats associated with the Salt Works where the birds were at their highest densities and were least exposed or acclimated to human disturbance, (4) enforce a no-(human) activity buffer zone of 328 feet (100 m) off the main shoreline, CVWR, and parts of the Silver Strand and prohibit watercraft of any kind from landing at the Reserve, and (5) prohibit low-altitude fly-overs by aircraft, mainly blimps.

Alternative management strategies have been proposed and used elsewhere to protect bird species and important use areas from disturbance.

Alternative management strategies that have been proposed or used in other areas to protect priority bird species and important use areas from harmful levels of disturbance include: (1) posting nesting colonies; (2) establishing temporary or permanent buffer zones and setback areas; (3) creating no-wake or non-motorized boating zones; (4) establishing inviolate refuges; (5) restricting certain activities such as fishing or hunting; (6) increasing public awareness; (7) increasing the quantity, quality, and distribution of habitats to alleviate overcrowding; and (8) providing alternative refugia away from disturbance (see Dahlgren and Korschgen 1992 and York 1994).

The extent to which current levels of disturbance diminish the health of birds and how best to manage those disturbances is not well measured and understood (but see discussion on the south bay survey report by Huffman). As pointed out by Bowles *et al.* (1991), stress is not necessarily indicative of negative consequences to individual life histories or to populations. The high recreational, commercial, and military values of the bay to boaters cannot be minimized, and it is important that compatible management of surface uses with bird and other wildlife populations properly weigh the costs and benefits of further surface use restrictions. Management of boating disturbance is difficult to prioritize in the context of its relative importance compared to other threats, such as:

- Loss, fragmentation, and degradation of salt marsh, sandy beaches, mudflats, and upland transition habitats.
- New introductions of natives not previously observed in the bay due to expanded ranges, perhaps due to problems elsewhere. This has occurred with the black skimmer, elegant tern, and gull-billed tern.
- Community level changes, such as the invasion of crows, as a result of continuing urbanization.
- Loss of breeding grounds outside the bay.
- Bioaccumulation. The brown pelican, peregrine falcon, and double-crested cormorant are all recovering from past effects from bioaccumulation. Bonaparte's gulls may be susceptible due to its proclivity for sewage outfalls. Birds migrating from southern latitudes may be more susceptible to this problem.

- Over-harvesting of prey. Commercial fishing operations often crop 50 to 70% of fish production so that little is left for natural predators (Furness and Ainley 1984, cited in Baird 1993). While such harvesting does not occur in the bay itself, fishing offshore can affect populations that migrate into the bay or use the bay for juvenile life stages, and are used as forage by sea birds.
- Climatic cycles or change.

Management Strategy—Water Surface Use and Shoreline Disturbances

Objective: Properly balance the various surface uses of the bay as a navigable waterway and associated shorelines with conservation priorities for waterbirds and shorebirds.

I. Establish priorities for managing disturbance to birds that use the open water and shorelines of the bay.

A. Identify species of primary concern and their habitats within each group that uses the bay (waterfowl, shorebirds, sea birds, and marsh birds).

B. Identify types, location, and frequency of disturbance to these birds and their habitats around the bay.

C. Identify specific standards of acceptable levels of disturbance for these species using criteria such as the rarity of the species and its habitat, sensitivity to disturbance, and period when birds may be most susceptible to and impacted by disturbance.

D. Identify zones of overlap among several important bird habitats and high disturbance to help prioritize disturbance management.

II. Establish specific management measures to minimize disturbance at high priority sites for conserving birds of special concern within each group.

A. Locate, time, and permit special boating events to minimize disturbance to high-use areas for birds.

B. Retain and enforce the 5 mph speed limit in existing areas and identify other sensitive areas needing speed limits (see also recommendation in San Diego Bay Interagency Water Quality Panel 1998).

C. Adopt the recommendations of Huffman (1999) for the south bay region during the months of January through March.

D. Review whether some or all of Huffman's recommendations are relevant to manage disturbance in other regions of the bay or at additional times in the south bay region.

E. Protect critical shoreline and transitional habitats from excessive land- and water-based disturbance through creation of buffer zones and setback areas of sufficient size for the species and type of disturbance. The buffer zones and setbacks may be seasonal to address lower levels of disturbance at critical times (e.g. nesting) or they may need to be permanent to address higher levels of disturbance (e.g. creation of new developments nearby).

F. Predation may be the greatest source of mortality and nesting failure of birds in the transitional habitats and a baywide predator management strategy needs to be developed.

G. Develop a baywide policy to address the harmful disturbance and predation of birds and nests by domestic pets at key sensitive sites.

H. Develop a baywide strategy and regulatory standards for minimizing the effects of lighting on sensitive habitats and sites.

1. Establish setbacks for new construction in association with other techniques that establish a no-net increase of ambient light that affects plant growth or other values at the Sweetwater Refuge and other important nesting and roosting sites.

2. Recommend that larger setbacks be a condition of permits issued by the CCC.

III. Recognize through regulatory oversight the extremely high foraging, nesting, and refugia values the remnant intertidal and transitional habitats represent to birds that use and rely on the bay.

A. Establish a policy of no net-loss of intertidal and transitional habitats.

B. Reestablish habitats that will promote populations of birds throughout the bay, such as intertidal habitats in north bay.

C. Consider these areas while planning, providing environmental documentation for, and permitting special boating events.

D. Develop a management plan that ensures maintenance and enhancement of the habitat values of the salt evaporation ponds at the Salt Works.

IV. Expand the public information and education program targeting surface disturbance of birds and habitats.

A. Expand the concept of the "Fisherman's Quick Reference Guide" to all segments of the recreational, commercial, and military boating publics.

B. Involve and work with the boating community to arrive at a solution to bird-boater conflicts.

5.3 Watershed Management Strategies

Watershed management is a critical component of a sustainable and compatible use strategy for San Diego Bay. By definition, watershed management integrates many of the natural resource issues related to water. Much of the local focus currently is on stormwater, or urban runoff, management but the subject extends beyond water quality.

5.3.1 The Watershed Management Approach

What is Watershed Management?

We all live in a watershed - the area that drains to a common waterway, such as a stream, lake, estuary, wetland, or, ultimately, the ocean.

The terms "drainage basin" or "catchment basin" are sometimes used synonymously with "watershed." Watersheds vary by scale and are categorized, from largest to smallest, as: River Basin, Subbasin, Watershed, Subwatershed, and Drainage (McCammon 1994). Embedded in the concept of watershed management is the recognition of the interrelationships among land use, soil and water, and the linkages between uplands and downstream areas (Brooks 1991). Habitat, soil erosion, flood protection, wildfire protection, water supply, and water quality are all interrelated and function at the watershed scale. Air pollutants and precipitation also act together to link atmosphere and water.

Federal and State Watershed Initiatives

EPA has long used a watershed approach to help restore and protect the nation's water resources through watershed planning and management.

The EPA has promoted the "watershed protection approach" since the late 1980s (EPA 1991, 1995). That agency defines the approach as "a strategy for effectively protecting and restoring aquatic ecosystems and protecting human health." The presumption is that many water quality and ecosystem problems are best solved at the watershed level rather than at the individual waterbody or waste discharger level. Four major features are involved: (1) targeting priority problems, (2) a high level of stakeholder involvement, (3) integrated solutions that make use of the expertise and authority of multiple agencies, and (4) measuring success through monitoring and other data gathering. This approach is a departure from EPA's traditional focus on regulating specific pollutants and pollutant sources by instead encouraging an integration of regulatory and non-regulatory programs.

Over the past decades, organizations and agencies have moved towards managing water quality by using a watershed approach. EPA states on its website that it "has embraced this change and is working with its partners to help coordinate the development of comprehensive watershed plans through the publication of planning guidebooks, implementation of live and on-line training courses, and the development of web-based tools." EPA encourages the development of watershed plans through use of the watershed planning process, which includes stakeholder involvement and management actions supported by sound science and appropriate technology. It also identifies water quality goals and specific actions required to solve those problems.

The U.S. Navy has a policy on Watershed Management (OPNAVINST 5090.1C: 9-5.2): *Installations should apply a watershed approach when evaluating the impact of their overall activities on the quality of area water resources and address water impacts by reducing pollutant discharges. A watershed approach is an integrated holistic management strategy that addresses the condition of land areas within the entire watershed. It ensures that non-point sources as well as point sources of pollution are addressed. Navy water program managers should consult other media experts (e.g. natural resources, Resource Conservation and Recovery Act/Comprehensive Environmental Response, Compensation and Liability Act [CERCLA], and air) to fully implement the watershed approach. Installations that discharge pollutants to or near impaired waters should get involved as early as possible in the state or local process that leads to the identification of impaired waters and the development of TMDLs.*

EPA and the SWRCB recognize that many water quality and ecosystem problems are best solved at the watershed level, by integrating regulatory with non-regulatory programs.

The SWRCB and the nine RWQCBs pursued the EPA approach by calling for a Watershed Management Initiative (WMI) in their 1995 Strategic Plan. They wanted their actions and decisions to be guided by a comprehensive perspective that considers all water-related impacts occurring in a watershed. Officially begun in July 1997, the Initiative is expected to be a long-term process that will take years to accomplish. The WMI establishes a broad framework overlying the numerous federal and state mandated priorities. As such, the WMI helps the Water Board to achieve water resource protection, enhancement and restoration while balancing economic and environmental impacts.

In 2004, a Watershed Management MOU between the California EPA and the Resources Agency defined a cooperative process for improving watershed health in California for their various agency programs. Implementation efforts are overseen by the Secretaries for California EPA and Resources. The MOU was designed to implement:

- The California Agency Watershed Strategic Plan
- Coordination of the Integrated Watershed Management Program (from Proposition 40 and subsequent bond measures) with other Watershed Programs
- Stakeholder advisory processes to assist in setting priorities and allocating funds
- Watershed protection objectives in the Governor's Environmental Action Plan and Ocean Action Strategy

The federal Safe Drinking Water Act of 1996 has also created another reason to focus on watershed management. In response to the act, the California Department of Health Services has implemented a Drinking Water Source Assessment and Protection Program. By addressing existing and potential sources of pollution of surface and groundwater within the watershed, local water districts can save money implementing drinking water source protection rather than expend extra dollars on new facilities to perform expensive treatment measures. Bacterial and viral contamination sources are of major concern to drinking water suppliers.

Federal and state programs provide grants for local watershed restoration efforts.

Watershed restoration at the local level is a focus of the State Coastal Conservancy as well as the Coastal America Partnership Project of federal agencies (Coastal America 1994; Kier Associates 1995). State and federal grant programs are available to assist local government and watershed organizations with watershed planning, management, and restoration project implementation.

The San Diego Bay Watershed

Covering 442 square miles, the watershed draining into San Diego Bay is a mix of major and minor sub-watersheds that encompass the jurisdictions of 7 cities, the county, the Port, State Parks, USFWS, and the U.S. Navy. The bay's watershed supports a resident population of almost 1 million as well as many more daily commuting workers and short-term visitors (Table 5-7) (San Diego WURMP 2003). The three primary sub-watersheds, from north to south, are: Pueblo (includes Chollas Creek and Paleta Creek), Sweetwater River, and Otay. San Diego Bay's subwatershed areas are delineated on Map 5-1, with lower reaches shown on Map 1-2.

Table 5-7. San Diego Bay watershed and sub-watershed area by jurisdiction.[a]

			Jurisdiction (% of total)								
Watershed	Size (Acres)	Percent	Chula Vista	Coronado	La Mesa	Lemon Grove	Imperial Beach	National City	San Diego	Unincorporated	Port of San Diego
San Diego Bay	282,632	100	10.8	1.7	1.0	0.9	0.2	1.6	13.1	69.8	0.9
Sub-watershed											
Pueblo	36,061	12.8			4.5	4.6		7.0	83.6		0.3
Sweetwater	148,038	52.4	8.9		0.8	0.6		1.2	1.4	86.6	0.5
Otay	98,533	34.9	17.6	5.0			0.7	0.1	6.7	69.7	0.2

a. Source: San Diego WURMP (2003).

San Diego County's Watershed Approach

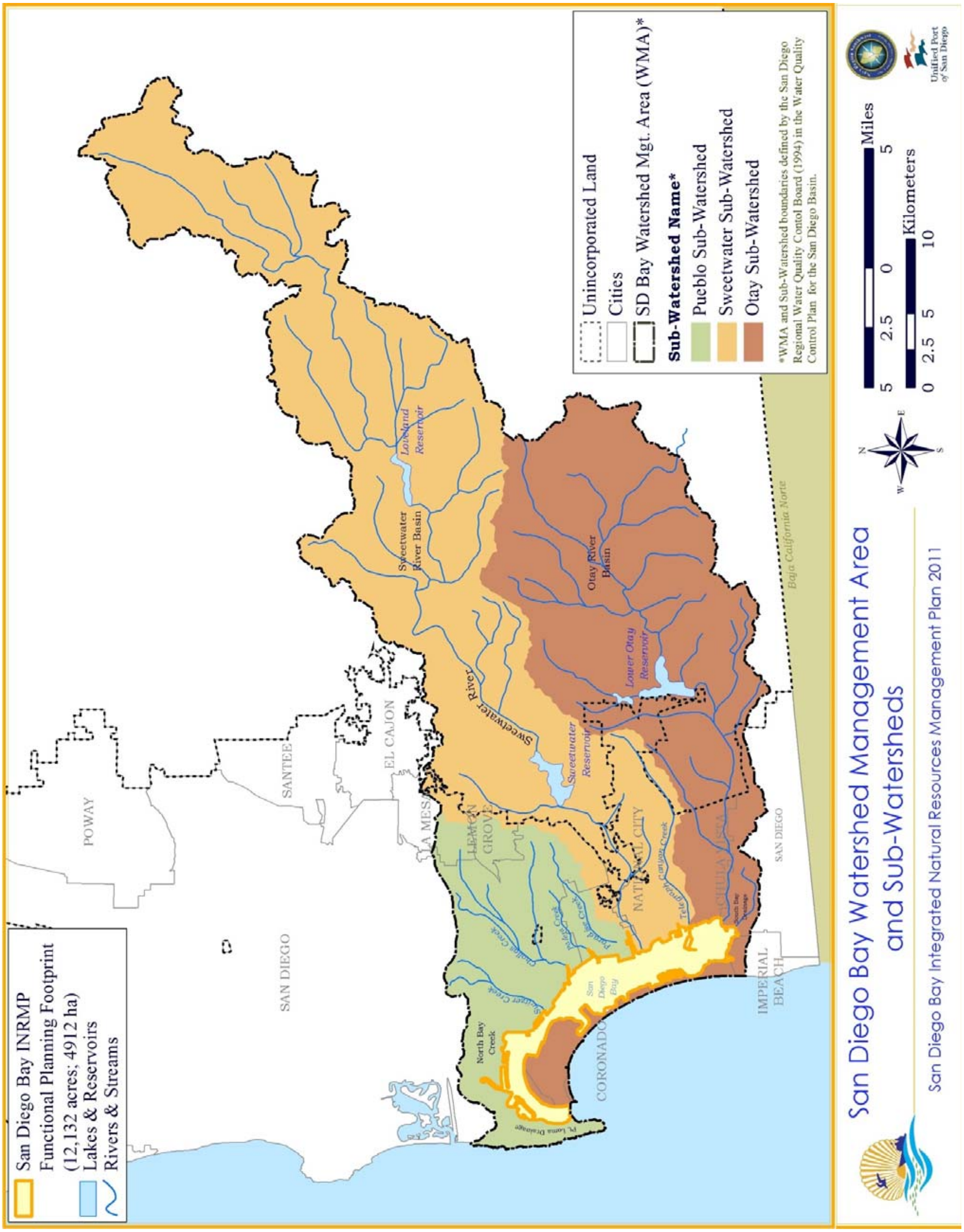
Community-based watershed organizations began in the County in the early 1990s.

Watershed-based efforts in San Diego County have developed for a variety of reasons. A brief history is valuable to show their evolution. Several local grassroots and government-based groups using a type of watershed approach began in San Diego County in the early 1990s, before the official push by EPA and the SWRCB (Johnson 1999). These community-based watershed organizations came together to address a multitude of issues, including water quality restoration, flood and floodplain management, water supply, invasive riparian species management, and stormwater management.

In 1992, the San Diego Bay Panel Interagency Water Quality Panel began focusing through its consensus process on ways to coordinate management activities of public, private, and non-profit organizations that could affect the bay. Watershed management was one of the strategies promoted in its final Comprehensive Management Plan (San Diego Bay Interagency Water Quality Panel 1998). A report produced by the Port Tenants' Association, called the “Bay White Paper”, highlighted the growing role of nonpoint source pollution, most notably from stormwater runoff, in the bay's watershed. It encouraged the use of a coordinated, watershed-based management approach to nonpoint source pollution (Science Applications International Corp. 1998). The importance of watershed planning, the overlay of watersheds with multiple local jurisdictions, and the population and current and projected land uses for each of the region's major watersheds were the subject of a SANDAG publication (SANDAG 1998).

The San Diego Bay Watershed Task Force was created in 1998 as an outgrowth of the Bay Panel program by SDUPD Commission Chair David Malcolm (Johnson 1999). A San Diego County Watershed Leadership and Coordination Conference was held that same year. The Task Force process established committees for the three major sub-watersheds of the bay: Otay River, Sweetwater River, and Chollas Creek (Johnson 1999). That year was also when the San Diego RWQCB released its Watershed Management Approach. The RWQCB later produced a Watershed Planning “Chapter” for the state WMI initiative (RWQCB 2002).

While the watershed approach combines both regulatory and voluntary mechanisms, the regulatory requirements to comply with the CWA at the watershed scale have become dominant in the past decade.



Map 5-1. Watersheds affecting San Diego Bay.

TMDL Development for Watersheds

One of the added incentives for local watershed planning is the need to accomplish TMDL plans for all waters that are listed as impaired under CWA §303(d) (see Table 2-3 for the list of all impaired sites within or adjacent to San Diego Bay). Upslope and upstream sources are identified as contributing to the load of certain pollutants to the bay, triggering a watershed view in problem-solving. All of the small creeks listed as impaired for the bay's watershed are located within the Pueblo sub-watershed.

The watershed-related TMDLs for the bay are listed in Table 5-8. The schedule for TMDL completion and adoptions by the RWQCB are dependent on state budget support for staff work and may be extended beyond this schedule.

Table 5-8. TMDL development for San Diego Bay's watersheds by San Diego RWQCB.

TMDL Location	Pollutants listed	Status	Regional Board Adoption	EPA Adoption
Chollas Creek	Diazinon	Done	August 2002	Nov. 2003
Chollas Creek	Metals (cadmium, copper, lead, zinc)	Done	June 2007	Jan. 2008
Bay - mouth of Chollas Creek	Metals, PCBs, non-polar organics	To be done	Sept. 2009	July 2010
Bay - 7th St. Channel / Paleta Creek mouth	Metals, PCBs, non-polar organics	To be done	Sept. 2009	July 2010
Bay - Switzer Creek mouth	PAHs, chlordane, lindane	To be done	Sept. 2010	July 2011

Other Watershed Efforts

Other regulatory requirements under the CWA for urban runoff control have also instigated collaborative watershed-based efforts around the bay. All of the municipalities (18 cities, county, airport, and Port) in the County are “co-permittees” on the Municipal Stormwater Permit (first issued in 1990, and most recently reissued in 2007) (RWQCB 2007). A sub-group of these municipal jurisdictions, as identified previously in Table 5-7, are together responsible to meet the permit's requirements for the bay's watershed in a program called the San Diego Bay WURMP. This effort is discussed below under Stormwater Management (5.3.2).

Wildfires in San Diego County in the past decade have triggered an upslope Emergency Watershed Protection Program, which is a part of the Natural Resources Conservation Service (NRCS). Locally sponsored by the County of San Diego, the Emergency Watershed Protection Program is federally funded through NRCS and works in cooperation with other agencies. The program is designed to remove hazardous trees on private property within the targeted areas. In removing dead, dying and diseased trees within 200 feet of structures current dangerous conditions are being corrected. The Watershed Recovery Project is augmented by additional federal funding to remove trees along public evacuation corridors.

Sub-watershed Management Efforts

Sweetwater River, Otay River, and Pueblo encompass the major sub-watersheds of the bay, from largest to smallest. Drainages within the Pueblo sub-watershed include Point Loma, north bay, Switzer Creek, Chollas Creek and Paleta Creek; within Sweetwater River sub-watershed is also Paradise Creek; and within the Otay River sub-watershed is Telegraph Canyon Creek, south bay, and Coronado (See Map 1-2, Map 5-1, and Table 5-7). Information is available about each sub-watershed's characteristics and activities on the San Diego Region's Project Clean Water website (www.projectcleanwater.org).

Local sub-watershed efforts are driven by many concerns. Water supply districts have a self-interest in protecting their drinking water sources and reservoirs for their customers while cities may also seek to enhance a creek's aesthetic environment for its residents and visitors. Protection of endangered species, both aquatic and terrestrial, can be the purpose of habitat restoration within the watersheds. Each sub-watershed is also the focus of state regulatory efforts for stormwater management (see 5.3.2 below) and impaired waters under the TMDL program.

San Diego Bay's subwatershed areas are delineated in Map 5-1, with lower boundaries also shown on Map 1-1.

The Sweetwater River Water Authority has developed a “total watershed management” program for the 40-mile (64-km) long ephemeral river and 200 mi^2 (518 km^2) watershed over several decades (Reynolds 1997). Figure 5-1 depicts the landscape features of the Sweetwater River Watershed, from its headwaters above Cuyumaca State Park to its mouth in Chula Vista and National City. Protection of the quality of water stored in its Sweetwater Reservoir, used for drinking water by 174,000 residents, is the first priority. Urban runoff and degraded groundwater sources were the original focus of proactive strategies. In 1998, the Authority began to involve stakeholders in the watershed to help protect the resources of the Sweetwater River since it only owns less than four percent of the watershed lands (Bostad 1999). A framework for a watershed management plan is done, with some state financial assistance. Its approach encompasses urban runoff diversion, demineralization of groundwater, groundwater storage, habitat management, and public outreach and education. A recent water quality assessment by the USGS of the Sweetwater Reservoir indicated that the watershed's increased urbanization is reflected in the persistent organic chemical concentrations that have built up in the bed sediments over the past 65 years, although the levels are well below limits set to protect human health (Majewski 2001).

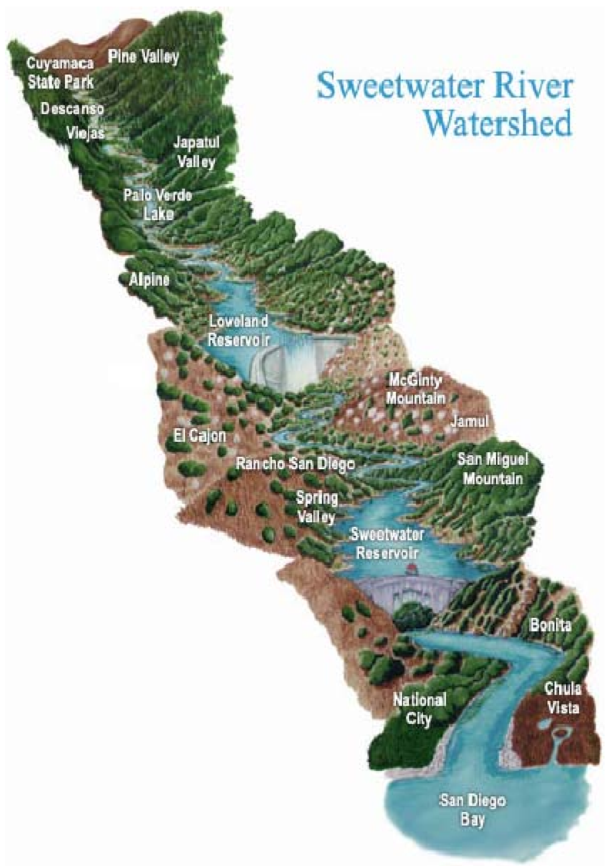


Figure 5-1. Sweetwater River Watershed map by Sweetwater Authority.

Since Chollas Creek is listed by the RWQCB and SWRCB as water quality impaired (for diazinon, metals, and bacteria), the Chollas Creek watershed was the focus of a TMDL study and watershed plan in 1999-2000 to address the causes of the impairment, with the TMDL for diazinon completed in 2002 (RWQCB 1999, 2002). The TMDL for metals was recently completed (and the creek was delisted as impaired for dissolved cadmium), and the TMDL for bacteria was also adopted. Now these two TMDLs are in the implementation phase of their action plans to reduce the pollutant loads. The City of San Diego adopted the Chollas Creek Enhancement Project in 2002 to aesthetically improve the creek and restore it to a natural setting. Design/Development Guidelines were approved to apply to all of Chollas Creek, which covers 25 miles of creek bed and floodplain. Components include wetland and upland restoration and rehabilitation, reconstruction of the concrete flood channel, landscaping, a trail system, public art, and education and interpretation. Nonprofit organizations are also actively promoting the Enhancement Project's implementation.

The Otay River Watershed Management Plan was completed in 2006 through a collaborative effort of the county, three cities, and the Port and is being adopted by each jurisdiction (ORWMP Policy Committee 2006). In 2008, a permanent Watershed Council is expected to be in place to coordinate with the jurisdictions in the Plan's implementation and updating. The Plan's strategy assures high WQS and the protection of natural aquatic and upland resources in the watershed. In addition, a SAMP under the federal CZMA was prepared as a coordinated, regional approach to problem-solving and addressing conflicting management interests. The CZMA describes a SAMP as a "comprehensive plan providing for natural resource protection and reasonable coastal-dependent economic growth containing a detailed and comprehensive statement of policies; standards and criteria to guide public and private uses of lands and waters; and mechanisms for timely implementation in specific geographic areas within the coastal zone" (16 USC 1453[17]). SAMPs may be a mechanism to address mitigation issues related to the CWA, such the issuance of §404 General Permits by the USACE, or the ESA in a coordinated and cooperative manner.

The Paradise Creek Enhancement Plan is being implemented by National City, an effort that originated and is led by community volunteers in a low-income neighborhood, and implemented in a stepwise fashion by many sponsors.

5.3.2 Stormwater Management

Specific Concerns

- Contaminants, sediment, and trash are delivered to the bay from the bay's large watershed due to nonpoint pollution sources through stormwater runoff.
- Many residents and other users of the bay's watershed are under the impression that storm drains connect to treatment plants and that their daily activities do not affect the bay's quality.
- Stormwater runoff carrying sewage from leaking sewer lines, animal wastes, and other sources has caused beach closures in the bay.
- Regulatory approach through Stormwater Permits under the CWA has provided incentives for cooperative monitoring but also has required some expensive solutions.

Background

Stormwater runoff is a significant source of pollution in the bay and one of the hardest to grasp for solutions.

Stormwater runoff is a significant source of pollution in the bay and one of the hardest to grasp for solutions. As point sources of pollution (e.g. discharge from pipes) have been better controlled or removed from the bay, "nonpoint" pollution from widespread sources has increased as a higher proportion of the problem. Nonpoint source runoff is now commonly agreed to be "likely the principal continuing source of pollution to San Diego Bay" (SAIC 1998; SDUPD 2007). Runoff of pollution through stormwater is the primary means of delivery to the bay.

Over 200 storm drain outfalls are located in and dump into San Diego Bay.

"Every day trash, litter and debris, sand, silt, and sediment, petroleum products leaking from motor vehicles, heavy metals in the dust from motor vehicle brake pads and diesel exhaust, animal feces, excess fertilizers and pesticides, and other pollutants are carried to the bay by urban runoff as a result of rain or excessive irrigation, or other sources of water in the urban environment," states the Port's website. Over 200 storm drain outfalls are located in San Diego Bay. Although many of the outfalls are located on the Port's shoreline property, the source of much of the runoff comes from the 442 square mile watershed draining into the bay. Two rivers and five creeks provide natural drainages into the bay in addition to the artificial storm drainage system and each contributes different pollutants. For example, Chollas Creek contributes copper, zinc, and bacteria to the bay while Switzer Creek delivers high levels of bacteria and sediment during rain events (SDUPD 1995a; San Diego Bay WURMP 2007).

Sources of stormwater pollution in the watershed are numerous. Copper contamination, for instance, can come from the normal degradation of automobile and truck brake shoes. During a rain storm, especially the first of the season, the particles that have fallen to highways, streets, parking lots, and driveways become washed into roadside ditches, which dump into storm drains or creeks, and eventually into the bay. Other sources of urban nonpoint pollution include automobile oil and grease, illegal dumping of chemicals, animal wastes, sewage from leaking sewer lines, lawn fertilizers, and sediment from soil erosion (SDUPD 1995a).

Since storm drains are not connected to sewers or a sewage plant stormwater's pollutants can be delivered directly to the bay.

Storm drains are not connected to sewers or a sewage plant. Unless natural or artificial filtering systems exist, every contaminant in the storm drains or creek systems is delivered into the bay. This problem is a significant stormwater management issue. The urban area's impervious surfaces, such as parking lots, roads, and buildings, reduce the natural filtering capability of the watershed and instead help pollutants wash off the “hardened” landscape (Center for Watershed Protection 2003).

In the mid-1990s, storm drains were identified as an important contributor of contaminants in San Diego Bay as based on the State Bay Protection and Toxic Cleanup Program's monitoring report (Fairey *et al.* 1996). In particular, high concentrations of metals and chlordane near the downtown anchorage monitoring station were attributed to the presence of a large storm drain and numerous smaller storm drains that empty into the bay near this station. Parking lots and light industrial and commercial areas contribute to these storm drains. Near the 10th Avenue Marine Terminal is a large storm drain system draining residential and industrial areas that appeared to be additional sources for the elevated levels of chlordane and PAHs detected at the stations. Other storm drains were also listed as contributors.

Bacterial contamination of the bay can come from leaking sewer lines and animal wastes washed off backyards and parks, among other sources. Public health is protected from the effects of polluted water by the San Diego County Environmental Health Division, which can close sites to fishing, swimming, or other uses when needed. One indicator of possible watershed-based bacterial contamination is the safety of swimming at beaches. Its monitoring of San Diego Bay's beaches between 2001 and 2006 (Table 5-9) reveals the following number of advisory Beach Mile Days due to bacterial exceedances:

Table 5-9. Beach Mile Days for bacterial exceedances (Advisories) between April 1 and October 31.

	2000	2001	2002	2003	2004	2005	2006
San Diego Bay	4.38	9.43	18.13	2.84	3.47	1.65	4.09

Current Management

Regulatory Approach

While pollution entering the storm drains is usually from diffuse or nonpoint sources, the outfalls of storm drains represent a point source of discharge into the bay. Any operator of a municipal separate storm sewer system that discharges urban runoff into the waters of the U.S. currently comes under regulation. The federal CWA, as amended in 1987 (§402[p]), and the CZARA of 1990 (§6217) are the driving regulatory forces in addressing nonpoint source pollution from urban and stormwater runoff, as interpreted by the SWRCB in its Nonpoint Source Pollution Control Program policies (SWRCB 2004).

Stormwater discharge to the bay is prohibited unless an NPDES permit is obtained.

Stormwater discharge to navigable waters is prohibited unless a NPDES permit is obtained. The EPA has delegated responsibility for the NPDES program to the SWRCB. In turn, the RWQCB in San Diego implements the program at the regional level. The CZARA requires EPA and the state to develop and implement management measures to control nonpoint pollution in coastal waters, which California has done through a procedural guidance manual produced by the CCC (1996). The relation of the CWA and CZARA programs is described in more detail in other sources (SWRCB 1994; CCC 1996; SWRCB 2004).

EPA's stormwater permit program is a phased approach, with large cities and industries first required to comply.

A tiered approach is used by EPA and the state in implementing the stormwater permit program. Phase I requires NPDES permits for municipal storm sewers serving large and medium sized populations (greater than 250,000 or 100,000 respectively) and for stormwater discharges associated with industrial activity that is already permitted. Phase II addresses smaller municipalities, small construction sites, and became effective in 2002. The CZARA's requirements for management measures apply to those activities not covered by Phase I, such as construction activities on sites less than 5 acres (2 ha) and discharges from wholesale, retail, service, and commercial activities, including gas stations (SWRCB 1994).

Local Permits and Programs

Municipal

In 1990, before EPA's implementing guidelines were issued, the San Diego RWQCB issued an “early permit” for the General Municipal Stormwater Permit for the 18 cities within San Diego County, the County of San Diego, the Airport, and the Port. This “Municipal Permit” was renewed by the RWQCB in 2001 and again in January 2007, each time with revisions and reportedly tougher regulations (RWQCB 2007). Multiple scales of urban runoff management plans (URMPs) and implementing programs were required to be prepared for these “co-permittees,” all of which have been prepared. These different plans are:

- Regional URMP – the San Diego Region scale
- Jurisdictional URMP (JURMP) – the individual city, county, and Port district scale
- WURMP – the watershed scale

The San Diego Bay WURMP coordinates the ten municipal copermittees who are required to meet the requirements of the San Diego RWQCB's Municipal Stormwater Permit within the San Diego Bay WMA (See Map 5-1). The program's goal is to “positively affect the water resources of the San Diego Bay Watershed while balancing economic, social, and environmental constraints.” Monitoring of water quality and abating pollutant sources is its primary focus.

Annual progress reports and plan updates, including water quality monitoring results, are published for each of these plans by each entity (e.g. City of San Diego 2007; SDUPD 2007; San Diego Bay WURMP 2007).

One means of implementation that has been done by all permittees is the adoption and enforcement of a local stormwater ordinance (e.g., SDUPD 2000). Ordinances usually recommend or require the use of stormwater BMPs. EPA's management measures and BMPs for urban runoff address six source categories: developing areas; construction sites; existing development; onsite disposal systems; general sources; and roads, highways, and bridges (CCC 1996). Handbooks describing stormwater BMPs applicable for California are available for municipal, commercial /industrial, and construction BMPs (Camp Dresser and McKee *et al.* 1993; California Stormwater Quality Association 2003). Each permittee has adopted a Standard Urban Stormwater Mitigation Planning document to guide construction practices (e.g. City of San Diego 2003; SDUPD 2003).

The design of new development (or retrofitting existing development) to control stormwater runoff is the subject of LID practices, which are becoming increasingly popular in the United States and other countries (Natural Resources Defense Council 2006) (See also Section 5.1: Toward a Sustainable Ecosystem in San Diego Bay). LID is defined as “a stormwater management and land development strategy that emphasizes conservation and the use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely reflect pre-development hydrologic functions" (RWQCB 2007). The 2007 Municipal Permit requires the co-permittees to place LID requirements as BMPs on priority development projects within their jurisdictions. BMPs, for example, would route runoff from impervious areas to pervious sites and use permeable surfaces for low traffic areas to help infiltrate into the soil. A recent study of the feasibility and benefits of using LID as "green infrastructure" for the San Diego region found that LID techniques "substantially preserve pre-development hydrologic conditions and prevent most or all pollutant transport to receiving waters" (Horner 2005).

The EPA has developed a website for LID Strategies and Tools for NPDES Phase II Communities at http://www.lowimpactdevelopment.org/lidphase2/ to assist stormwater Phase II communities integrate LID strategies into their compliance programs. The NAVFAC Atlantic has a LID Design Manual developed in cooperation with the LID Center.

Port staff are implementing stormwater BMPs in many ways.

Port staff are implementing stormwater BMPs in many ways: as erosion control measures on construction projects, in staff training and reporting of new stormwater pollution sources, integrated pest management to prevent pesticide runoff, and environmental review of proposed tenant improvements. Tenants are given stormwater BMP materials and recommendations for improvements.

Pollution prevention educational brochures are a part of public education efforts by the Port. See also Section 5.6: Outdoor Recreation and Environmental Education.

Public education efforts by the Port include an extensive nonpoint source pollution education program with local schools through a contract with the Resource Conservation District of Greater San Diego. With the San Diego BayKeeper, the Port produced brochures, "Preventing Stormwater Pollution: A Guide for Businesses", "Preventing Stormwater Pollution: Residential Guide", "Preventing Stormwater Pollution: Integrated Pest Management", and a Boater's Guide. An Annual Creek to Bay Cleanup, sponsored by I Love a Clean San Diego since 2003, has collected over 217 tons of trash and recyclables (CreektoBayCleanup 2008). (See Section 5.6: Outdoor Recreation and Environmental Education for a more extensive description.)

5.3.2.1 Industrial

The Port maintains NPDES industrial stormwater permits for its two marine terminals and cruise ship terminal as well as an Industrial Stormwater Program. The Port has coverage under three stormwater permits: the statewide General Industrial Storm Water NPDES Permit, the statewide General Construction Storm Water NPDES Permit, and the municipal Storm Water NPDES Permit. The Port has assumed responsibility for reviewing SWPPPs, monitoring reports, and submitting annual reports for its tenants' industrial activities for the marine terminals and cruise ship terminals.

A shipyard or other industrial facility located on Port tidelands, but not located at the Marine Terminals, must obtain its own individual coverage under the statewide General Industrial Storm Water Permit or under another NPDES permit that incorporates stormwater requirements. An example of such a permit is the General Shipyard NPDES Permit, a permit that only applies within the San Diego Region. Construction projects on Port tidelands are covered under the statewide General Construction NPDES Permit. Either the Port or other developers may obtain coverage for individual construction projects.

Point source discharges from the commercial shipyards and boatyards on the bay are regulated through NPDES permits; site-specific industrial stormwater permits were recently adopted by the RWQCB for three commercial shipyards (NASSCO, BAE, and Continental Marine) and the commercial boatyards. Contaminants from stormwater runoff from shipyards are now being systematically contained by having berms or collection troughs built around them. These permits are in addition to any possible Cleanup and Abatement Order for contaminated sediment at such industrial sites.

Navy efforts are directed at reducing the quantity of hazardous substances that could potentially contaminate stormwater.

The U.S. Navy (CNRSW) policy related to stormwater management is: "Develop, implement, and maintain current stormwater management plans, and comply with federal, state, and local regulations and permit conditions, as applicable." The Navy has coverage under two general stormwater permits: the statewide General Industrial NPDES Storm Water Permit and the statewide General Construction NPDES Stormwater Permit. The Navy is not covered by the Municipal NPDES Stormwater Permit for San Diego

County municipalities, though it has been suggested, which would include participation in the "San Diego County Co-Permittees" group. Naval facilities at the bay have already implemented the Consolidated Hazardous Material Reutilization and Inventory Management Program. As a result, the Navy believes it has significantly reduced the quantity of hazardous substances that could potentially contaminate stormwater. Used Oil Management Plans and Spill Prevention Control and Countermeasures Plans have been developed, implemented, and routinely updated to identify sources, recycling options, and oil product storage containment (San Diego Bay Interagency Water Quality Panel 1998). The Navy has a SWPPP and a Storm Water Working Group.

Three new NPDES permits for industrial stormwater were issued by the RWQCB for each of the U.S. Navy installation complexes in San Diego Bay since 2002: NBPL, NBSD, and NBC. These permits cover new requirements for regulating and monitoring point sources and industrial stormwater that RWQCB staff say provide protection of water quality equivalent to the protection provided by NPDES permits for the bay's shipyards. Industrial stormwater discharges are required to achieve a specific toxicity level: 90% survival, 50% of the time, and not less than 70% survival, 10% of the time. The Navy had this requirement as a performance goal until September 2006, after which it became an enforceable effluent limitation. In the interim, the Navy was asked to conduct a study of toxicity in stormwater discharges from all areas where industrial activities are undertaken and to recommend a scientifically valid survival rate for acute exposure to these discharges. In addition, the Naval facilities are to "terminate" the first flush of runoff (i.e. first ¼ inch), which assumes water storage to prevent the expected higher concentration of contaminants (e.g. copper, zinc) of this discharge from entering the bay. If copper and zinc concentrations exceed certain levels, then more BMPs and monitoring are also required.

Over a recent two-year period, the Navy's SSC developed an effective methodology for characterizing the quality, quantity, and impact of stormwater discharges under the Navy's Pollution Abatement Ashore Technology Demonstration/Validation Program. It was successfully demonstrated at Naval Station San Diego. This study found that measurements made at the end-of-pipe stormwater drains do not necessarily reflect the nature of impacts observed in the receiving waters. While most of the discharge water failed to meet the chemistry or toxicity requirements, no water quality problems were found in the bay below the outfall. The most sensitive organisms tested showed no toxicity effects, leaving the study to conclude that bay waters are able to assimilate these discharges without effects to water quality and that "end-of-pipe measures alone are insufficient to evaluate risk to the receiving environment."

During the SB 68 process, a Stormwater Advisory Committee composed of the Navy and shipyards raised questions and discussed related issues to these toxicity standards. They believed that considerable effort and funds had been expended to comply with these standards and with some success, but were frustrated by the apparent inflexibility and additional costs of the requirement. The final report of the San Diego Bay Advisory Committee for Ecological Assessment (2005) included these findings on the topic:

- "Specified industrial stormwater permits include acute toxicity standards for the U.S. Navy, shipyards, and boatyards. Similar standards are not included in the Municipal Stormwater Permit for the cities and county, nor in other NPDES permits in the San Diego Region."
- "To date, the impacted industrial permittees have not identified a reliable, permanent means of complying with the toxicity provision of their permits. Considerable effort and funds were expended to try to comply with toxicity standards. Both successes and failures have occurred in trying to meet toxicity standards with available treatment technologies."
- "The current means of compliance may not be available in the future. At present, for most storm events all three shipyards capture and contain the industrial stormwater runoff from their facilities and divert into the City's sanitary sewer system. It is uncertain how much longer the City of San Diego will authorize these discharges into their system."

Both the Port and Navy continue to do trash removal on Chollas and Paleta Creeks. The Navy is currently assessing dinoflagellate toxicity test kits for screening toxicity of NPDES effluent.

Monitoring Efforts

Monitoring requirements of the San Diego Municipal Storm Water Permit are quite specific and include different monitoring types. For compliance purposes, the co-permittees must measure “pollutants of concern” for each stream. A priority can also be to perform a type of “forensic” monitoring, by trying to investigate the sources of a contaminant, such as bacteria. They must also monitor the implementation of BMPs for stormwater management within their jurisdictions, as required by their implementing ordinances. The effectiveness of the Storm Water Programs at the different scales (Regional URMP, Jurisdictional URMP, and WURMP) must be assessed. Annual reports are provided to the RWQCB by each program (e.g, SD Bay WURMP 2007; SDUPD 2007b).

A Joint Wet Weather Monitoring Program measures water quality constituents at different times of the year: at “first flush” following the first significant rainfall of the season, before February 1st, and after February 1st. A Dry Weather Monitoring effort is also in place, as urban runoff and illicit discharges can occur without wet weather. The monitoring effort seeks to understand pollutant loading to the bay and to evaluate changes that could be attributed to the effectiveness of BMPs. In addition, the Port visually inspects and screens selected storm drains once per month, with flows screened for selected water quality indicators. The City of San Diego's Environmental Health Division continues to sample certain storm drains to help identify and correct contaminant inputs to the bay.

San Diego Bay is part of the SCCWRP, the largest regional water quality monitoring program of its kind in the country. Using standardized monitoring procedures, the project should help with certain monitoring and evaluation needs, though only on five-year increments (1998, 2003, 2008, etc.). The 2003 results for San Diego Bay recently became available and are discussed under Section 2.3: Physical Conditions of the Bay (see also: www.sccwrp.org). However, it does presently not measure streams draining into the bay.

San Diego Bay is part of the SCCWRP, the largest regional water quality monitoring program of its kind in the country.

Recent monitoring and evaluation studies have focused on Chollas Creek because of its earlier TMDL schedule (U.S. Navy 2000; Schiff *et al.* 2003; SCCWRP and U.S. Navy 2005; Weston Solutions 2006). The Chollas Creek TMDLs have numeric targets and waste load allocations for the listed constituents (such as diazinon). Monitoring of the TMDL requirements must be performed by the Municipal Stormwater Permit co-permittees with jurisdiction in that watershed.

Expectations are being built into the stormwater permitting programs that “adaptive management” should occur - where feedback from annual monitoring results can be used to adapt the monitoring effort and the Storm Water Management program to be more useful. The Municipal Permit, for example, requires co-permittees to collaborate with each other to develop a Long-Term Effectiveness Assessment. Pollutants of concern can change over time, with some being dropped and others added as monitoring results indicate their importance.

Evaluation of Current Management

Water and Sediment Quality Conditions

The present condition of the bay's water and sediments is discussed in Chapter 2.3.2. While some conditions have improved and others have not, it is difficult to directly relate the bay's water quality condition to watershed management efforts. However, urban runoff contributions are known to be significant, especially for heavy metals.

Implementation and Enforcement Efforts

Chollas Creek was contaminated with the pesticide diazinon. In August 2002, the Chollas Creek TMDL for diazinon was adopted by the RWQCB and by the EPA in November 2003. Since then, the pesticide has been phased out and no diazinon has been detected in Chollas Creek since 2004, offering encouragement for focused efforts. Diazinon is no longer a high priority pollutant in that stream but only a COC.

The Chollas Creek TMDL for metals (copper, lead, and zinc) was recently adopted by the RWQCB in 2007 (See Table 5-8).

Improvements in the implementation of BMPs under the Port's stormwater program have been documented by the Port (SDUPD 1995b, 2007). The environmental community credits regulation and mitigation with bringing about the improvements in the bay's overall cleanliness and argues that fair and effective regulation should be maintained (Kuehner-Hebert 1998). However, the regulated community is concerned that excessive regulation or unreliable compliance indicators could become counterproductive (San Diego Bay Advisory Committee for Ecological Assessment 2005).

Training of municipal, Port, and Navy employees in BMPs has benefited implementation. More training is needed, especially with staff turnover. Smaller cities, for example, may lack the staff and funding. There is still a sense by the general public that storm drains go into sewage plants, which creates an "out-of-sight, out-of-mind" attitude. People working on their cars in the streets and releasing oils and grease into a street far from the bay need to become aware of their impact on the bay. Educational programs have begun to make an impact. The City of San Diego's Storm Water Pollution Prevention Program had its public information campaign evaluated after a one year effort. The survey found success with two of the Program's goals: improve awareness of the "Think Blue" slogan, and change behaviors of polluters (such as changing car oil). However, the program did not succeed in increasing awareness that stormwater flows to the bay untreated.

Biologists support the use of natural and artificial wetlands within the watershed to help regulate the quality and quantity of stormwater runoff.

Biologists have observed the need for natural filters within the bay's watershed to help trap runoff, sediment, and pollutants. Natural and artificial wetlands, such as ponds, riparian zones, swales and salt marsh can store sediment and its associated contaminants. Aquatic and riparian vegetation, such as cattails and bulrush, can also take up or alter some of the excess nutrients and contaminants, including the erosion products of large fires in the upper elevation watersheds. In contrast, concrete-lined ditches, storm drains, and flood control channels offer no filtering effects through the soil or the vegetation but instead flush contaminants directly to the end of the drain. Managed wetlands or sediment ponds can collect contaminants during rain storms and store sediment under controlled conditions. BMPs based on wetland systems were rated as the most effective in a recent SCCWRP evaluation (Brown and Bay 2007). A series of natural and artificial wetlands, including vegetated swales adjacent to roads, can regulate both the quality and quantity of storm runoff to the bay as part of a more comprehensive watershed management strategy.

Integrating fire and watershed planning allows for thinking about how sediment is processed post-fire in the watershed. One of the most damaging effects of a wildfire to the land is soil erosion. Under normal circumstances, roots help to stabilize soil, while stems and leaves slow water down, giving it time to absorb or soak into the soil. These protective functions can be severely compromised or even eliminated by fires. In the aftermath of a fire, the potential for flooding, debris flows, and erosion is greatly increased.

Watershed planning is essential for the protection of San Diego Bay, concluded the SB 68 report and the State of the Bay 2007 report. Plans for managing stormwater runoff have met with some success by cities, the county, and the Port, but full implementation is needed. These efforts need to have full integration with the bay's water quality priorities as well (SDUPD 2007b). SANDAG also encourages municipalities to adopt a Water Quality Element as part of their general plans in order to better address watershed and nonpoint source management through land use planning (SANDAG 1997).

On the other hand, upslope problems like urban runoff and watershed protection are being addressed well through cross-jurisdictional efforts (e.g. Municipal Co-permittees and San Diego Bay WURMP; Otay River Watershed Management Plan & Interim Watershed Council), while the bay itself lacks such a formal mechanism. Implementing the concept of LID to maintain pre-development hydrologic conditions will require guidance documents and training programs, such as for government planners and designers.

SB 68 Report Recommendations. The San Diego Bay Advisory Committee for Ecological Assessment, by consensus, made three recommendations to the Legislature with which this INRMP will be consistent.

1. Create A Partnership to Facilitate Cross-Jurisdictional Implementation.
2. Implement Habitat Enhancement Projects that are Key to Bay Health.

3. Implement a Biological Indicator Development Program.

Monitoring and Research

Improvements in monitoring strategy are being identified through new stormwater permits, URMP updates (by jurisdiction and watershed), external evaluations, and new research. Monitoring sites have tended to be selected for the purpose of compliance monitoring rather than for effectiveness monitoring of specific BMPs or for trend monitoring of different streams or their reaches over time. Water districts within the watershed also monitor reservoir inflow quality for compliance with drinking water standards. Information useful to detect stormwater pollutant sources (e.g. forensic monitoring) and to evaluate urban runoff BMPs could be derived from expanding current monitoring programs from their compliance orientation to effectiveness and trend purposes.

Concern was expressed by San Diego Bay Advisory Committee for Ecological Assessment over the inconsistent standards for collecting and analyzing data related to the bay. It recommended standardized protocols for collection and storage of all data. The Navy recently performed a detailed assessment on the fate and transport of stormwater contaminants once they reach the bay, including the extent of impacts to bay sediments in and around Navy facilities and to the bay as a whole, and has programmed additional sediment-related and TMDL studies (B. Gordon, L. Sinfield, *pers. comm.*).

Adequate funding of monitoring, research, and implementation will always be an issue. Voter awareness of the need for improved stormwater management became apparent in Los Angeles and Santa Monica, where voters recently gave a two-thirds vote in support of ballot measures for a $500 million bond (in Los Angeles) and a special tax (in Santa Monica) for stormwater projects (Water Education Foundation 2007).

Objective: Reduce and minimize stormwater pollutants harmful to the bay's ecosystem from entering the bay from watershed users.

Management Strategy—Watershed and Storm Water Management

I. Encourage the further development and implementation of new or existing stormwater pollution prevention and water quality efforts throughout the bay's watershed.

- *A.* Create a Bay Partnership to facilitate Cross-Jurisdictional Implementation and encourage the integration of regulatory and non-regulatory programs.
  - *1.* Work with the Municipal Stormwater Co-Permittees and Industrial Stormwater permit holders to connect watershed efforts with those of the bay.
  - *2.* Develop formal coordination arrangements as needed.
  - *3.* The Navy and Port should survey stormwater education and pollution prevention efforts with the goal of updating these efforts.
  - *4.* The Navy, Port, and cities should identify pollutants and potential pollutants in stormwater runoff for all installations around the San Diego Bay.
- *B.* Promote an effective public education program such as the “Think Blue” campaign. Provide consistency with a similar message and the pooling of financial resources among the municipal co-permittees and watershed educators in their outreach efforts.
  - *1.* Support the completion and maintenance of storm drain stenciling around the bay's watershed to alert the public of the endpoint of any dumping in storm drains.
  - *2.* Target education efforts to focus on watershed subareas and main contributors and problem inputs of nonpoint source pollution to the bay.
  - *3.* Employ a multilingual effort to better communicate with all neighborhoods and businesses.
  - *4.* Employ focused and frequent public service announcements on local radio and television.
  - *5.* Evaluate the before-and-after levels of public understanding of the problem and solutions and adjust the education strategy as needed to be more effective.

6. Use educational organizations to help enhance and extend the educational messages to a broader audience, including private landowners (such as through Resource Conservation Districts).
7. Continue to address and assist Port tenants with stormwater compliance through Port commercial and industrial programs.

C. Promote the integration of fire and sustainability planning in the wildland-urban interface.

1. Landscaping that is fire-safe and watershed wise is drought tolerant, provides wildlife habitat, keeps soils on slopes, and does not promote invasive plants or wildlife. A project called Sustainable and Fire Safe Landscapes is developing guidelines for creating and maintaining fire-safe, environmentally-friendly landscapes in the wildland-urban interface that minimize the use and spread of invasive plants. It is a collaboration between the UCCE—Los Angeles County, the Los Angeles and San Gabriel Rivers Watershed Council, the Los Angeles County Fire Department Forestry Division, and numerous other governmental, nonprofit and business organizations. Support is provided by the National Fish and Wildlife Foundation and the CDFA.
2. Collaborate with other organizations. Examples are Resource Conservation Districts, San Diego Fire Safe Council, and Watershed Fire Council of Southern California (organized in 1954 to promote the wise use and protection of the wildland resources through proper planning and management by the Boards of Supervisors of nine Southern California counties (including San Diego County) to address fire in watersheds).

D. Support the various Storm Water Management Programs aimed at solving contamination of the bay from runoff.

1. Identify BMP demonstration projects and locations that could serve as local models.
2. Identify and obtain the necessary funding to design and implement demonstration projects.
3. Encourage the development of and work closely with cooperative, community-based watershed groups in developing watershed problem and need assessments, in identifying and implementing BMPs, in monitoring their effectiveness, and in communicating their successes and challenges to others.

E. Promote urban runoff BMPs that support stormwater pollution prevention and reduction.

1. Explore the opportunity for better use of natural and artificial wetlands as upslope filters to trap runoff sediment and pollutants.
   a. Investigate where retention basins and engineered treatment facilities may be effective.
   b. Identify specific candidate locations for treatment wetlands in the bay watershed.
2. Support LID practices to mimic natural runoff patterns.
   a. Facilitate opportunities to address runoff at the community or sub-basin scale rather than site or project scale.
   b. Support educational tools such as webcasts and podcasts that teach about how communities can more effectively manage rainwater where it falls. “Green” streets and landscapes beautify, preserve water quality, minimize urban heat island effect, and reduce a community’s carbon footprint. Other practices include rain gardens, curb cuts, bioswales, and green roofs to address stormwater runoff. An example of an audio program is from the Office of Wetlands, Oceans, and Watersheds (http://epa.gov/owow/podcasts/).
3. Encourage appropriate habitat enhancement projects in bay watersheds that promote infiltration and riparian values.

a. Support river park programs in bay subbasins.

b. Integrate watershed planning with natural community conservation plans.

4. Work closely with community-based watershed groups in evaluating the effectiveness of BMPs, and communicate the technological challenges and successes to others.

5. Identify and encourage use of household products unlikely to cause a harmful input to bay waters.

6. Implement a hazardous materials collection event or station for marinas.

F. Promote construction of sewer infrastructure improvements to prevent sewer overflows, and broken or leaking sewage lines.

II. Improve the effectiveness of the water quality regulators and the municipal and industrial stormwater permittees in cleaning up stormwater runoff.

A. Improve coordination and communication among all of the bay's municipalities, including the Port and Navy, in the design and implementation of an urban and industrial runoff program.

1. Address the general problem of access, collation, and interpretation of storm drain and water quality data in San Diego Bay by storing these data in a single database.

2. Actively participate in the RWQCB's TMDL processes.

3. Obtain coverage for the Navy's non-industrial facilities under the Municipal Storm Water Permit.

B. Develop an improved training program for appropriate government and private sector employees.

1. Support regular workshops on the need, design, and implementation of BMPs.

2. Train selected employees to train others.

3. Provide training on LID to maintain pre-development hydrologic conditions.

C. Encourage agencies to improve relevant administrative and planning practices.

1. Encourage municipalities to adopt Water Quality Elements as part of their general plans in order to better address watershed and nonpoint source management.

2. Support the coding of all existing and new RWQCB permit applications and Notices of Intent with a hydrologic subarea.

3. Ensure that stormwater quality controls are considered during the site planning and design phase and not tacked on after the fact.

4. Examine location and evaluate need to reposition outfalls in relation to effects on sensitive bay habitats.

5. Identify ways to improve response times and avoid or minimize the release of episodic sewage runoff into the bay from sewer pipe breaks.

D. Target monitoring efforts to evaluate the effectiveness of BMPs and trends in water quality of sub-basins leading into the bay. Perform adaptive management.

1. Continue the Navy's detailed assessment of the fate and transport of stormwater contaminants once they reach the bay, including the extent of impacts to bay sediments in and around Navy facilities and to the bay as a whole.

2. Position monitoring stations at key sites within sub-basins to better track "hot spot" sources of stormwater pollution. Assess results of dry weather and wet weather monitoring.

3. Evaluate the effectiveness of the applied urban runoff BMPs through the use of a targeted effectiveness and trend monitoring in the watershed.

4. Continue identifying sources of improper discharges through dry season stormwater monitoring.

5. Implement a Biological Indicator Development Program to better evaluate the effects of urban runoff on the bay's ecosystem.
6. Re-evaluate the design and use of BMPs based on the results of the monitoring program.

5.3.3 Freshwater Inflow Management

Specific Concerns

- Changes in freshwater runoff amounts and timing have affected salt marshes and the ability to restore them in ways that are not quantified. For example, if low salinities persist due to these hydrologic modifications, brackish marsh vegetation and exotic species can invade the coastal wetland site and marine fish and invertebrates can be eliminated. Imported municipal water creates an artificial water regime in the bay's watershed, with irrigation and other runoff occurring during unnatural times of the year and creating too much fresh water out-of-season. Natural sediment transport functions have also been altered from their natural role in the bay by dams and diversion.
- Channelization of streams has prevented them from fulfilling their natural functions, which include species support, nutrient filtering, groundwater recharge, aesthetic, and recreational values.
- Wildfires in large portions of the bay watershed could seriously impact the quantity and quality of runoff into the bay.

Background

Freshwater inflows into San Diego Bay were first significantly altered when San Diego River was permanently diverted into Mission Bay in 1875. In the late nineteenth century, lower and upper Otay and Sweetwater reservoirs were constructed for water storage to “save the greatest floods” for supplying drinking water to the growing communities around the bay (Boone 1912).

Before these diversions, fresh water would flow into the bay during the rainy season from November to April. Runoff and streamflow mimicked the rainfall amount and pattern, with rarely any snowpack in the mountains to sustain prolonged flows. The streams were ephemeral or intermittent during the dry season, at least in their lower reaches. This led to higher salinity in the southern portion of the bay. Sub-surface flows of groundwater into the streams and the bay may have extended beyond the period of upstream surface flows. High rainfall seasons, drought, and floods have always cycled and brought annual and seasonal fluctuations to freshwater inflow to the bay.

Excess freshwater runoff, especially during low tides, can harm intertidal animals (Martin *et al.* 1996). While marine invertebrates living in the intertidal zone are generally well adapted to fluctuations in temperature, pH, oxygen, and carbon dioxide, extreme reductions in salinity (“hyposalinity”) in their environment can lead to stress. Stress can cause disease, slower growth, increased susceptibility to parasites, and even death. Runoff at artificial outfalls that is prolonged over several days during low tide is potentially “extremely detrimental” to marine organisms, particularly those that cannot move away from the source (e.g. sessile animals). Drought years can even lead to an increase in the population and diversity of intertidal animals.

Lowered salinities caused by prolonged reservoir discharge, irrigation runoff, and street drains can also cause a shift in species distributions downstream into the estuarine marshes (Zedler 1991). For example, the southern cattail is not a salt marsh species but it was able to invade the San Diego River marsh following the 1980 flood and the prolonged period of reservoir discharge. While its population declined after several low flow years, it was not eliminated and now competes with native plants. In the Sweetwater River marsh, curly dock was able to invade the periphery of the salt marsh when conditions of low salinity (<10 parts per thousand) persisted beyond the normal wet winter season.

Freshwater inflows would normally have delivered sediment from the watershed into the salt marshes once located at the mouths of each tributary to the bay. With dams trapping the sediment upstream, the remaining marshes (Sweetwater and Otay) are no longer receiving these natural nutrient inputs and sources of habitat maintenance and dynamics. Researchers have found that infrequent streamflow influxes of nitrogen have impaired the development of constructed marshes and the maintenance of existing marshes (Langis *et al.* 1991).

Sweetwater and Otay marshes no longer receive natural nutrient inputs because of dams upstream.

Current Management

Reservoir management is under the jurisdiction of several local entities. The two reservoirs on Sweetwater River, Loveland and Sweetwater, are owned and managed by the Sweetwater Authority and have a combined capacity of 53,500 acre-feet of water storage. Lower Otay Reservoir is owned by the City of San Diego and stores 49,500 acre-feet of water (CDWR 1993). These reservoirs are apparently managed to store water for water supply rather than for flood control purposes.

Water management within the bay's watershed is also provided by municipal water purveyors. The Sweetwater Authority provides water to the City of Chula Vista (Otay Water District) and National City. Imperial Beach's water is purveyed by the California American Water Company. The City of San Diego has its own water department. The San Diego Water Authority wholesales imported water from the State Water Project and other sources to the local water purveyors and to large agricultural water users.

Much of the water presently used by residential, commercial, industrial, and agricultural customers in the watershed is imported from outside the region. Under normal water conditions, most of San Diego County receives about 90 percent of its water via the large aqueduct systems from the Colorado River or the State Water Project. For the Sweetwater Authority, 30% of its water supply is from imported sources although it can receive 100 percent imported water under emergency conditions (Sweetwater Authority 2007). While most is probably consumed and delivered to the sewage system for export or lost through evaporation during storage and irrigation, runoff amounts are increased by this additional water to the watershed.

Much of the water in the watershed is imported from outside the region.

Stormwater runoff is being managed by all of the local jurisdictions, as noted in the above section. The emphasis of the state and federal stormwater management programs is on improving the quality of urban runoff, not the quantity. A recent workshop on the "hydromodification" of natural streams in southern California concluded that physical degradation of stream channels in the region's semi-arid climate may be detectable when the basin's impervious cover (e.g. due to hard surfaces such as roads, parking lots, and buildings) is between 3-5%, while biological effects may occur at even lower levels (Stein and Zaleski 2005). One of the recommendations was to "integrate management of hydromodification into a multi-objective strategy that addresses hydrology, water quality, flood control, stream ecology, and overall watershed and land use planning."

Sediment in the local reservoirs is periodically dredged and removed to a legal fill site to maintain their storage capacities.

Evaluation of Current Management

Besides the issue of the quality of stormwater runoff (wet and dry weather), the effect of the timing and quantity of freshwater inflows to the bay does not appear to be a significant issue that is being addressed by local watershed managers.

One concern is if municipalities are able to shift their treated wastewater discharges from the existing ocean outfalls to coastal rivers (live stream discharge), as some have proposed, then wetlands ecologists fear that streamflow regimes for coastal water bodies will be permanently altered (Zedler 1991).

This freshwater inflow management issue was not addressed in the 1998 plan prepared by the Bay Panel (San Diego Bay Interagency Water Quality Panel 1998). However, the recent SB 68 Report and the State of the Bay-2007 Report both identified the lack of natural sediment transport by the bay's tributaries, due to dams, diversions, and channelization, as a factor in impeding the natural role of fresh water and organic matter within the bay (San Diego Bay Advisory Committee for Ecological Assessment 2005; SDUPD 2007a).

Experiments with pulsed-discharge of fresh water and wastewater from constructed wetlands during outgoing tides were attempted in the Tijuana Slough National Wildlife Refuge (Zedler *et al.* 1992). Results were promising, demonstrating that such wetland designs can be used to protect downstream coastal wetlands from excess reduction in salinity. More demonstration projects of this type are needed in the bay watershed. Eventually, excess fresh water flows in all 200 stormwater outfalls and each creek should be addressed.

A Water Budget is a commonly used hydrologic tool to help understand the natural and artificial inputs, outputs, and storage for a basin, much like a balance sheet (Leopold 1974). On the credit side would be water input in the form of rainfall, snowfall, and water imports. On the debit side would be removal of water from the land, such as through streamflow, deep seepage of groundwater to the ocean, transpiration from plants, and evaporation from streams, reservoirs, and the moist soil. While a daily budget may require too much data, an average annual budget is more readily prepared. For comparison, an estimated historic (pre-development) water budget and a current water budget could both be prepared. Drought years would also be quite different from above average rainfall years. The value of having a water budget is to help understand the implications of the altered hydrology on the bay's ecosystem and to help find management tools to mimic the natural, prediversion of runoff into the bay.

Management Strategy—Freshwater Inflow Management

Objective: Encourage water managers within the bay watershed to manage freshwater inflows to help maintain the natural salinity and nutrient levels of the bay's wetlands and intertidal zone.

I. Seek methods of water management that will mimic the natural, prediversion, regime of runoff (frequency, duration, and amount).

- *A.* Promote demonstration projects of pulsed-discharges from artificial wetlands within the watershed.
- *B.* Maintain good tidal flushing and rapid dilution when discharges must be made.
- *C.* Prepare a Water Budget for the San Diego Bay watershed, indicating freshwater inputs, outputs, and storage to help understand the implications of the altered hydrology on the bay's ecosystem.

II. Manage the runoff input of needed sediment to the bay.

- *A.* Seek opportunities to use dredged sediment from the reservoirs for nutrient and organic supplements to the natural and artificial salt marshes in the bay.
- *B.* Seek regulatory guidance for the restoration of sediment transport by the rivers and streams entering the bay.

III. Prevent new channelization of streams discharging into the bay and restore natural floodplains and overbank areas, where possible. Adopt ecologically sound engineering designs in balance with the need to manage for floods.

IV. Conduct research on whether nitrogen/nutrient input from streamflows is excessive or limiting, and what role it plays in bay productivity.

5.4 Cleanup of Bay Use Impacts

5.4.1 Remediation of Contaminated Sediments

Specific Concerns

- While pollution abatement measures have been very effective in eliminating the inflow of contaminants from many major sources, they have had no effect on the toxic chemicals still resident in the bottom sediments which are a legacy from past practices.
- Stormwater runoff and other freshwater runoff from urban and industrial areas, contaminant particles settling from the air, accidental spills, and illegal discharges, all continue to contribute pollutants to the sediments of San Diego Bay.
- Contaminants can have an adverse effect on the health and survival of marine organisms associated with the sediment. These include not only benthic algae and the invertebrate infauna and epifauna (Fairey *et al.* 1996), but also fishes and crustaceans that live and feed near the bottom.
- Contaminated sediment can also lead to bioaccumulation and biomagnification of sediment contaminants in organisms up the food chain. Bioaccumulation is the process in which biological uptake and retention of contaminants in the tissues of an organism results from feeding, contact with the sediments and overlying water, or some combination of these. In this process, concentrations of many contaminants can biomagnify in body tissue concentrations as they move up through the food web from small invertebrates to fishes, birds, and even to humans.
- The effects of bioaccumulation on migratory birds is a concern, including for listed species like the brown pelican and California least tern. Fish and wildlife can be affected by direct mortality, or at lower contamination levels by sublethal effects on reproduction and survivability of young.
- Another area of specific concern is the possible adverse effects of contaminated bay sediments on human health. These involve three primary pathways of exposure:
  - Consumption of fish and also shellfish, such as California spiny lobsters, rock scallops, clams, and mussels, that live or feed in areas of San Diego Bay where contaminated sediments are present (Gonaver *et al.* 1990).
  - Direct skin contact with heavily contaminated sediment by swimmers, divers, and others working in the bay.
  - Accidental ingestion by humans of contaminated sediment or suspensions of it in the water column.
- Certain sportfish species in the bay are known to accumulate PCBs and mercury at levels that could pose health risks for consumers. In 2005, new signs were posted by the San Diego Bay Council, warning of the dangers of consuming fish and shellfish from San Diego Bay.

Background

An important environmental issue for San Diego Bay involves the problems of contaminated bottom sediments and associated management, and regulatory and technological approaches to remediation. Based on discussions at the 1990 San Diego Bay Symposium, Barker (1990) provided a comprehensive summary of sediment contamination problems in San Diego Bay at that time, application of remediation methods to them, and the consequences of remediation. Since then, the SCCWRP Bight studies have improved understanding of the baseline condition of bay sediments.

Contaminated sediments are those containing chemical substances at levels that can adversely affect the environment, associated communities of organisms, or human health. Contamination of sediments occurs primarily because toxic chemicals have an affinity for sediment particles, effectively making these pollutants an integral part of the benthos. This problem is seriously compounded by the fact that many contaminant chemicals become concentrated at very high levels in the bottom sediments and persist there for long periods of time. Also, these chemicals can become biomagnified at higher trophic levels. Figure 5-2 is taken from a SWRCB (2008, adapted from Bridges *et al.* 2005) staff report on sediment quality and depicts some of the processes involved.

Prior to the 1970s, systems for collecting and treating sewage and industrial wastes before discharging these into the bay were not employed or were relatively ineffective, as noted in Section 2.4.1: Historical Change in Water Quality Condition.

Prior to the 1970s, systems for collecting and treating sewage and industrial wastes before discharging these into the bay either were not employed or were relatively ineffective, as noted in Section 2.4.1: Historical Change in Water Quality Condition. From 1900 to 1963, substantial population growth and commercial development, coupled with lax environmental management practices prevalent at that time, led to serious contamination of sediments in many parts of San Diego Bay. Industrial and military waste discharges included toxic trace metals, chlorinated hydrocarbon compounds, solvents, degreasers, waste oil, and paints. Because of the tendency of many pollutant chemicals to become concentrated at high levels in the bottom sediments, these discharges had serious cumulative effects on the benthos in some areas (SDUPD 1995a; Fairey *et al.* 1996, 1998). Relatively weak natural tidal flushing action, particularly at central and inner bay locations, also contributed to large accumulations of toxic chemicals from these waste discharges.

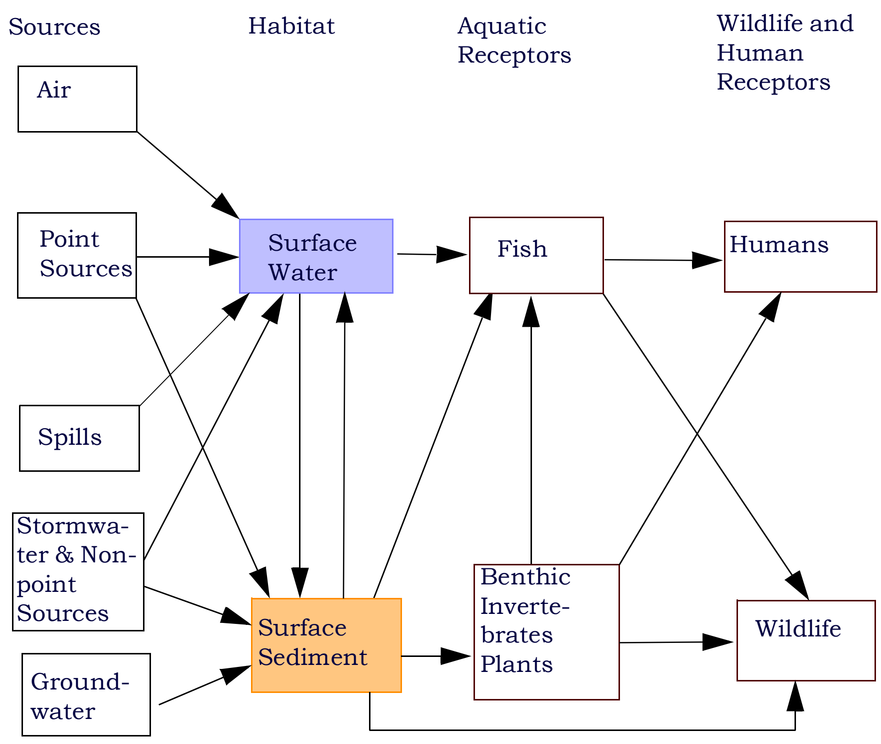


Figure 5-2. Principal sources, fates, and effects of sediment contamination in enclosed bays and estuaries, adapted from Bridges et al. (2005) and State Water Resources Control Board (2008).

Following completion of the Point Loma Municipal Sewage Treatment Facility in 1963, sewage discharges to the bay ended. In the 1970s and 1980s, industrial and military discharges were also reduced or eliminated and water quality criteria and their associated discharge limitations were established.

Bioaccumulation of potentially toxic chemicals by organisms in the food chain is a concern that is still being studied. One study compared the bay to nonurban sites and found high concentrations of PCBs in liver tissues of white croaker, barred sandbass, and black croaker from several sites (McCain *et al.* 1992). Barred sandbass showed symptoms of fin erosion (but later studies have not found this–see the Bight'98 study described below). Based on the potential health risk determined in a toxicological study of sport-caught fish, the San Diego County Health Officer posted health advisories starting in 1990. In 2005, new signs were posted warning of the dangers of consuming fish and shellfish from San Diego Bay. The new signs are intended to warn people that the bay is contaminated and that people, especially children and pregnant women, should limit their consumption (EPA 2006). According to the California Office of Environmental Health Hazard Assessment no specific fish species within San Diego Bay are identified as health hazards (http://oehha/ca.gov/fish.html). These advisories are not intended to discourage individuals from eating fish. Sport fishing still continues in the bay, with the effect of these warnings on the popularity of the sport not yet determined. Fishing in the bay is a combination of catch-and-release and subsistence fishing thus health risks vary among ethnic and economic groups and probably effect the ethnic groups that consume the whole fish more than groups that consume only the muscle tissue. Health risks are dependent on the types and frequency of fish consumed (CDFG 2007a).

Sediment contamination was looked at starting in 1987, when the San Diego Bay Interagency Water Quality Panel (Bay Panel) was formed by legislation (California Law Chapter 1087), in part to encourage agencies to coordinate their efforts and to provide technical information and advice to the San Diego RWQCB. The goals of the panel were to characterize the ecological state of San Diego Bay, including identifying long term environmental trends in sediment contaminant levels, and to address public concerns about the exposure to contaminants from eating fish captured in the bay. The mission of the panel was passed on to the RWQCB when the Bay Panel disbanded in 1997 (City of San Diego 2003).

SCCWRP's Bight'98 Regional Monitoring Project was part of an effort to provide an integrated assessment of the SCB through regional-scale EMAP style stratified random sampling (see Bight'98 Steering Committee 2003). Each of the major sampling components of the Bight'98 survey was used to characterize the state of the subtidal habitats in San Diego Bay. These components include sediment particle size and chemistry characteristics, macrobenthic invertebrate communities, trawl-caught fish and megabenthic invertebrate communities, and contaminant levels in fish tissues. Sediment toxicity samples were also collected by the City of San Diego during the course of this survey, and the SCCWRP analyzed these samples.

All of the sediment toxicity results for Bight'98, including an evaluation of samples from San Diego Bay, are reported in the Bight'98 Sediment Toxicity Report (Bay *et al.* 2000). The study was unique in its comprehensive coverage of San Diego Bay. First, it includes the first random survey of fish and invertebrate populations in the bay. Second, it provided an assessment of contaminants in the tissues of fishes in order to address human health concerns and ecological impacts (e.g. muscle tissue vs. whole fish samples). Finally, this report also provided the first comprehensive comparison of conditions in San Diego Bay to other bays and harbors in the SCB. Such comparisons were possible because these areas were sampled at the same time using the same Bight'98 sample design. Sediment samples were collected at 46 stations distributed throughout San Diego Bay at depths ranging between 3 and 16 m. All samples were analyzed to determine particle size composition and concentrations of various trace metals, chlorinated pesticides, PCBs, and PAHs.

In addition, five species of fish were collected at 24 stations in San Diego Bay and analyzed to measure the accumulation of contaminants in their tissues. Whole fish samples of California halibut were collected at seven stations and analyzed for the presence of pesticides and PCBs. The contaminant levels present in these fish were compared to those found in whole halibut samples from the other southern California bays and harbors, as well as to predator protection limits for mammals and birds. Samples of muscle tissue were also collected from halibut and four other species of sport fish (i.e., calico bass, spotted sand bass, barred sand bass, yellowfin croaker) at the remaining 17 stations in the bay. These muscle tissue samples were analyzed for the presence of metals, pesticides, and PCBs, and the results were then compared to human health consumption limits. All whole fish samples of California halibut collected in San Diego Bay during 1998 contained detectable levels of PCBs and DDT. Concentrations of PCBs exceeded the predator protection limits for mammals, while DDT concentrations exceeded the protection limits for both mammals and birds.

Overall, San Diego Bay ranked fourth out of the five southern California embayments sampled for whole fish in terms of total DDT. The bay ranked first in terms of total PCBs, with the average detected value in San Diego Bay halibut being an order of magnitude higher than in fish from the other bays and harbors (Bay *et al.* 2000).

Muscle tissues contained many of the COCs previously listed for San Diego Bay. For example, PCBs and the metals mercury and zinc were detected in almost all of the muscle tissue samples, while the other COCs occurred much less frequently or not at all in bay fishes. Of the metals and pesticides for which thresholds are available, chromium and arsenic exceeded human health consumption limits in only a single sample each. Overall, PCB concentrations were very high in the muscle tissues of San Diego Bay fish, especially when compared to species of flatfish, rockfish and sand bass sampled off the outer coast of San Diego over the past several years (Bay *et al.* 2000).

The study concluded that contamination remained widespread in San Diego Bay sediments and affects the tissues of various species of fish that are subject to human consumption. Contaminants previously identified to be of concern in the bay, such as chromium, copper, lead, mercury, zinc, PCBs and PAHs continue to be present at levels that exceed one or more sediment quality criteria thresholds. This is particularly true for sites where the percentage of fine sediments is high. Such areas are typically located near or within marinas or shipyards where currents are less strong, and where various physical structures reduce tidal flow or create eddies that allow suspended particles to settle. Several of these contaminants also occurred in relatively high concentrations in the tissues of fish from the bay. For example, mercury, zinc, PCBs and DDT occurred in over 80% of fish tissues, and both PCBs and DDT exceeded at least one of the mammal and bird predator protection thresholds.

In general, the overall level of contamination in the bay appeared less in 1998 than in previous decades. For example, concentrations of copper, mercury, tin, TBT and PAHs were lower in the sediments in 1998 than in previous studies. Additionally, contaminant loads of DDT, mercury and selenium in fish tissues were also less in 1998. In contrast, arsenic levels in fish tissues were slightly higher in 1998 than in previous surveys, while concentrations of chromium remained about the same. Finally, the absence of any evidence of fin erosion in fishes also suggests that conditions have generally improved since 1984 -1988 when the prevalence of fin erosion in black croaker and barred sea bass was relatively high (Bay *et al.* 2000).

Current Management

The cleanup or remediation of polluted sediment in San Diego Bay is regulated by several state and federal statutes. The primary laws that apply, or may apply in some instances, are summarized in Section 3.6: Overview of Government Regulation of Bay Activities in Chapter 3. The most important of these is the Porter-Cologne Water Quality Control Act, which forms part of the California Water Code.

Similarly, several different federal, state, and local governmental or regulatory agencies have official responsibility for issues involving contaminated sediments in San Diego Bay, as shown in Table 5-10. Agency roles are described in Section 3.6: Overview of Government Regulation of Bay Activities. The lead agencies are the RWQCB, the EPA, and the USACE. Both the Navy and the Port have major roles in the process, as does the San Diego County Department of Health Services for sediment issues related to human health.

Table 5-10. Federal and State Statutes affecting management of contaminated sediment.

Federal Statutes	State Statutes
Clean Water Act	California Water Code, Division 7
Rivers and Harbors Act of 1899	California Health and Safety Code
Marine Protection, Research, and Sanctuaries Act	California Fish and Game Code
National Environmental Policy Act	California Environmental Quality Act
Fish and Wildlife Act	California Food and Agricultural Code
National Historic Preservation Act	California Harbor and Navigation Code
Endangered Species Act	California Coastal Zone Management Act

Since 1990, the Port has removed contaminated marine sediments from Tenth Avenue Marine Terminal, National City Marine Terminal, ACH, and East Harbor Lagoon (SDUPD 1995b) (Campbell Shipyard). Regional Board Cleanup and Abatement Orders require that remaining sediments in boatyards achieve a copper level below 530 ppm and a mercury level below 4.8 ppm. According to the RWQCB, San Diego Region, the following sites have been cleaned up as of September 2007:

- PACO Terminals at 24th St. Marine Terminal (copper)
- Kettenburg boatyard (copper, mercury, TBT)
- Bay City Marine boatyard (copper, mercury, TBT)
- Driscoll boatyard (copper, mercury, TBT)
- Mauricio boatyard (copper, mercury, TBT)
- Campbell Marine Shipyard (on-site chemical stabilization of 30,000 cubic yards of petroleum contaminated soil-completed 2001; excavation and off-site disposal of 30,000 cubic yards of benzene contaminated soil completed 2003)

The following sites have cleanup agreements with RWQCB:

- National Steel and Shipbuilding shipyard
- BAE Systems

The following sites are capped:

- Teledyne Ryan Aeronautical storm drains (PCBs)
- Stennis Ocean Control Carrier (CVN) site (PCBs, copper, zinc)

The Port reports the following remediation projects in progress:

- Former Teledyne Ryan facility redevelopment
- BF Goodrich south campus redevelopment

The Campbell Shipyard operated near the corner of 8th and Harbor Drive in San Diego from 1910 to 1999 (Photo 5-3). Also located in this area were a manufactured gas plant waste facility and a bulk petroleum distribution facility. Remedial activity is being performed in accordance with a 1995 Cleanup and Abatement Order issued by the RWQCB and an agreement with the RWQCB under the Polanco site redevelopment statute. The remediation of the site's impaired sediment is currently being permitted. The planned project is a sub-aqueous sand and rock cap over a 9.2-acre area. This cap will include a 1.6-acre habitat area. The cap will isolate the site's impaired sediment from environmental receptors and allow for its continued use for navigation.

The Navy has ongoing sediment sampling projects such as (L. Sinfield, *pers. comm.*):

- Chollas/Paleta Creek Mouth TMDL ($300,000 in sediment sampling).
- Chollas Creek watershed metals and diazinon TMDLs.
- NBSD Middle Piers TMDL (sediment sampling in Fiscal Year 2008).
- SUBASE sediment TMDL (resulted in request for delisting).
- NBSD Graving Dock NPDES sediment sampling (semiannually for ten years). Includes background sampling near Broadway pier and Shelter Island.
- Sediment sampling related to ongoing Installation Restoration Activities.

Some sediment sampling projects tied to planned construction or dredging are for the NBSD Pier 12 Construction, and Chollas Creek mouth for maintenance dredging. For long-term monitoring, the Navy teamed with SCCWRP on Bight 03' and 08' (SCCWRP uses Navy SPAWAR vessels when sampling in San Diego Bay). Sediment sampling at the mouths of Chollas/Paleta Creek and NBSD is also done in partnership with SCCWRP. (L. Sinfield, *pers. comm.*)

The Navy teamed with SCCWRP on Bight 03' and 08' (SCCWRP uses Navy SPAWAR vessels when sampling in San Diego Bay). Sediment sampling at the mouths of Chollas/Paleta Creek and NBSD is also done in partnership with SCCWRP.

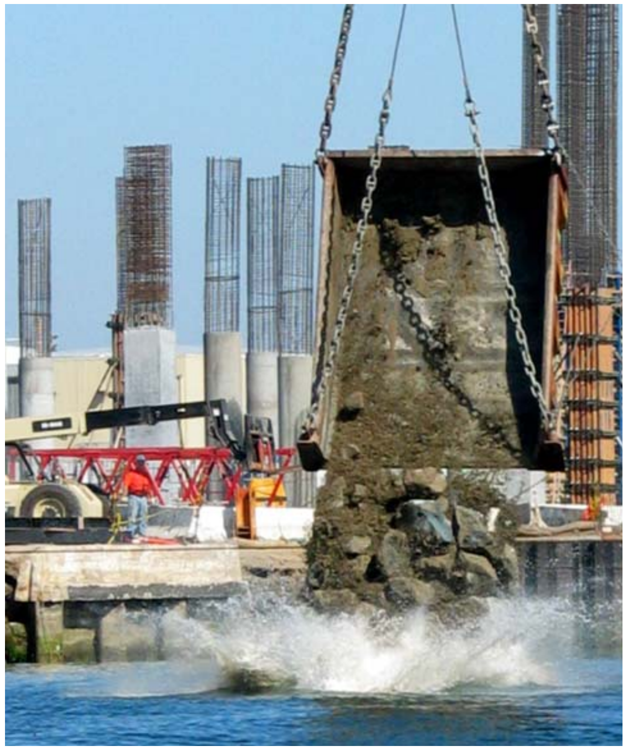


Photo 5-3. Campbell shipyard remediation. Photo courtesy of Eileen Maher.

The Navy has active research and development studies underway to evaluate sediment contamination at Navy sites in San Diego Bay and the effectiveness of methods for remediation. The primary project objectives are to characterize existing sediment contamination at this site, evaluate the processes that control contaminant levels and transport processes, and study the treatability of these contaminants (B. Chadwick, SPAWAR, *pers. comm.*) The Navy's Remediation Research Laboratory, at SPAWAR, conducts studies on science and technology issues that are relevant to remediation of contaminated soils and sediments, including those in San Diego Bay (S.E. Apitz, SPAWAR, *pers. comm.*).

The Navy's policy on sediment cleanup where several responsible parties are involved is described in a statement from the Chief of Naval Operations to the Commander, NAVFAC (Navy/Marine Corps Installation Restoration Policy on Sediment Investigations and Response Actions [8 February 2002]). The policy specifies that the source must be identified and controlled before cleanup, the cleanup must be risk-based and have site-specific cleanup goals, and the monitoring criteria for any monitoring plan must be established before the first sample is collected. All sediment investigations and response actions must be directly linked to Navy contaminated releases. Directly linked means that the sediment contamination is scientifically connected to a Navy Installation Restoration site. This Policy requires that:

1. All sources shall be identified to determine if the Navy is solely responsible for the contamination. Source identification is very important in determining the Navy's cleanup responsibility and if a site will be recontaminated after cleanup is complete. The extent of the Navy responsibility shall be determined. Therefore, the project team will generate a Watershed Contaminated Source Document (not a watershed investigation) if there are potentially other non-Navy sources contributing to the contamination of the sediment. All sources of Navy and non-Navy contamination at the site should be identified.
2. All investigations shall primarily be linked to a specific Navy CERCLA/Resource Conservation and Recovery Act site. If it is established that only Navy activities contribute sources to a water body then investigating that water body using a

watershed approach may be beneficial and cost effective. Investigating (collecting and analyzing samples) entire watersheds that contain non-Navy sources is not an appropriate use of cleanup funds. Any proposed broad watershed investigations with non-Navy sources and potential cost sharing with non- Navy entities must be approved by Chief of Naval Operations (N45) Office.

3. All sediment investigations and response actions shall be consistent with Navy polices on risk assessment and background chemical levels.
4. Sediment cleanup goals shall be developed based on site-specific information and shall be risk-based. If unacceptable risk to human health and/or the environment is identified, risk-based sediment cleanup goals shall be developed using site-specific information. The cleanup goal must be risk-based and achievable. Ecological screening values must not be used as cleanup goals nor shall cleanup values below background chemical levels be used. Development of cleanup goals should include, but not be limited to, land use and bioavailability.
5. The Navy shall not clean up contamination from a non- Navy source where the Navy has not contributed to the risk in sediments. The Navy will not clean up a site before the source is contained. Any potential re-contamination by non-Navy sources shall be documented. Only sediment sites with known contamination from Navy sources that demonstrate unacceptable risk will be remediated. All Navy sources shall be contained before sediment response actions are initiated. The information provided in these reports, documents that the Navy has cleaned up its responsibility.
6. A monitoring plan with exit strategies shall be developed before collecting the first monitoring sample.

As the lead regulatory agency, the San Diego RWQCB fulfills its two primary functions in dealing with contaminated sediment issues in San Diego Bay:

- to ensure reasonable protection of beneficial uses in the bay; and
- to ensure the prevention of nuisance conditions resulting from excessive discharges of waste.

The SWRCB adopted a Statewide Consolidated Toxic Hot Spot Cleanup Plan on June 18, 1999. The Regional Board has the authority to take enforcement action against those who violate its waste discharge requirements or discharge prohibitions as they apply to sediment contamination. The three primary enforcement remedies available to the Board are: cease and desist orders; cleanup and abatement orders; and administrative civil liability monetary penalties.

The presence of contaminated sediments in representative areas of San Diego Bay can be characterized from the results of the Bight ‘03 program (See Section 2.4: Water and Sediment Quality).

Contaminants of concern are identified by comparing measured sediment concentrations with proposed sediment quality guidelines (note that no sediment quality criteria presently exist). Contaminants of greatest concern in San Diego Bay are metals (copper, mercury, and zinc), a pesticide (chlordane), a chlorinated hydrocarbon (PCBs), and PAHs. It should be noted that the use of PCBs and chlordane has been banned for decades. The presence of these contaminants represents remnants of these persistent compounds that remain in the watershed and in the bottom sediments of San Diego Bay.

Cleanup and remediation methods that apply to San Diego Bay are summarized in Figure 5-3. As shown in this diagram, remedial measures can be classified as either removal actions or nonremoval actions. As the term indicates, removal actions involve the physical removal of contaminated sediment, normally by dredging, and its disposal with or without treatment. Nonremoval methods can include in situ remediation by capping (the method used in the East Harbor Island Lagoon project), use of a chemical sealant, or grouting with cement or other materials (Barker 1990). The other nonremoval approach is to take no action, simply allowing the contaminated sediment to be buried by natural sedimentation processes, to naturally degrade, or to disperse from the site.

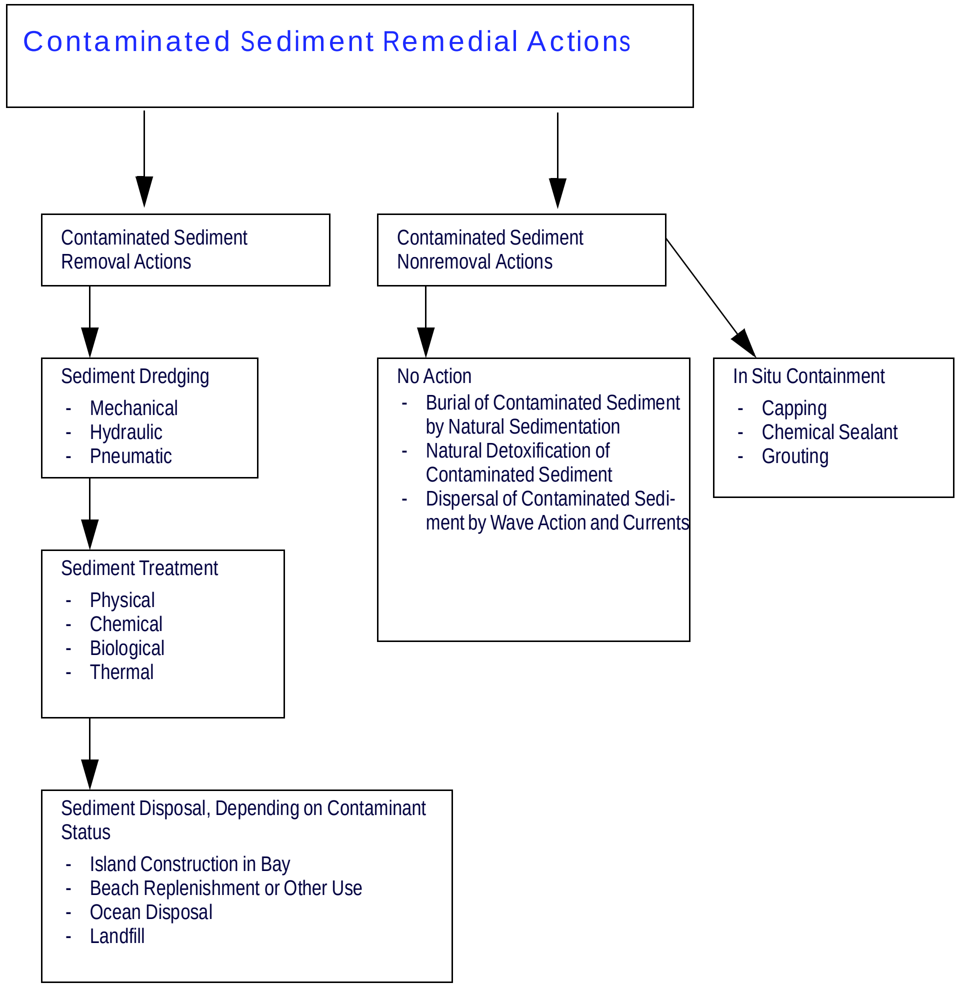


Figure 5-3. Contaminated Sediment Remedial Actions Flowchart (after Barker 1990).

Nonremoval methods of cleanup and remediation include capping, which is a relatively new technology. Its effectiveness has not been evaluated over the long term.

Taking no action may be the preferred alternative in cases where dredging or otherwise disturbing the contaminated sediment would produce more adverse environmental effects than if it were left in place. On the other hand, the length of time required for natural processes to isolate or disperse the contaminants must also be considered in making this decision. That time period may be unacceptably long.

Evaluation of Current Management

The environmental effects of contaminated sediment, as well as the effective remediation of these problems, are both relatively new areas of concern, study, and technology. In light of this, it is important to review both past and current management and regulatory practices for contaminated sediments in San Diego Bay. Clearly, the current regulatory focus of the RWQCB San Diego, as well as the recent investigations sponsored by the SWRCB and Navy laboratories at SPAWAR, are sound management and research practices.

Contaminants of concern are identified by comparing measured sediment concentrations with sediment quality guidelines.

That said, there are many valid reasons for the delays that have occurred in the remediation of contaminated sediments in San Diego Bay. These include time-consuming appeals by entities responsible for funding the remediation, and limited funds for staffing at the RWQCB and other agencies. In addition, attaining the desired level of cleanup or remediation at a given site often takes a substantial amount of time, sometimes untested technologies, and funding. This associated planning process is also hampered by delays in adopting clear criteria, such as sediment quality objectives, on which to base decisions about the most appropriate remediation method to use. Finally, there are many technical difficulties and unknowns in applying relatively new remediation methods, such as capping, or even in applying established methods under different site conditions. As knowledge in the field of contaminant remediation advances many of these problems will be alleviated.

The issue of sediment toxicity is being at least partly addressed by the RWQCB through the TMDL process. Much of San Diego Bay's sediment is listed as impaired for benthic community effects and sediment toxicity under CWA §303(d), which requires a TMDL be established for each pollutant. As noted in Table 5-11, a time schedule to complete TMDLs exists for many of the bay's "hot spots." Trash listing for Chollas Creek is under consideration for the 2008 303(d) list (A. Monji, *pers. comm.*).

Table 5-11. Status of TMDL development for San Diego Bay by the RWQCB (San Diego RWQCB,10/01/10).

Project Name	TMDL for Pollutants:	Status	RB Adoption	EPA Adoption
Chollas Creek	Diazinon	Done	August 2002	Nov. 2003
Chollas Creek	Metals (cadmium, copper, lead, zinc)	Done	June 2007	Jan. 2008
SD Bay - Mouth of Chollas Creek	Metals, PCBs, non-polar organics	Ongoing	Sept. 2009	July 2010
SD Bay - Shelter Island Yacht Basin	Copper	Done	Feb. 2005	Feb. 2006
Shelter Island Park, G St., B St. Pier, Tidelands Park	Indicator Bacteria	Ongoing	June 2008	Pending
SD Bay - 7th St. Channel / Paleta Creek	Metals, PCBs, non-polar organics	Ongoing	Sept. 2009	July 2010
SD Bay - Switzer Creek	PAHs, chlordane, lindane	Ongoing	Sept. 2009	July 2010
SD Bay - B St. Broadway Piers	Likely for Metals (mercury, copper, selenium, zinc), PAHs, PCBs	Ongoing	Sept. 2010	July 2011
SD Bay - Downtown Anchorage	Chlordane, metals, PCBs, non-polar organics	Ongoing	Sept. 2010	July 2011
SD Bay - Navy SubBase	Navy conducting study of impairment	Ongoing	Uncertain	Uncertain
SD Bay - Naval Station San Diego. 32nd St.	Navy conducting study of impairment		Uncertain	Uncertain
SD Bay near Coronado Bridge	Listed for benthic community effects and sediment toxicity		Uncertain	Uncertain
SD Bay 24th St. Marine Terminal	Listed for benthic community effects and sediment toxicity		Uncertain	Uncertain
SD Bay	PCBs			
SD Bay Shoreline	Copper			

The problems associated with remediation of contaminated sediment are obviously complex and most remediation methods themselves are costly. The following approaches are recommended as a management strategy to increase the efficiency of the process in San Diego Bay.

Management Strategy—Remediation of Contaminated Sediments

Objective: Ensure that San Diego Bay finfish and shellfish are safe to eat, that the food web is not adversely altered and that risks are minimized to recreational and commercial water contact users from the effects of contaminated sediment.

I. Collect and distribute data on sediment contamination.

- *A.* Continue to participate in the SCCWRP's Bight sampling program. The Navy should participate with this program with contributions of sediment data for San Diego Bay.
- *B.* The Navy and the Port should participate in RWQCB sediment workshops to discuss the means of determining clean levels or targets for sites.
- *C.* The Navy and Port should continue to update source control programs, both on the bay and upstream.
- *D.* The Navy and Port should update point-source pollution prevention plans for facilities on the bay.
- *E.* The Navy should contribute to the Regional Harbor Monitoring Plan.

II. Protect the public from health risks associated with consuming seafood by ensuring that San Diego Bay finfish and shellfish are safe to eat.

A. Characterize consumption of seafood organisms taken from San Diego Bay.
    1. Evaluate existing information on shellfish abundance and consumption from the bay, and conduct a survey of consumption rates and patterns if necessary.
    2. Building on the results of the San Diego Bay Health Risk Study, evaluate the fish consumption from the bay and conduct a follow-up survey if necessary.
B. Use Bight '98, '03, and '08 data to establish baseline contaminant levels and trends in selected San Diego Bay seafood species.
    1. Conduct a trend analysis of metals, PCBs, and DDT levels in topsmelt as important prey for fish, seals, and other bay fauna.
    2. Conduct a trend analysis of dioxin and radionuclide levels in spotted sand bass and barred sand bass.
    3. Conduct a trend analysis of dioxin levels in other fish species that have been determined to be consumed in significant quantities.
    4. Review existing data on shellfish contaminants to evaluate their adequacy for establishing any ongoing estimates of risks to consumers, as well as the need for future monitoring.
C. Characterize risks resulting from consumption of chemically contaminated fish and shellfish from San Diego Bay.
D. Combine available consumption and analytical data as determined above to quantify risks to human consumers.
E. Periodically update risk estimates as trend monitoring data become available.
F. Monitor trends in contaminants determined to be present in seafood organisms at levels that may pose significant risks to human consumers.
    1. Monitor trends of metals, PCBs, DDTs, and dioxins in spotted sand bass and barred sand bass.
    2. Monitor trends of metals, PCBs, and DDT in Pacific mackerel.
G. Develop and implement strategies for minimizing the exposure of seafood consumers to contaminants determined to pose significant health risks.
    1. Support the development and implementation of pollution prevention practices (e.g. integrated pest management) for land owners and businesses surrounding San Diego Bay and its watershed with the goal of eliminating discharges of toxic substances.
    2. In the cleanup of sediments, priority should be given to sites where sediments contain elevated levels of persistent and/or bioaccumulative toxic contaminants, as well as sites that may have lower contaminant concentrations but a higher chance of exposure to consumers. Use the Ecological Risk Assessment model under development at SPAWAR (K. Richter, SPAWAR, *pers. comm.*).
    3. Issue consumption advisories or bans when potentially significant health risks to shellfish consumers are determined to be present.
    4. Provide education and counseling about potential health risks to consumers of San Diego Bay fish and shellfish with consideration given to the diversity of the population catching and consuming fish from the bay.

III. Minimize risks to recreational and commercial water contact users.
A. Characterize bacteriological water quality at selected locations around San Diego Bay.
    1. Monitor indicator bacteria (total and fecal coliform) to determine compliance with state recreational water standards or other relevant criteria.
    2. Monitor and evaluate temporal trends in indicator bacteria at selected locations.
    3. Minimize the exposure of recreational and commercial users to pathogens.
    4. Design and implement management practices to prevent the introduction of pathogens to the bay.

B. Continue to quarantine water contact areas when potentially significant health risks to recreational commercial users are determined to be present.

IV. Minimize risks to the bay's wildlife species.

A. Monitor topsmelt for potential for bioaccumulation of metals, PCBs, and DDT, since it is a resident of the bay and is a primary prey for federally-listed and other migratory birds.

B. Ensure that bay-wide monitoring programs are designed to consider the lower contaminant levels that can affect successful reproduction and survivability of young, such as those programs implemented through SCCWRP, County Environmental Health, California Office of Environmental Health Hazard Assessment, San Diego Toxic Substances Monitoring Program, CDFG, EPA, and USFWS.

C. Conduct autopsies within 24 to 48 hours on birds found dead in the bay area.

V. Conduct planning and research in support of the management objective.

A. Support a cooperative research program based on USGS' Physical Oceanography Real-time System to enhance oil spill prediction and response, understand what drives sediment redistribution, and analyze compatible use of boat traffic/recreational water contact users in the bay.

B. Participate in watershed-based, cooperative efforts to set sediment cleanup targets, including the development and implementation of TDMLs.

5.4.2 Oil Spill or Hazardous Substance Prevention and Clean Up

Specific Concerns

- Cumulative effects of small, medium, and large oil spills from boats, personal watercraft, and ships can contaminate the bay and affect natural resources.
- Coordinated planning for oil spill cleanup activities should be integrated with conservation priorities of this Plan.
- The collection and maintenance of ecological information required by OPNAVINST 5090.1C (Chapter 22) is essential to pre-incident planning on behalf of the Navy's Regional Environmental Coordinator.
- There is a need to incorporate planning for a NRDA under both federal and state oil spill prevention regulation, as well as to establish a quantitative baseline to support natural resources management decisions, habitat restoration and enhancement planning, and sustainability planning.

Background

Federal Regulatory Framework

The federal Water Pollution Control Act of 1972 (33 USC 1251, et seq.), as amended by the CWA of 1977, authorizes the President, in the case of an oil or hazardous substance release, to take any action necessary to mitigate damage to the public health and welfare; including, but not limited to fish, shellfish, wildlife, public and private property, shorelines and beaches. Natural Resource Trustees are authorized to recover damages for injury to, destruction of or loss of natural resources resulting from a discharge or the substantial threat of discharge, of oil into navigable waters.

The CWA prohibits spills, leaks or other discharges of pollutants into waters of the United States in quantities that may be harmful, which includes discharges of pollutants that: (1) Violate applicable WQS; (2) Cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines; or (3) Cause sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

The OPA of 1990 amended the CWA to expand oil spill prevention activities, improve preparedness and response capabilities, and ensure that companies are responsible for damages from spills. The USCG is the lead agency for oil spill prevention and response, and is authorized to direct state and local agencies in controlling pollution in bays and coastal waters.

Hazardous substances other than oil are addressed by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, 42 USC 9601, et seq.), which authorizes Natural Resource Trustees to recover damages for injury to, destruction of or loss of natural resources resulting from the release of a hazardous substance.

NOAA is assigned responsibility for NRDA from spills, and the Navy has adopted NOAA procedures for damage assessment (15 CFR 990). Similarly, the U.S. Department of the Interior is in charge of damage assessment for hazardous substance spills under EO 12580. The baseline condition of the natural resources and services that would have existed had the oil or hazardous substance release not occurred is estimated using historical data, reference data, control data or data on incremental changes, alone or in combination, as appropriate. Navy guidance (OPNAVINST 5090.1C) suggests that this information may be obtained from INRMPs, NEPA Documents, or special studies.

State Regulatory Framework

The OSPR is responsible for protecting California's natural resources by preventing, preparing for, and responding to spills of oil and other deleterious materials, and through restoring and enhancing affected resources. The OSPR was formed after the Exxon Valdez oil spill in 1989, and the spill off of Huntington Beach by the American Trader in 1990. These events inspired the California Legislature to enact legislation in 1990 called the Lempert-Keene-Seastrand Oil Spill Prevention and Response Act. The Act also gave the SLC certain authority over marine terminals. The OSPR's responsibilities under the Act are:

- Development of contingency plans for the protection of fish and wildlife
- Establishment of rescue and rehabilitation facilities
- Establishment and funding of a network of rescue and rehabilitation facilities, known as the Oiled Wildlife Care Network
- Assessment of injuries to natural resources from a spill
- Development of restoration plans to compensate for adversely affected wildlife resources and habitats.

Both the federal and state statutes (OPA 90 and SB 2040) were enacted in consequence of the catastrophic oil spills of 1989, and both required contingency planning for both state and federal governments. The USCG and CDFG - OSPR agreed to joint preparation of contingency plans through co-chairing the three Port Area Committees for Contingency Planning: USCG Port Areas for San Francisco, Los Angeles/Long Beach, and San Diego.

OSPR's Resource Assessment Program conducts NRDA of pollution events that result in significant injuries to wildlife and/or habitat. The goal of OSPR's NRDA program is to quantify the damages, to seek compensation from the responsible parties, and to both restore the injured resources and compensate the public for the lost interim ecological benefits and uses of these resources.

The OSPR has developed a California Wildlife Response Plan (CDFG and OSPR 2011) to augment the Area Contingency Plan (ACP). The Wildlife Plan details the Wildlife Operations Branch purposes, goals, objectives, responsibilities, and structure. The Wildlife Operations Branch is in the Operations Section of the Incident Command System for oil spill response. The Wildlife Operations Branch structure needed in California and detailed in this plan is expanded beyond that described in the USCG Incident Management Handbook. CDFG normally leads wildlife response during a spill in California.

Current Management

Table 5-12 shows the total recorded oil spilled in San Diego Bay between 1993 and 2006. Navy installations have historically been hot spots for spills, at 32nd Street Naval Station, the NASNI Carrier Basin, and the installations under Coronado Bridge, with smaller hot spots around the SUBASE, FISC Fuel Depot pier, and NAB. Non-Navy related hot spots are likely at Commercial Basin, 10th Avenue Terminal, and National City Marine Terminal. The USCG recorded 4,035 spills in San Diego County from 1993 through 2006 (5,110 days). This equates to approximately three spills of 35 gallons every four days.

Table 5-12. Oil spill data from San Diego Bay. Data courtesy of the U.S. Coast Guard (2007).

	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993
Total Reported Pollution Incidents	373	316	289	166	216	136	269	294	303	370	361	353	302	287
Total Incidents Unknown Source	151	163	138	73	90	55	78	144	147	206	211	159	193	148
Total Incidents Source Identified	222	153	151	93	121	81	191	150	156	164	150	195	109	143
Total Incidents Involving the Navy	109	96	111	81	103	53	101	51	110	N/A	N/A	N/A	N/A	N/A
Known Gallons Spilled by the Navy	620	1310	3394	902	1237	719	5235.5	743	N/A	N/A	N/A	N/A	N/A	N/A
Total Reported Gallons Spilled	4215	4388	4216	1449	2531	1318	6089	1501	13516	6290	27421	9083	45245	8406

The trend in number of Navy incidents shows no evidence of changing, but the total number of spilled gallons appears to have declined since the early 1990s. The Navy has a $24 million Bilge Oily Waste Treatment Facility at 32nd Street. Operating like a sewer for oily waste, all ships using the 32nd Street facility pump their oily waste for treatment there. The plan is to have a Bilge Oily Waste Transportation System at every pier, in which bilge waste will be pumped directly to storage facilities on shore for treatment. To further reduce the risk of in-port spills, the Navy no longer requires its ships to keep their tanks full of fuel while in port. Instead, they hook up with an oiler once they depart the bay. The Naval Station, NASNI, and SUBASE all have spill response teams with Boston whalers, water pump boats, and oil absorbing material.

All ships using the 32nd Street Facility will pump their oily waste for treatment at the Bilge Oily Waste Treatment Facility.

Three tenant firms of the Port, with the assistance of the Port, form the San Diego Spill Alliance. Arco Products Company, Chevron Products Company, and Jankovich and Sons, Inc., which operates the Port's bunker fuel facility, are part of a mutual aid agreement to provide personnel and oil spill containment and recovery equipment to any member of the Alliance who requests assistance in dealing with an oil spill. All three of these firms are located in close proximity to the Tenth Avenue Marine Terminal. Although not a signatory to the Alliance, the Port provides support by making space available at its piers and wharves without charge to member firms for the deployment of equipment during training exercises and actual oil spills.

Area Contingency Plan

The OPA addressed the development of a National Planning and Response System. As part of this system, an Area Committee is formed to develop a preparedness document called the ACP to protect natural resources from marine pollution spills. The Committee is comprised of personnel authorized to make decisions on behalf of federal, state, and local agencies, and they advise on the Plan development and implementation. The ACP is implemented in conjunction with the National Contingency Plan and shall be adequate to remove a worst-case discharge of oil or hazardous substance, and to mitigate or prevent a substantial threat of such a discharge from a vessel, offshore facility, or onshore facility operating in or near the geographic area. Each Area Committee is also responsible for working with state and local officials to preplan for joint response efforts, including appropriate procedures for mechanical recovery; dispersal; shoreline cleanup; assigning priorities for the protection of sensitive environmental areas; and protection, rescue, and rehabilitation of fisheries and wildlife. The Area Committee is encouraged to solicit advice, guidance, or expertise from subcommittees comprised of facility owners/operators, shipping company representatives, cleanup contractors, emergency response officials, marine pilots associations, academia, environmental groups, consultants, response organizations, and concerned citizens.

The ACP provides guidance for the first 24 hours of response, with detailed evaluation and recommendations for the State's shoreline resources. The ACP for San Diego Area (California OSPR 2008). It contains site Priority Rankings (A through F) for the bay based on decisions of the Area Committee. The top protection areas (categories A and B) in the bay are, from north to south: marine mammal pens, Magnetic Silencing Facility, marine mammal pens of central bay Delta Beach, Paradise Marsh, Emory Cove, Sweetwater Refuge, Otay River Channel, and the CVWR.

Annual exercises are conducted regularly in the form of comprehensive table-top drills, or the Regional Environmental Coordinator may conduct them in combination with area spill response exercises. Contracted support personnel are relied upon in local contingency plans are also invited to participate in these exercises. The USCG produces a semi-annual San Diego ACP newsletter "The Contingent" as part of its Regional Contingency Plan implementation.

NRDA and Ephemeral Data Collection Plan

DoD guidance (DoDI 4715.3) states that "All DOD Components shall develop and promulgate criteria and procedures for assessing natural resource damage claims in the event natural resources under DoD control are damaged [injured] by oil or a hazardous substance released by another party." Navy requirements (OPNAVINST 5090.1C), however, go beyond DoD 4715.3 and apply to natural resource injury occasioned by oil or hazardous substance releases from both DoD and non-DoD sources.

Where an oil spill, regardless of source or physical location, injures or threatens to injure natural resources within Navy management or control, NOAA NRDA procedures serve to guide Navy activities in the mitigation, assessment and collection of natural resource damages occasioned by the spill. In the case of other hazardous substance releases, the Department of the Interior has established other types of natural resource damage assessment regulations. One method calculates resource damages called a Resource Equivalency Analysis, also known as Habitat Equivalency Analysis, is the most common method used in NRDA cases nationwide. It has been endorsed by the courts on two occasions. The injury is assessed in terms of degree (percent of baseline injured), duration (years until recovery), and size (number of acres, stream miles, birds, etc.). A trajectory estimating the recovery to baseline is also estimated. The injury may be described in terms of lost acre-years or stream mile-years or bird-years of lost ecological services. The benefits of a restoration project are quantified in similar terms: degree of benefit (e.g. percent services per unit area), duration of the project, and trajectory of the benefits over time. With this information, the size of the project is scaled until the benefit of the project is equal to the injury. The final step is to cost out the project. This cost becomes the measure of damages.

The baseline assessment compiled prior to a spill becomes essential to both pre-incident planning for response, as well as this post-incident assignment of damages. This baseline ecological information is required under OPNAVINST 5090.1C, Chapter 22 on behalf of the Navy Regional Environmental Coordinator. Baseline data specifically includes this INRMP.

NAVFAC Southwest has recently developed an Ephemeral Data Collection Plan in support of NRDA. Immediately during and after a spill, data will be collected in order to evaluate the injury. Examples include macroinvertebrate surveys, water and sediment samples, and vegetation surveys. Following federal guidelines, this is often done cooperatively with the responsible party, as well as with fellow trustee agencies. The NAVFAC plan identifies specific locations, methodologies, and responsibilities for data collection.

Recent baywide bird surveys (2006-2007) funded by both the Port and the Navy integrated these data collection locations into the study design, to improve the quantification of baseline status of natural resources in the event of a spill.

Harbor Safety Plan

The San Diego Harbor Safety Plan provides mariners using the waters of San Diego Bay a guide to navigation information that will enhance vessel safety, with the ultimate goal of pollution prevention and protection of the region's natural resources.

This plan has been developed by the San Diego Harbor Safety Committee as mandated in the California Oil Spill Prevention and Response Act of 1990, as codified in Title 14, Division 1, of the California Code of Regulations. To view or print the Harbor Safety Plan, see http://www.sdmis.org/maritime/safety.pdf.

The Act (SB 2040) created harbor safety committees for the major harbors of the state of California: “for the vessels within each harbor…(by preparing)….a harbor safety plan, encompassing all vessel traffic within the harbor.” Harbor Safety Committees were established for: San Diego, San Francisco (including San Pablo and Suisun Bays), Los Angeles/Long Beach, Port Hueneme, and Humboldt Bay.

Management Strategy— Oil Spill Prevention and Cleanup

Objective: Prevent spills of oil and other hazardous substances, and ensure the effectiveness of prevention and response planning.

I. Integrate the conservation priorities of this Plan into contingency spill response and NRDA planning.

  A. Continue to update GIS layers of bay natural resources to support preparedness planning.

  B. Continue to integrate baseline ecological surveys into preparedness planning, such as the study design modifications implemented in baywide avian species surveys in 2006-2007.

  C. Integrate invasive species response planning with oil spill contingency plans.

II. Continually enhance oil and hazardous substances spill response capabilities through equipment procurement, training, and participation in drills and area exercises, and continue active membership in the Harbor Safety Committee and Area Contingency Planning Committee.

  A. Continue to test the local ACP with annual table-top exercises and periodic drills.

  B. Continue spill response, regardless of its source, in partnership with the USCG in accordance with the existing MOU between the USCG and the Navy.

5.5 Cumulative Effects

Specific Concerns

- As in other ecosystems, significant piecemeal habitat loss and fragmentation continues in San Diego Bay, and species continue to be listed, despite the intent of cumulative effects analysis under NEPA and other laws.
- Certain habitat losses are so severe in the bay that the remaining fragments have become increasingly more sensitive. Furthermore, smaller habitat areas have not been mapped. The cumulative effect of additional loss would be the deciding factor in determination of a significant impact, even though the project footprint itself may be small. However, there traditionally has been little documentation available to support a determination.
- Recent court cases have highlighted the need to analyze climate change in a consistent manner baywide.
- Despite the obligation of agencies to quantify the effects of projects from a cumulative perspective, we are technically unable to do this because it entails a need to quantify connections among species and among habitats, and between the proposed project and all past, present, and reasonably foreseeable future actions at a site.
- There is no mechanism to ensure the quality of discussion on cumulative effects in environmental documents, especially for projects that are small but that are repeated on a wide scale. There is no way to identify at what point a loss becomes significant and at what scale of analysis.

- Incomplete or inadequate information sharing among agencies makes it difficult for project proponents to summarize past actions.

Current Management

Under NEPA, cumulative effects are those that result from the incremental impacts of the action when added to other past, present, and reasonably foreseeable future actions regardless of which agency (federal or nonfederal) or person undertakes those actions.

The definition of cumulative effects differs under NEPA than under the ESA. Under NEPA, cumulative effects are those that result from the incremental impacts of the action when added to other past, present, and reasonably foreseeable future actions regardless of which agency (federal or nonfederal) or person undertakes those actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7). Under the ESA, cumulative effects include the effects of future state, tribal, local, or private actions that are reasonably certain to occur in the action area considered in a biological assessment or opinion.

The definition under the ESA is narrower. Cumulative effects include the effects of future state, tribal, local, or private actions that are reasonably certain to occur in the action area considered in a biological assessment or opinion. Future federal actions that are unrelated to the proposed action are not considered because they require separate consultation pursuant to Sec. 7 of the ESA (USFWS and NMFS 1998). Usually, the NEPA/CEQA cumulative effects analysis is taken and applied to the narrower ESA definition.

Potential cumulative effects from bay projects include:

- Habitat conversion, loss, fragmentation, or degradation.
- Changes in sediment or salinity dynamics.
- Habitat degradation for birds with projects that increase boat traffic.
- Increased risk of oil spills and exotic species invasions with increased maritime traffic or other activities that act as vectors of invasive species.
- Increased risk to water or air quality.
- Hardening of the intertidal zone that reduces forage for shorebirds.
- Increased disturbance of birds using shoreline areas.

Individual projects may have little measurable ecological effect beyond the project footprint. However, dozens of similar projects could measurably change sediment erosion and deposition patterns, organic matter production and movement, as well as affect types and extent of habitat within the bay. Modeling of cumulative impacts requires this quantification of links between habitat "quality" and biological resource use, and these are generally poorly understood. For example, the cumulative effects of armoring on habitat functions other than resource use are not predictable at present, such as changing longshore drift velocities and lowering of the beach profile such that organic deposition on beaches is altered, as well as nutrient flux from sediments (Thom *et al.* 1994).

Evaluation of Current Management

NEPA and ESA both fail to provide means to ensure the proper consideration of cumulative effects.

Congress passed NEPA out of concern that the nation's limited natural resources were being lost in "small but steady increments" (S. Rep. No. 296, supra note 2, at 5, as cited in Thatcher 1990). However, the law provides no mechanism to ensure the proper consideration of cumulative effects, with the quality of the analysis dependent on the author of the environmental documentation. Typical cumulative effects sections in environmental documents are brief and vague, and they are recycled from report to report (Parry 1990).

Strategy for Cumulative Effects

Objective: Minimize adverse cumulative effects on habitats and species of the bay ecosystem.

I. Standardize the format by which cumulative effects are discussed in environmental documentation (Parry 1990) as shown below and in this outline (sections *II* and *III*):

  A. Documentation should be presented at different hierarchical scales that are standardized to the extent possible from lowest to highest scales, such as by inlets, the bay as a whole, SCB, state of California, or the Pacific Flyway.

- *B.* Ensure climate change and sea level rise scenarios are considered using a standardized range of possible outcomes over 50-100 years or other defined time period.
- *C.* Ensure standardization of the habitat classification system to be used in cumulative effects documentation.
- *D.* The assessment should provide a check on the fragmentation and loss of connectivity among remaining habitats.
- *E.* The assessment should provide a check on the minimum size of viable habitat parcels, using management indicator species to define “viable” parcels.
- *F.* The format should support an information base on local extirpations or declines of species at risk, both listed and others of concern, so that additional effects to these species from a project can be more easily reported upon.

II. Properly bound the spatial and temporal extent of projects, such that all other projects that overlap in time and space are considered.

- *A.* Geographic boundaries of a proposed action should be defined by actual effects, not administrative or ownership boundaries.
- *B.* The immediate geographic boundary of an analysis should be expanded until trends show that project effects diminish sharply.
- *C.* Identify crucial agents of connection or interaction between habitats that may be affected by projects, such as water/watershed, sediment movement, animal movement, and wind transport.
- *D.* If information is not available, such as a project site is known but no other supporting engineering or natural resource data, use data from this Plan to support the analysis.

III. Improve mapping of habitat values in the bay, and subsets of these values, in order to improve assessment of cumulative effects.

IV. Use management indicator species identified in this Plan (see Chapter 6.0) that represent values at risk for a particular project, both directly and due to connections up the food chain or among habitats, to help focus the analysis of potential impacts.

V. Once a standardized format is established, make the information accessible to project proponents and agencies to update and include in cumulative effects documentation.

- *A.* Use standardized analysis of impacts such as those presented in the California Sediment Management Plan.
- *B.* Develop a web-based database to track projects affecting the San Diego Bay natural resources. A database should be developed specific for San Diego Bay to help evaluate cumulative effects of projects and effects over time to natural resources. This database should be public information for all to access to keep the public well informed of projects and any public commenting periods. The California Department of Toxic Substances has a web-based database that could be used as a model.

Develop a web-based database to track projects affecting the San Diego Bay natural resources and to support a consistent approach to analyzing the cumulative effects of projects.

VI. Support research to improve the adequacy of cumulative effects analysis at predicting when habitat or species effects become significant.

- *A.* Promote research on connections among habitats and species, and the relationship between habitat “quality” and resource use.
- *B.* Support research on the effects of habitat fragmentation, using indicator species.
- *C.* Support research on the minimum size and proximity of habitat parcels as viable habitat for animals of different sizes and dispersal capabilities.

VII. Develop conservation measures for cumulative effects.

5.6 Outdoor Recreation and Environmental Education

Recreational boating is addressed under Section 5.2.4: Water Surface Use and Shoreline Disturbances.

Specific Concerns

- Other than its use as a setting or backdrop for activities occurring in the bayside municipalities, there are relatively few events that showcase the bay as a resource unto itself.
- Education about the bay could benefit from better integration into the existing network of professionals in natural resource interpretation.
- Understanding of the bay's cultural value, how it has been viewed and used past and present, is an information gap that needs to be filled in order to make education programs effective at reaching target audiences.
- Adult education is not as well targeted as K-12 school-level education. Compounding this is that the demographic composition of residents living near the bay has changed over the last 10 years.
- Professionals who manage the bay and political decision-makers need to be informed about bay natural resource issues in order to advocate for them.
- Secure, long-term funding is needed to ensure the continuance of environmental education programs at San Diego Bay.

Current Outdoor Recreation and Environmental Education Initiatives

Teaching people about the bay's natural resources, the need for conservation, and the watershed's influence on the bay is an important component of an ecosystem management strategy. Environmental education is presently targeted at both school-age children and adults but usually through separate programs. A sampling of existing environmental outreach projects on the bay include:

- The Port currently has funded school partnership projects with:
  - WiLDCOAST (cross-border media campaigns and education on the green sea turtle)
  - Aquatic Adventures (science education for underserved youth to including increased exposure to marine habitats and sponsors of annual community event called Wetland Avengers)
  - Green Machine (addressing pesticides in Chollas Creek watershed)
  - Habitat Heros (jointly with USFWS Refuges and other federal agencies, provides second graders through community college students education on invasive plants and stormwater pollution, including the national website "Hands on the Land")
  - Birch Aquarium exhibit on San Diego Bay and field trips
  - Pro Peninsula (field-based experience for 6th graders on green sea turtles of San Diego Bay, co-funded with assistance from NOAA)
  - Adult lecture series with the San Diego Natural History Museum; San Diego Maritime Museum (adult Pilot Boat tours)
  - Lectures in association with cleanup events
  - Resource Conservation District (watershed program)
  - Chula Vista Nature Center support for field trips
  - Project Stewardship: Watershed Education Learning and Leadership (SWELL) for classroom field trips
- The Port has five brochure-style guides for protecting natural resources: Guide for Businesses; Guide for Residences; Guide for Integrated Pest Management; Boaters Guide and a Birding Hot Spots Guide.

- The Port sponsors annual seminars directed toward over 200 Members of San Diego County landscaping and pest control industry on Integrated Pest Management.
- The Port sponsors working waterfront tours and harbor cruises
- County Water Authority programs
- Storm Drain Stenciling Program
- Paradise Creek Watershed Project
- Strand Beautification Program
- County Office of Education - Watershed Program
- San Diego Coastkeeper - clean-up, environmental education
- San Diego Audubon Society - clean-up, education, Audubon Adventures
- Environmental Health Coalition - clean-up
- City of San Diego - “Think Blue” (including Port support)
- City of San Diego Storm Water Office - “Stream Team”
- Municipality Programs - Chula Vista
- San Diego Divers Association - underwater clean-up
- Oceans Foundation - underwater clean-up

A few environmental education signs about the bay’s natural resources are displayed at several key points along the bay. Signage has been funded by the Port, Navy, USFWS Refuges, Coastal Conservancy, County of San Diego, City of Coronado, Port Public Art Committee, and Port tenants. Some of the interpretive signs are along the Bayshore Bikeway.

The Chula Vista Nature Center offers natural history interpretation of the Sweetwater Marsh Unit of the NWR for school children and the general public. Exhibits at its museum feature the ecological zones of the marsh, coastal and marine animals, and plants displayed in aquaria and terraria, a unique display on the light-footed clapper rail, and a shark and ray “petting tank.” Managed by the non-profit Chula Vista bayfront Conservancy Trust and its broad-based Board of Directors, the Center depends on a small staff and many volunteers to carry out its programs. For example, every year work groups from the Audubon Chapter, San Diego Coastkeeper, and other community groups help remove tons of trash that drift into the Sweetwater Marsh area of the Refuge.

The Chula Vista Nature Center, National City, and Gunpowder Point at the Sweetwater NWR Refuge Unit also provide outdoor classroom and natural settings for study and education about the bay. For example, a program entitled *Sweetwater Safari*, created by the San Diego Zoological Society, Chula Vista Nature Center, and San Diego NWR Complex, through a grant to the Zoo’s Habitat Conservation Education Department, was created to learn about science and the local environment by hands-on experience. This program meets the state of California’s science standards for fourth grade. To lead the self-guided on-site program, which takes place on Gunpowder Point, the instructor must first participate in a training session conducted by NWR staff, Chula Vista Nature Center staff, and other volunteer teachers. The Nature Center also conducts weekly docent-lead nature hikes along the trail system on Gunpowder Point. Approximately 35,000 people visited the Nature Center during 2003.

The Resource Conservation District assists with stormwater education outreach to elementary school classrooms around the bay with the help of funding from the Port. The Resource Conservation District also sponsors “Habitat Heroes”, and an annual Backyard Stewardship Poster Contest, Project WET (Water Education for Teachers) workshops for school teachers, scholarship awards, and speech contests, among other educational efforts.

A public event to increase resident and tourist awareness and appreciation of the area’s bird populations is the Imperial Beach Bird Fest, which began in 1997 and is becoming an annual event with free walks and guides. This event has expanded recently to include the whole bay as well as adjacent environments. Diverse support is provided by San Diego Natural History Museum, Chula Vista Nature Center, Tijuana River NWR, San Diego Audubon Society, Imperial Beach Chamber of Commerce, and the Chula Vista Convention and Visitor’s Bureau.

Supported in part by the Coastal Conservancy, a good example of the contribution of volunteers is the Paradise Creek Watershed Project. A small group of community activists, teachers, students and sponsors joined together to preserve and restore one-half mile stretch of Paradise Creek, a tidal salt marsh that runs adjacent to Kimball Elementary School in National City. Paradise Creek connects San Diego Bay and the Sweetwater National Wildlife Refuge to the community of National City. A grassroots group formed the Paradise Creek Educational Park Inc., a legally incorporated non-profit organization with a mission to protect and restore Paradise Creek, and assist with projects associated with Paradise Marsh and Sweetwater Marsh. The group's mission includes environmental education programs, and to operate Paradise Creek Educational Park and a proposed Science Center in National City. The first program initiated by the group is the after-school program for the students in the community called “The Egret Club.” Students participate in after-school and weekend events such as trail and creek cleanups, removing non-native plants along the creek shoreline, and propagating and planting wetland and upland plants. In addition, they take part in a monthly birdwatching bike trip around San Diego Bay.

Evaluation of Current Outdoor Recreation and Environmental Education Initiatives

Most data sets and studies have been generally inaccessible to educators and the public, having been presented in this Plan sometimes for the first time beyond the offices of the sponsoring agencies. The bay is also generally out of the public mindset, with most news being negative, the occasional sewage spill or concern about contaminants. Few understand the global significance of the natural resources here.

Volunteers from the community are an essential ingredient in helping to make these educational efforts a success beyond their often meager budgets. Since its beginning (having just celebrated its 20th anniversary in 2007), the Chula Vista Nature Center (operated by the City of Chula Vista) noted several hundred volunteers had officially helped them over the years, contributing hundreds of thousands of hours. Funding for the Center’s projects has come from a variety of sources, such as private donations and bequests, awards from legal settlements, and grants from the State Coastal Conservancy and the Port. A long-term source of support for the museum and its programs is a local assessment district (Chula Vista Bayfront Conservancy Trust 1997, reorganized into Friends of the Chula Vista Nature Center in 2001).

Most of the educational emphasis relating to the bay and its watershed is on school children. Since much regulatory attention and agency funding is presently focused on water quality, educational efforts tend to reflect that issue rather than an ecosystem viewpoint. An exception is the Chula Vista Nature Center, which seeks to impart knowledge about food chain relationships and habitat needs for species. Recent interpretive signage projects also contribute to public awareness about natural resources values. Expanding the adult audience could be facilitated through better collaboration with art programs such as the Port’s Public Art program, and updated approaches such as the use of webcasts and podcasts.

Management Strategy

A sense of ownership and responsibility for the bay may be fostered by a curriculum of stories to be told about living resources that share residence with San Diegans.

Bay environmental education should blend the culture of San Diegans with local natural resource values. In order to develop caring and responsibility for the bay’s resources, an educator’s job is to foster a “sense of place” (Nabhan 1998), or ownership in the living organisms that share residence with San Diegans. This is facilitated by developing a curriculum of stories to be told about living resources and how people relate to them now, or have related to them in the past. To build the stories, educators require direct access to technical data sets, and accurate summaries of these data sets so that they can be effectively interpreted in a manner that captures the public’s attention and imagination.

Separate lists of sample target audiences, potential implementers of environmental education programs, and potential funding sources are identified in Table 5-13.

Management Strategy—Outdoor Recreation and Environmental Education

Objective: Establish a culture of conservation for the bay as an ecosystem, including the relationship to its watershed.

I. Conduct an assessment of how this Plan can be integrated into the current recreational boating and environmental education network as a precursor to a marketing plan for natural resources of the bay to county residents. This may be a requirement of some funders, and should be accomplished in consultation with the EPA.

- *A.* Begin the process of integrating this bay INRMP into all the other, existing thinking processes on environmental education under an umbrella concept of developing a “Sense of Place” for county residents.
- *B.* The top priority is to build on and expand existing partnerships and programs.

II. Improve access for environmental educators to studies, data sets, and summary reports so that curriculum development can be facilitated.

III. Develop community festivals, ceremonies, and ecotourism that involve direct interaction between the public and San Diego Bay.

Table 5-13. Sample target audiences, implementers, and funding sources for environmental education projects.

Target Audiences	Potential Project Implementers	Potential Funding Sources
Adults (through media)	California Coastal Conservancy (clean-ups)	California Coastal Conservancy
Compatible recreation groups - windsurfers, kayakers, etc.	California CREEC - San Diego County Environmental Education Coordinator	California Department of Boating and Waterways
Decision makers	Chula Vista Nature Center	City Attorneys Office
Developers	City of San Diego	Cities of San Diego, Chula Vista, National City, Coronado
Families (through children)	City of San Diego “Think Blue”	District Attorneys Office
Housing developments / residents	City Storm Water Office - “Stream Team”	EPA
Industries / Businesses	Convention and Visitor’s Bureau	Federal Attorneys Office
Navy families	Coastkeeper (clean-ups)	Individual / corporate donors, such as Kelco
Port Tenants (boating community)	County Office of Education - Watershed Program	National Fish and Wildlife Foundation
Schools and youth organizations	County Water Authority	NOAA/NMFS
Aquarium Trade	Ducks Unlimited	Packard and other private foundations
Bike riders	Environmental Health Coalition - educate county organizations, Clean Bay Campaign	Port of San Diego
Educators	Friends of Famosa Slough	San Diego County Wildlife Commission
Environmental and Civil Engineers (water quality)	Friends of SDBNWR	State Department of Education
Fishermen	Girl and Boy Scouts / 4-H Clubs / Other Youth Clubs	U.S. Fish & Wildlife Services Refuges
Landscape Architects	Heal the Bay (Los Angeles)	U.S. Navy
Planners	Housing developments / “Bayscaping”	
Shoreline Project Engineers	I Love A Clean San Diego	
Tourists	Local television and radio personalities	
Zoo members and members of other partners	NOAA/NMFS	
	Port of San Diego	
	Resource Conservation Districts	
	San Diego Audubon (clean-ups, elementary education, Audubon adventures)	
	San Diego Natural History Museum	
	Birch Aquarium	
	Sea World	
	Surfrider, Surfers Tired of Pollution	
	USFWS National Wildlife Refuges	
	West Marine	
	Zoological Society of San Diego	

- *A.* Begin a San Diego Bay Education Campaign
  1. Continue to partner with the City of San Diego’s “Think Blue” and use their spokesperson.
  2. Organize “Earth Day on the Bay” or “Bay Days” as community events.
  3. Bring the Shorebird Sister School Program and the Black Brant Internet Project to San Diego. Organize events around when these birds arrive in San Diego Bay for their migratory stopovers.

B. Expand existing bird festivals and encourage bird-a-thons as a means to learn about diversity, habitat, and trends. Demonstrate their economic benefit to municipalities and other decision makers.

IV. Establish a new or build on an existing community-based restoration program, in cooperation with government agencies and private non-profit groups already involved in the bay or environmental education, e.g. San Diego Natural History Museum, Chula Vista Nature Center, Paradise Creek Watershed Project, Environmental Health Coalition, Oceans Foundation, UC Sea Grant, NMFS, etc.

A. Support and publicize existing or nearby efforts. Examples might be:

1. Paradise Creek marsh restoration.
2. Chollas Creek Linear Park.
3. Chula Vista Bayfront Development.
4. Otay River Wetlands Working Group watershed management effort.

B. Target new locations for restoration.

1. Invasive plant removal at Chollas Creek—City of San Diego, U.S. Navy.
2. Sweetwater River edge softening—City of Chula Vista, National City.
3. Dune restoration on both sides of Silver Strand—City of Coronado, U.S. Navy.
4. Mouth of the Otay—USFWS, City of Chula Vista.
5. Intertidal enhancement at Biological Study Area and CDPR lease site—U.S. Navy, CDPR, County of San Diego.
6. Power plant property, if the future use allows for it—Port.

Navy installations are required, as applicable, to incorporate into natural resource management planning provisions for habitat restoration projects, public access where feasible, and participation in outreach programs for recreational fisheries. In keeping with EO 12962, Federal agencies shall improve the quantity, function, sustainable productivity, and distribution of U.S. aquatic resources for increased recreational fishing opportunities by restoring degraded habitat, fostering conservation, providing access and awareness of opportunities for recreational fishing (OPNAVINST 5090.1C).

C. Conduct restoration projects in support of recreational fisheries, in compliance with EO 12962.

V. Expand existing educational partnerships among nonprofit organizations, the Port, government, schools, and businesses that focus on the bay.

A. Foster cooperative agreements between each city and local environmental education, interpretive, or nature centers.

1. Distribute “Trekking the Refuge” backpacks—San Diego Zoo, Chula Vista Nature Center, USFWS.

B. Initiate a “Bay Camp” oriented towards high school students that includes a mentorship program pairing students with bay researchers.

C. Continue to cosponsor workshops, seminars, literature, web page, and other outreach activities.

D. Institutionalize permanent interactive environmental educational programs with local schools about the bay and its watershed.

1. Promote the use of the South Bay Marine Biological Study Area by universities for education and research studies. Place an interpretive sign and birdwatching platform there.
2. Schools should be given real problems with real data sets to work with. Involve high schools in long-term monitoring of basic measurements.
3. Expand the use of boats for educational field trips, Maritime Museum, Coastkeepers, etc.
4. Support the development of a K-12 curriculum, such as Project SWELL (which curricula promotes a sense of environmental stewardship in children) that includes and accurately describes the bay’s ecosystem. To assess the program’s viability, start with a bay “road show” for which funding agencies support an educator to visit schools.

E. Support training and use of volunteers to provide additional outreach to adults and children.

1. Provide recognition of volunteer contributions.

2. Encourage volunteer assistance with Christmas bird counts organized by the San Diego Audubon Society (www.sandiegoaudubon.org).
3. Encourage participation in the San Diego Wildlife Tracking Team (www.sdtt.org).
4. Encourage collection of water quality data for the San Diego Citizens Water Monitoring team (www.sdcwmc.org).

VI. Support ecotourism by expanding interpretive activities.

A. Take advantage of interpretive opportunities where and how people currently access the bay.

1. Involve municipalities in developing a regional "Walk of Discovery" map that shows bay access and points of interest, targeting pedestrians and bicylists.
2. Install biological and cultural interpretive signs at key viewing areas of wildlife activity or interest that detail features of the viewpoint. This could be done by the Port, cities, USFWS or U.S. Navy. Good examples exist at the observation platform at Kendall-Frost Marsh, Mission Bay.
   a. Maintain the signs current, clear, and in good condition.
   b. Hand out informational brochures at key locations. One could be an "Environmental Dictionary for San Diego Bay" which defines words like "eelgrass," "intertidal habitat," etc.
3. Continue to inform the public about "Birding Hot Spots" such as with the Port's so-named brochure.

B. Promote appreciation of San Diego Bay's native wildlife and habitats through public art: unique tourist postcards, children's coloring books, posters, art contests, murals on buildings, statues in public areas, and other forms.

C. Develop new access opportunities by partnering with private and non-profit or public groups, such as through implementing the San Diego Bay NWR CCP.

VII. Target awareness for city commissioners and planners, engineers, Port personnel, Navy personnel, CCC, and other managers and decision makers.

A. Announce and carry out a highly visible pilot project in which different types of materials and designs are tested for shoreline structures that improve habitat value.

B. Develop a presentation that explains the economic benefits of a healthy bay to the public and decision makers.

C. Promote awareness of this Plan and its use as a reference tool.

"Lessons learned through observation of nature benefit all." ~Les Perhacs, artist and creator of loon statue at Lindbergh Field.

VIII. Evaluate the effectiveness of existing environmental education programs.

A. Continue to compare the before-and-after awareness level of the participants.

B. Continue to update the targets for desired awareness levels on different topics for each age group, including adults.

1. Topics should include diversity of fish and wildlife, wetlands, watershed connection to bay, nondisturbance of bird foraging and nesting sites, stewardship, recreational impacts, and historical and current habitats.

C. Adjust the programs if desired awareness is not achieved.

IX. Secure long-term funding to ensure continued environmental education programs about San Diego Bay.

A. Explore use of a Special District for funding educational (and other, such as stormwater) programs.

B. Explore the use of a "bed-tax" from visitors' hotel tax as a source of interpretation funds at tourist sites.

C. Seek private foundation funding for special projects.

D. Explore use of environmental license plate funds from state's special coastal license plate.

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6.0 Monitoring and Research

The monitoring and research needs identified so far in this INRMP are placed in a program framework here. They are then integrated with the rest of the strategies and prioritized in Chapter 7. An ecosystem based and collaborative San Diego Bay Monitoring and Research program is proposed.

6.1 Monitoring to Support Management Decisions

This chapter provides for adaptive management to enhance understanding and capacity to respond to a changing San Diego Bay, through monitoring and research support.

San Diego Bay receives waters and urban runoff from a watershed of 415 square miles within which 50% of the county's population lives or works. The San Diego Metropolitan Area is the seventh largest city in the country and second in California. In 2010, the estimated population[1] of cities within the San Diego Metropolitan Area totaled 1,724,163 (SANDAG 2010). In addition, tourists swell the population year-round with roughly 30 to 32 million annual visitors (SDCVB 2010).

Each day, the military trains on the shores and waters of San Diego Bay, while the Port provides for commerce, industry, tourism and recreation. Millions of fish and wildlife use the bay's waters simultaneously, whether they are abundant prey or rare and endangered birds. Within San Diego Bay's watersheds, over 1.6 million people use water for their lawns and gardens, to wash their cars, to drink, and to fill bathtubs. While astonishing gains have been made in the bay's health since CDFG declared it a virtual "marine desert" in the early 1960s (see Appendix H "Ecological History of San Diego Bay"), there remain urgent challenges and threats to address. Due to its relatively small size, unique natural resources, and intense uses, San Diego Bay has perhaps the most potential for natural resource conflict than any bay on the west coast. Yet there is limited ability to report on the status and trend of natural resources in a manner accessible to the bay's decision-makers and the public.

Some of the challenges faced by bay managers are increasingly complex, including:

- Water quality and sediment quality impairment, caused in part by hard-to-regulate sources such as urban storm drain runoff;
- Historic sediment pollution that is a legacy from past industrial development of the bay and its use for maintaining commercial and military vessels. This includes bio-accumulation of toxins in the food web due to pollutants in degraded sediments;

1. Census data for 2010 currently unavailable. This estimate is dated January 1, 2010.

- Invasions from exotic species that disrupt the bay's ecology; and
- Climate change, with related sea level rise and changes in water temperature and chemistry.

An Era of Climate Change

Complicating the task of bay managers separating out change related to management versus natural cycles of the earth's climate. The earth's climate system varies naturally across a range of temporal scales, including the year's seasons, inter-annual patterns such as the ENSO, inter-decadal cycles such as the PDO, and multimillenial-scale changes such as the glacial to inter-glacial transitions (Harley *et al.* 2006). See Section 2.2 for a summary of climate change predictions relevant to San Diego Bay.

Tools for Making Management Decisions

One of the most pressing challenges that bay managers face is meeting compliance responsibilities with constrained budgets. In order to address current and future resource management challenges for the bay, managers will need a monitoring program that allows them to prioritize and allocate effort and resources towards environmental compliance obligations, but also targeting a broader ecosystem management approach.

In an era of climate change, environmental monitoring programs for the bay will require monitoring tools that allow managers to gather better quality and more regularly produced information with greater spatial and temporal resolution. Improved use of tools such as and indicator species, aggregate measures of bay health, and cost-benefit analyses that allow one to differentiate between important and directly applicable information from secondary information will help managers improve and streamline their resource management decision-making.

Given the above context, what is it that environmental managers should be monitoring in order to conserve and restore the natural resources of San Diego Bay?

Opportunities for Better Decisions Through Better Monitoring Strategy

This Chapter proposes to monitor sediment and water quality in greater detail than the previous INRMP (Navy and SDUPD 2000). Many previous species surveys in the bay have been geographically limited or short-term, so few “status and trend” conclusions were possible. However, new data on the bay are becoming available through the SCCWRP, and the SCB Regional Monitoring Program (2003, 2005, 2006, 2007). With these data, there are opportunities to compare San Diego Bay to other harbors in southern California, as well as to other areas in the Bight. Trend information is also becoming available since the sequence of studies use the same sampling methods. These efforts by the SCCWRP will ultimately provide insight into many concerns affecting the California coast, including contaminants and food web.

Upon this baseline, additional bay-wide data sets, as well as localized surveys, can be better interpreted. Bay-wide fish surveys conducted in 2005 (VRG 2006) have now been repeated, and avian species were completed for the first time in 2006-2007 (TDI 2009). The avian species surveys have also now been repeated. The CDFG survey of invasive species conducted in 2000 (CDFG-OSPR 2002) and 2005 (Marine Pollution Studies Laboratory at Moss Landing Marine Laboratories 2007) in conjunction with the Aquatic Nuisance Species Research Program comprehensive survey of California's coast (Ray 2005) added many more invasive species to the INRMP species list (Navy and SDUPD 2000). The SCCWRP data confirmed the high abundance of invasive exotic species in the San Diego Bay (SCCWRP 2007) that the CDFG and the Aquatic Nuisance Species Research Program monitoring programs had identified during their surveys.

In addition to regular surveys and monitoring, 13 research topic areas were proposed in the 2000 INRMP (Navy and SDUPD 2000) to support natural resource management decisions. However, there has been no organized means to pursue this research, which is generally considered peripheral to the organizational missions of the primary bay stakeholders. Also proposed were a biennial report on status and trends, and a biennial workshop or conference, either on San Diego Bay alone or to be held jointly with neighboring bay and harbor programs.

The opportunity exists to better institutionalize the guiding principles of ecosystem management and sustainability for San Diego Bay (See Section 1.3) in the effort to use monitoring and research to pursue better daily decisions for natural resources. The Joint Ocean Commission Initiative (2009) cautions local leaders, managers, and citizens to remember that humans do not manage the ecosystems that provide food, shelter, air, jobs, joy and recreation - we have little control over where wild fish swim or how ocean currents and winds move. Rather, the Joint Initiative suggests that we seek to understand these processes, identify and monitor indicators that gauge the effectiveness of our management measures, and modify human actions to accurately take ecosystem interactions into account in our pursuit of healthy and prosperous coastal communities (Joint Ocean Commission Initiative 2009).

Since we have little control in managing the ecosystems that we rely on, our goal should be to understand processes and identify indicators to assess our management effectiveness and to modify our actions accordingly (Joint Ocean Commission Initiative 2009).

A long-term environmental monitoring program that detects threats, monitors risky conditions for bay health and helps us address conditions that will become greater problems down the road is the highest priority. The program proposed here builds upon similar coastal and bay monitoring programs that have been successfully employed in the United States and abroad and that are discussed in greater detail in subsequent sections of this chapter. Such a system will require better coordination and use of existing data and technologies, and standardizing protocols for collecting and storing of all data, in order to ensure the best available science is behind it.

6.1.1 Key Management Questions

The monitoring and research program should focus on answering key management questions, which should provide a sense for the variation that can be expected over different time scales, regardless of its cause. Key management questions include (see also Section 2.9.1: What We Need to Know to Describe the State of the Bay Ecosystem):

Two goals of the EO on stewardship of oceans and coasts (19 July 2010) addressed in this chapter are (1) improve understanding and awareness of changing environmental conditions, trends, and their causes, and of human activities taking place in ocean and coastal waters; and (2) foster a public understanding of the value of the ocean and coasts to build a foundation for improved stewardship.

1. What is the variability in the biological, chemical, and physical factors influencing San Diego Bay? How much of that variation is due to humans and what are the natural local and regional patterns?
2. Are we detecting threats of whole-scale ecosystem impacts in time to do something about them?
    a. Are we able to rank relative threats?
    b. Are we detecting how urgently intervention is necessary?
    c. Are vulnerable or scarce habitats adequately protected?
    d. What are the greatest threats to vulnerable or scarce habitats and species?
    e. How can activities be modified to abate these threats?
3. Is the San Diego Bay ecosystem function and long term health adequately protected?
    a. What is the condition of the bay ecosystem, and what is the relative importance of factors that contribute to it working well?
        i. Are habitats, singly and together, providing their full benefit to fish and wildlife populations, food chain pathways, elemental/nutrient cycling, and natural diversity?
        ii. How do human activities such as military support, commercial shipping, recreation, and fisheries affect the continued viability of specific aspects of ecosystem functionality?
        iii. What specific factors of ecosystem functionality are presently threatened by human activity? What is the relative importance of substrate, tidal flushing, freshwater or nutrient flows from stormwater, predation, competition, or other parameters in contributing to or moderating these threats?
        iv. What is the relative importance of climate cycles or natural episodic events in structuring the ecosystem and driving change?

   b. To what ecosystem trends are human activities contributing? Are basic markers of environmental structure changing, such as temperature, salinity, dissolved oxygen concentration, nutrients, and water transparency?
      i. What are the correlations between changes in environmental structure and populations?
      ii. Is energy flow (productivity and nutrient cycling) changing?
      iii. Is community structure changing (diversity, patterns of dominance, functional groups)?
   c. To what extent are specific, observed changes in the elements described above due to human versus natural causes, or local versus regional causes?
4. Are vulnerable or scarce populations adequately safeguarded?
   a. What are the trends in the distribution, composition and abundance of phytoplankton, zooplankton, invertebrates, fish, bird, and mammal populations?
   b. What are the causes of those trends? Are the causes of the trends things that may be affected by management, or are they beyond the control of local or regional managers (e.g. climate change)?
5. What human activities conflict with maintaining functions of the bay ecosystem and how can they be minimized or compatibility achieved?
   a. What fraction of the trends in bay structure and function is due to human activity versus natural change?
   b. How can project avoidance, minimization or any necessary mitigation be most effectively managed to benefit the bay?
   c. What are the predictable future changes in the bay and its use that are most likely to alter its current state?
   d. What is the best way to evaluate and avoid the negative cumulative effects of human activities?
6. What species should be monitored in order to detect status and trend of sediment and water quality?

6.1.2 Tenets for a Monitoring and Research Program

The most effective and complete approach to understanding the bay is to combine long-term monitoring with experimental research and the development of conceptual models about how the ecosystem sustains itself, or is resilient to disturbance. This is the only way to determine the cause and effect of changes in the bay ecosystem.

The ability to use the best available science to adaptively plan for and manage the bay on an ecosystem basis is constrained by the lack of sufficient ease to collaborate on studies and to integrate scientific work conducted outside of agency venues. Ecosystem management, which is based on a scientific understanding of ecosystem composition, structure, function, and interlinking processes, requires more and better research and data collection, as well as better coordination and use of existing data and technologies. Standards should be established for the collection, taxonomy, distribution, exchange, update, and format of ecological, socioeconomic, cartographic, and managerial data. Consensus needs to be reached among stakeholders on standards for collecting and analyzing data concerning the bay's ecosystem.

The following are important tenets to be considered in the design of a monitoring and research program for San Diego Bay:

1. The program should be aimed at detecting large changes within a reasonably short time frame.
2. The program should include environmental processes and organisms likely to be influenced by human activities.

3. The program should be intended and designed to be conducted in perpetuity.

There will always be a need for environmental information that describes the health of the bay. In order to ensure that long-term time series data sets are collected in perpetuity the following considerations need to be acknowledged from the onset of implementation for this San Diego Bay INRMP:

- Bay manager objectives for research and monitoring need to be constantly and iteratively refined through an adaptive management approach in order to meet management needs and guide researchers;
- The broad purpose of monitoring and research is to help management attain improvement in the quantity and quality of scarce and valued habitats and communities without trying to “reach” the past;
- Questions need to be integrated across monitoring components to ensure that attempts to correlate the monitoring of physical or chemical factors should be related to trends in habitat quality, species abundance, and distribution on a routine basis;
- The program should build upon existing programs and avoid duplication of effort;
- Standardized state-of-the-art sampling protocols, equipment, and analytical methods should be used;
- Monitoring and research need to take place at various scales appropriate to the management problem and the natural scale at which processes operate (i.e. inter-bay, whole-bay, bay region);
- Habitat specific and project specific scales are appropriate for different management questions;
- The appropriate scale for a particular question can be partially evaluated by looking at selected species life histories that span them, including those that migrate and disperse over great distances using multiple habitats, and those that have little dispersal capability;
- Use of target species or the landscape/seascape species approach can help provide a focus for management and provide the detail needed to highlight important problems for species that are dispersal limited, process limited, food resource limited, or habitat area limited;
- The monitoring and research approach should foster integration and accessibility of results to researchers, managers, and the public;
- There should be vigilantly kept, clear link to agency management and policy issues;
- The bay's resource managers (agencies, landowners and tenants) should have the final say in the type of research and monitoring conducted; however, input from scientists should be sought;
- Our bay regions (as discussed in Section 2.3.5: Hydrodynamic Regions of the bay) should be adopted as a standard means to stratify sampling and report monitoring and research results;
- Researchers should be asked to make explicit the conceptual model being used in their research design concerning how the ecosystem is structured and functions.

The last topic discussing the conceptual model of ecosystem structure and function is important because these models can be employed for three separate functions (Walters 1998). These functions include:

1. Problem clarification and enhanced communication to help narrow the list of variables to be considered;
2. Policy screening to narrow the list of actions that most likely will not do any good;
3. To aid in the identification of gaps in key knowledge areas.

The following sections in this Chapter discuss the current and proposed plans for a monitoring program to assess the environmental information that will be needed to describe the health of the bay ecosystem to managers, policy makers, and the public.

6.2 Program Elements

Addressing these key management questions will require both detection and control of short-term environmental threats in conjunction with long-term monitoring, improved standardization and coordination of existing monitoring, a focused research program, and a program for providing this information to managers and the public.

6.2.1 Short-term / Immediate Threat Detection

In addition to long term monitoring to assess the status and trends of the bay's resources there are also short term threats that may require immediate action by bay managers. Federal and state agencies have spill response plans and natural resource damage assessment protocols in place to address a short term threat such as a hazardous material spill from private, commercial, or military vessels. However, bay managers do not have protocols or plans developed yet to deal with immediate threats such as the identification of an invasive exotic species, harmful algal blooms, outbreak of a fish and wildlife disease, or a pulse of garbage entering the bay from storm water or creek flow. Immediate threat detection needs to be considered to address any of these potential short-term environmental threats. Areas of interest include:

Invasive Exotic Species. An ecological invasion from an exotic species represents a short term threat that if responded to quickly would prevent larger scale problems from occurring. Recall that invasive exotic species were discussed in Section 4.4.1. Invasive Species. This section identified an ecosystem based management strategy to address a group of selected exotic species that have already invaded the bay ecosystem. It is important to ensure that there is a clear distinction between exotics and invasive exotics in this San Diego Bay INRMP. Federal law defines an “invasive species” as one that is non-native to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. All non-native species are not necessarily a problem for bay management. Rather, invasive exotics are the problem that bay managers need to address. Bay managers will need to understand how the interaction between native species and invasive exotic species could change as a result of shifts in global temperature. Bay managers will also need to use management and monitoring programs to help them understand the effects of human induced changes to habitats as well as the potential for natural colonizations of native species migrating to new areas where temperature regimes have shifted as a result of global climate change.

There is a legislative mandate for federal research and coordination on harmful algal blooms, the Harmful Algal Bloom and Hypoxia Research and Control Act (Harmful Algal Bloom and Hypoxia Research and Control Act 1998 with Amendments 2004) (Center for Sponsored Coastal Ocean Research 2009). The Act requires establishing research priorities and guidelines, and for federal coordination of all levels of government in controlling the environmental impacts of hypoxia.

Harmful Algal Bloom. Harmful algal blooms are a global threat to living resources and human health (West Coast Regional Harmful Algal Bloom Summit 2009). The frequency of harmful algal bloom events is increasing and their geographic distribution now impacts all coastal states. They have had significant ecological and socioeconomic impacts on California, Oregon, and Washington coastal communities for decades (West Coast Regional Harmful Algal Bloom Summit 2009). Often referred to as “red tides,” these blooms occur on a seasonal basis in the coastal waters of the San Diego Bay region. The problem with a “red tide” event is the production of toxins by the blooming phytoplankton. For example, blooms of the plankton species Pseudo-nitzschia may produce domoic acid which often has harmful effects on fish and wildlife in coastal southern California waters (Schnetzer 2007). These toxins have the potential to bioaccumulate in food web pathways if the “red tide” event persists for long periods of time. To safeguard marine resources and human health from the harmful algal bloom threat, a regional approach to coastal ecosystem management is needed (West Coast Regional Harmful Algal Bloom Summit 2009). Recognizing this need the West Coast Governor's Agreement on Ocean Health (West Coast Oceans 2009) is currently integrating actions to promote interstate coordination of research and monitoring efforts in their Ocean Health Action Plan (West Coast Regional Harmful Algal Bloom Summit 2009; West Coast Oceans 2009). There is a legislative mandate for federal research and coordination on harmful algal blooms, the Harmful Algal Bloom and Hypoxia Research and Control Act (Harmful Algal Bloom and Hypoxia Research and Control Act 1998 with Amendments 2004) (Center for Sponsored Coastal Ocean Research 2009). The Act requires establishing research priorities and guidelines, and for federal coordination of all levels of government in controlling the environmental impacts of hypoxia.

Fish and Wildlife Disease Outbreak. The outbreak of a fish or wildlife disease is another short term environmental threat that bay managers should be able to detect and respond to. The monitoring of such an outbreak is not a component of any existing or proposed long term monitoring program in the bay. However, detecting disease emergence and rapidly responding to an outbreak may reduce the severity of impacts to local wildlife populations - including both robust and threatened populations of fish and wildlife that reside in the bay's numerous habitats. Bay managers may also want to develop a prototype rapid response plan for certain target species prior to developing a rapid response plan for all bay species.

Garbage Pulse from Storm Water or Creek Flow. The ability to quickly detect and respond to a pulse of garbage and debris entering the bay from storm water or creek flow following a storm would help avoid impacts to natural resources. It is after this peak flow of freshwater into the bay that garbage carried in with it becomes a short term problem. Solutions, such as removing the garbage pulse from the bay, could be developed that are similar to oil spill response efforts. Proposals to develop TMDLs for garbage may provide a regulatory mechanism for bay managers to address this issue.

6.2.2 Long-term Monitoring for Bay Condition and Trend

Summary of Specific Concerns

- While much information has been collected on the bay's physical, chemical, and biological attributes over the years, little of it provides a holistic understanding of the status and trends for the health of the bay ecosystem and does not provide direction for management to achieve better bay health.
- Low-frequency variability (long-term change such as that associated with El Niño and climate change) often tends to be greater in magnitude than changes on seasonal and shorter time scales. A key and very difficult question for management and decision-making is whether an observed change is due to natural or anthropogenic causes. These and many other management questions cannot be answered without long-term data sets that track conditions in the bay and their cause. In general these long-term data sets are poorly accessible to management.
- Management questions also need to consider whether an anthropogenic cause is due to local, regional or large-scale processes. This means monitoring protocols should be related to those on a regional or larger scale to be most telling. Populations of some species should be tracked regionally to provide understanding of their local dynamics.
- Better definition of management issues will allow more focused objectives for assessment and monitoring and more cost-effective strategies to reach each objective. In some cases, we do not have the baseline information or perhaps the insightful understanding necessary to define these issues and state specific objectives.

Current Management

Few time series studies specific to San Diego Bay had been underway prior to 1998; however, since then, a number of efforts are beginning to benefit bay managers' understanding and decision-making regarding bay resources. The following are examples of San Diego Bay time series studies:

1. Southern California Coastal Water Research Project. The SCCWRP organized more than 40 public and private organizations for a regional water quality monitoring program in the SCB. These efforts are funded primarily by local municipalities that have agreed to work cooperatively toward a regional assessment of coastal condition. In lieu of their ongoing routine monitoring, participants are asked to disperse their sites and use standardized methods throughout the region once every five years and, in this way, help make Bight-wide assessments for little to no increase in cost over their existing program. The types of stations sampled in the bay by SCCWRP included fish collection using the same stations and collection methods as used in Navy-Port sponsored studies Allen (1999), but adding benthic invertebrate, sediment chemistry, and water quality sampling by the City of San Diego using the SCCWRP's standard methods (25 feet [8 m] fish trawl net) at random stations. See Table 6-1 for an overview of Bight Program sampling approach. The pilot project was in 1994 (SCB 1994 Pilot Project 1998). The 1998 effort was the first to include San Diego Bay as part of a comparative harbors investigation (SCB 1998 Regional Monitoring Program 2003).
2. NOAA's National Status & Trends Program, National Benthic Surveillance Program (1984-1993): physical, chemical, and biological parameters (diseases and bioaccumulation in fish); offshore in central and north bay (Benthic Survey Sites 2009).
3. NOAA's National Status & Trends Program, Mussel Watch Project (1986-present): bioaccumulation in mussels, plus other parameters; offshore in south bay and intertidal and offshore in north bay. There are too few sites, but there are trends over time (Center for Coastal Monitoring and Assessment 2009).
4. SWRCB and CDFG, State Mussel Watch Program (1977-present): bioaccumulation in mussels (transplanted), plus other parameters; offshore throughout entire bay and bay approaches (SWRCB 2002a; SWRCB 2002b).
5. Eelgrass surveys every five years have been completed by Merkel & Associates and the U.S. Navy, and then more recently by both the Navy and Port (Lockheed 1979a, 1979b; SDUPD 1979; U.S. Navy 1994; Merkel & Associates 2000, 2005, 2009).
6. A long-term fish study by Hoffman conducted from 1988 to 1992 (NMFS Southwest Regional Office 2009) had been the only true time series for fishes in San Diego Bay prior to the work by Allen (1999). Follow-up fish surveys were conducted in 2005 (VRG 2006) and 2008.
7. The first bay-wide avian species survey was supported by the Port, Navy, and USFWS-Refuges in 2006-2007 (TDI 2009).
8. The Pacific Estuarine Research Laboratory conducted a study of efforts to reintroduce salt marsh bird's beak to Sweetwater Marsh, funded by the National Biological Survey and Caltrans. The transplanted population increased in size for several years, with a peak in 1995 (National Research Council 1992; Zedler 2000).

Time series studies coordinated from the local to regional level provide the greatest benefit to monitoring programs whose goal is to assess the status and trends of key areas in order to identify the health of the bay ecosystem. In particular, the SCB Regional Monitoring Program described above provides a useful time series data set specific to the bay ecosystem that is also coordinated with a larger Bight regional monitoring program (SCCWRP 2008). The monitoring parameters used by the SCCWRP SCB Regional Monitoring Program are listed in Table 6-1.

The SCCWRP's SCB regional monitoring program has three components: Coastal Ecology, Water Quality, and Shoreline Microbiology. The Coastal Ecology component focuses on answering two questions:

- What is the extent and magnitude of contamination and associated biological effects in the Bight? and
- What constitutes the mass of pollutants accumulated in the SCB?

Table 6-1. Monitoring parameters used by SCCWRP in the Bight regional monitoring program. Ten different strata of stations are sampled in this survey. These strata are classified as follows: Channel Islands, shallow offshore (5-30 m), mid depth offshore (30-120 m), deep offshore (120-200 m), continental slope (200-500 m), lower slope and inner basin (500-1000 m), small publicly owned treatment work outfalls, large publicly owned treatment work outfalls, marinas, ports/bays/harbors, and estuaries. The Bight studies use a probability-based sampling design developed by EMAP.

Community/ Substrate	Indicators of Ecosystem Health
Benthic Infauna	Infaunal assemblages
Sediment Chemistry	Sediment characteristics, sediment contamination, toxicity
Demersal fish and invertebrate assemblages	Gross fish pathology, biomarkers, and bioaccumulation (tissue chemistry)
Marine debris	Plastic, lumber, vegetation, glass, etc.

The first question is being addressed through sampling of more than 400 randomized locations for sediment toxicity, sediment chemistry, infaunal biological communities and bioaccumulation in fish tissues (SCB 1994 Pilot Project 1998; SCB 1998 Regional Monitoring Program Executive Summary 2003; SCB 2003 Regional Monitoring Program 2005; Bay *et al.* 2007). Sampling is stratified to include five depths in the near coastal zone (including continental shelf, slope, and basins to a depth of 1000m), four embayment habitats (marinas, ports, bays, and estuaries), and habitats near anthropogenic discharges (such as publicly owned treatment works).

The second question addresses the fate of pollutants entering the coastal environment by comparing the amount of material discharged to the Bight with the pool of contaminants residing in three different environmental compartments; the water column, sediments, and tissue of biota. Additional sampling to address this question involves coring and radiodating sediments (to assess pollutant accumulation rates), measuring of water column pollutants, and measuring pollutants in tissues of mid-water fish that comprise the bulk of the biomass in the Bight (and are rarely sampled for tissue analysis) (Bay *et al.* 2007).

The second component, Water Quality, addresses the question: What is the spatial extent and duration of stormwater plumes in the coastal ocean? Stormwater runoff is known to contain bacteria, viruses, toxic chemicals and nutrients that can affect ocean waters, but little is known about how far offshore these contaminant plumes extend following rain events and how long they last after the rain ends (Bay *et al.* 2007).

The third component is Shoreline Microbiology. The primary question for this component is: What is the relationship between bacteria concentration in ankle deep water, where most monitoring samples are collected, and the surf zone, where much of the water contact recreation occurs? To answer this question, the study is focused along beaches near storm drains throughout the Bight during both dry and wet weather (Bay *et al.* 2007).

Many other major regional time-series monitoring programs do not contain data specific to San Diego Bay or any neighboring harbor. However, these regional time series monitoring programs are state-of-the-art and useful for larger questions concerning the health of the Bight or the California current. Conservatively, at least $31 million is spent annually on monitoring in the SCB (National Research Council 1990a; SCCWRP 2008). These regional monitoring programs include:

- The California Cooperative Oceanic Fisheries Investigation. This program examines hydrology, primary production, zooplankton biomass, and larval fish distributions. It originated in response to the collapse of the sardine fishery in 1947 (California Cooperative Oceanic Fisheries Investigation 2007). It is unparalleled in its spatial extent, duration, and consistency through time of its study of the ocean and fisheries biology. Sampling occurs in offshore and coastal waters.
- Data collection on sea surface temperature and other parameters from near the turn of the century at Scripps Pier, Scripps Institute of Oceanography (Scripps Institution of Oceanography Climate Research Division 2009).

Evaluation of Current Management

Most of the Key Management Questions listed in Section 6.1.1: Key Management Questions cannot be answered without long-term monitoring data, with the exception of those directly tied to habitat loss. Habitat loss or degradation is one of the most direct and obvious anthropogenic impacts in San Diego Bay. There is direct regulatory/management control through the permitting process and mitigation to address this issue. Many species declines are believed to be directly tied to these habitat losses, including the federally protected light-footed clapper rail, California least tern, and western snowy plover. However, for many questions, the influences of changing food chains and other aspects of environmental structure may be greater than direct habitat modification. The relative importance of the effects of habitat modification versus other influences upon key species in San Diego Bay is poorly documented and understood.

Managers concerned with ensuring the long-term health of the San Diego Bay ecosystem need to know what the long-term trends are in bay populations and what is causing those trends. Some of these trends are largely driven by climatic change rather than any local human activity. Or, the change may be due to a natural but sporadic event like drought, storm surges or El Niño-La Niña cycles. Populations fluctuate for a variety of reasons, and managers need to know what fraction of the variability is due to a anthropogenic disturbance such as a particular project.

Once trends are established, the key issues for targeting monitoring efforts are determining whether changes in populations are due to natural variability or human influences. If the trends are anthropogenic, are they caused by local influences that may be corrected by San Diego Bay management? Or are they large-scale influences that may be beyond the scope or only partly addressed by local management? Bay managers have direct control only over trends that are local and attributable to human activity. However, even if disturbance in the bay is not the primary reason for a species' decline, for example, it still must be managed as a declining resource if disturbance is believed to be a contributing factor.

Existing monitoring programs, as discussed in the previous section, had been insufficient because they were not time series or they did not include San Diego Bay as part of their regional sampling scheme. Bays do not necessarily function the same as waters offshore, so data collected elsewhere in the Bight may not apply. For example, conclusions about pollution from regional programs within the Bight may not apply to bays and harbors, which are more contaminated than the open coast (Mearns 1992). However, the now-repeated sampling in San Diego Bay associated with the SCCWRP Bight program conducted in 1998, 2003 and 2008 will allow insights into many concerns identified in this INRMP. These data are only beginning to be fully integrated into planning by bay natural resources and water quality managers.

Current environmental monitoring is not efficient in terms of cost, and it has not been used as well as it could to support management decisions, as has been thoroughly discussed elsewhere (National Research Council 1990a).

Most of the Bay Panel's proposed Comprehensive Monitoring Program, shown in Table 6-2, is retained in the proposed monitoring program for this INRMP.

However, this Plan has a broader purpose, goal, and objectives than did the Bay Panel, which focused mostly on water quality. As a result, priority monitoring elements differ somewhat. For example, long-term examination of phytoplankton and zooplankton would be considered a much higher priority under the objectives of this Plan than it was for the Bay Panel, because of its importance to food chain health.

A long-term commitment is the core of the monitoring and research program proposed in this Plan. Time series data will support and serve as a powerful backdrop to all other aspects of monitoring, research, and conceptual modeling about ecosystem structure, function, and interdependencies that take place in the bay.

The aim is for a robust ability to detect status and trends by striking the best balance between measuring a broad suite of environmental properties and species of interest, comparing new observations to the limited data set from the past, comparing trends in San Diego to trends in other regions (to separate local from large-scale influences), and keeping the costs down to an absolute minimum (to ensure that the time-series data collection can be maintained). Priorities should be kept to the minimum program needed to detect long-term trends. Once such trends are detected, additional research may be needed to understand the causes and consequences of trends.

Table 6-2. Examples of the Bay Panel's proposed use of ecological indicators to learn about San Diego Bay's condition and trend.

Plankton

Plankton remains a key component of a long-term monitoring plan because one of the most direct ways in which environmental change (natural or anthropogenic) influences ecosystems is through the food web. Many of the changes seen in fish, mammal, and bird populations in the offshore waters of California appear to be caused by trophic interactions. The ecosystem changes in ways that affect the growth rate and abundance of the phytoplankton plants at the base of the food chain (usually the nutrient input is changed). This, in turn, affects the abundance of the herbivorous zooplankton that feed upon the phytoplankton plants. The zooplankton are the food source for the birds, fish, and mammals, either as adults or their juvenile stages.

Temperature and Salinity

Temperature and salinity are strongly correlated with the success of many fish and invertebrate species. Allen (1999), in his five-year study on fishes of San Diego Bay, determined that almost 76% of the total variation in the individual station abundances of the 25 most abundant bay species could be explained by these factors. In San Francisco Bay, the position in the estuary of the line of tidally averaged, near-bottom salinity equivalent to 2 psu is used as a management tool and is related to the physical response of that estuary to freshwater flows. The survival and abundance of a number of fish and invertebrate species are highly correlated with this line, either negatively or positively.

Shoreline Change

Monitoring the condition of the shoreline in terms of its natural or artificial state, habitat value, erosion, and even accumulation of marine debris can provide a publicly credible index of health in this transition interface between marine and upland habitats, and possibly highlight the need for improvement in this area.

Target Species

California halibut, a commercially harvested species, has declined in numbers and a primary reason appears to be the loss of juvenile rearing habitat (Kramer 1990), such as San Diego Bay provides. Minimizing adverse impacts to the juvenile halibut (0.4–6 inches [10–150 mm] SL) at this stage, which lasts one to two years, is critical to the size and health of the entire population. Halibut use unvegetated and vegetated shallows, as well as intertidal habitats during this juvenile period, as shown by this brief description of their use of San Diego Bay resources.

After metamorphosis, young halibut migrate into protected bays or other coastal nursery areas (Kramer 1990). They can be found primarily in the shallows of bays and estuaries at less than 3 feet (1 m) in depth (Kramer and Hunter 1987). Bay habitats are characterized by several biological, chemical, and physical factors that result in greater food supply and greater survival for juvenile California halibut. Water temperatures can be 5°C warmer than adjacent coastal waters. This increase in temperature may be the initial cue for settlement of recently metamorphosed halibut, or possibly even the cue for metamorphosis to begin (Kramer 1990). The warmer water temperatures are also important for increased growth and metabolism, given an adequate food supply (Haaker 1975; Innis 1980 in Drawbridge 1990). Drawbridge (1990) found that in warmer waters, there are fewer halibut with empty stomachs and stomachs are fuller than in halibut sampled in cooler coastal water. This apparently comes from greater feeding activity and digestion rate. Bay-reared halibut, therefore, have an advantage over coastal halibut in the same age class.

California halibut also prefer water with higher salinity. Horn and Allen (1981) found a greater abundance of halibut in more saline waters of bays. In a laboratory study, Baczkowski (1992) determined that small juveniles in particular are more susceptible to a decrease in salinity. The extra energy spent in osmoregulation results in weight loss and a decline of survivorship. In the early juvenile stage, halibut are coming into bay openings, where salinity is higher. They apparently can tolerate the natural salinity of shallow bay waters, as they are found there in great abundance.

Certain other biological factors of bay habitats make them particularly good rearing areas for juvenile halibut, including access to prey found abundantly in intertidal habitats. Allen (1988), Haaker (1975), and Drawbridge (1990) provided the following food habits summary for juvenile halibut in bays and estuaries. Halibut that are <0.8 inch (20 mm) SL feed on harpacticoid and calanoid copepods (small, mostly planktonic crustaceans). Individuals between 0.8 and 2 inches (20 and 50 mm) SL add gammarid amphipods and mysids to their diet. Small fish, primarily gobies, replace the small crustaceans in the diet of halibut >2 inches (50 mm) in length. In a stomach analysis of bay juvenile halibut, Drawbridge (1990) found small crustaceans in 60% of analyzed stomachs and small fish in 80% of those stomachs. Crustacean species accounted for 90% of all prey species identified in these stomachs, while fish species accounted for only 8%. However, crustacean species contributed <10% of the total prey biomass and fish contributed 67% of that biomass.

California halibut prefer a sandy substrate at all life stages except juvenile (Drawbridge 1990). Adults are able to successfully bury themselves and blend in with the coarser grain sediments along the coast and in outer bay areas. It was demonstrated in lab tests that juveniles 0.5–1.1 inches (12–29 mm) SL had difficulty in concealing themselves when presented with coarser grains and they significantly selected sediment with a grain size <2.5 inches (63 mm) (Drawbridge 1990). It appears that the fine sediments of shallow bay waters improve the survival of very small halibut, compared to populations off the coast. Older juveniles (>2 inches [50 mm]) also benefit from their association with silty muddy intertidal habitats, as that is the habitat for important food items like gobies.

Water turbidity can also affect both the survival and feeding success for a flatfish like the California halibut. The fine sediments of shallow bay areas combined with freshwater runoff result in higher turbidity than is found at the mouth of the bay or in coastal waters, where the water column deepens and the substrate is coarser. Small juveniles (<2 inches [50 mm]) likely benefit from the higher turbidity as a means of avoiding predation (Drawbridge 1990). The primary predators of halibut in the bays are other halibut, staghorn sculpin, and shorebirds. Larger juveniles (>50 mm and <4.3 inches [110 mm]) have a greater feeding success in shallow turbid waters. Gobies tend to concentrate at the bottom of the water column when turbidity is high. Turbid conditions bring prey closer and reduce the reaction time for halibut to ambush their prey (Drawbridge 1990). As juveniles grow and prey on increasingly larger fish, high turbidity may hinder their hunting efforts. It is probably at this time (>4.3 inches [110 mm]) that they begin their migration to deeper bay and eventually coastal waters (Kramer 1990).

The abundance of small juveniles in bays suggests higher survivorship compared to coastal residents in this size class. The number of predators associated with California halibut are fewer in bays and there is greater chance of escaping predation in the turbid waters and fine sediments. Larger juveniles in bays probably experience greater growth rates than their coastal counterparts due to warmer waters, larger prey availability and size, energy efficient feeding techniques, turbidity, and substrate.

In summary, halibut dependency on juvenile rearing and feeding in unvegetated shallows and intertidal areas of bays and estuaries, make them potentially useful as an indicator of the health of these habitats.

For the purposes of this Plan, a long-term monitoring using a suite of science based indicators would support a regular "San Diego Bay Status and Trends Report" for both decision makers and the public. An "indicator" is a measure that presents relevant information on trends in an understandable way. The proposed "San Diego Bay Status and Trends Report" monitoring and research framework is based on programs currently in use in California (San Francisco Bay and Heal the Ocean), the eastern seaboard of the United States (Chesapeake Bay), the EPA's National Coastal Condition Report program, the Sustainable Water Resources Roundtable, abroad in other countries in the western hemisphere (Mesoamerican Reef Healthy Reefs for Healthy People initiative) and by the World Bank. Use of indicators by these programs as a management tool supports these advantages:

- Fosters continual reevaluation of efforts and refinement of objectives;
- Helps communicate a consistent public message;
- Supports program planning and strategic direction-setting;
- Supports targeting of limited resources.

Indicators are defined as "something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable." An indicator's main characteristic is that it quantifies and simplifies information in a manner that promotes the understanding of environmental problems to both decision makers and the public.

Indicators are defined as "something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable" (Hammond *et al.* 1995; World Bank 2002). An indicator's main characteristic is that it quantifies and simplifies information in a manner that promotes the understanding of environmental problems to both decision makers and the public (World Bank 2002). The use of indicator species alone does not allow the same robustness as a combination of several metrics to provide multiple lines of evidence, illustrating more readily the change due to anthropogenic impacts (Karr and Chu 1996; Bay Institute 2004a).

Finding and selecting the best indicators to evaluate the bay's ecosystem health can be challenging. For example, the Sustainable Water Resources Roundtable recently identified over 400 possible indicators to help understand how well the United States manages its water and related resources (Sustainable Water Resources Roundtable 2005). Using a "rigorous selection process," the Sustainable Water Resources Roundtable eventually singled out 17 indicators from their initial list of 400 (Wells 2006). They first adopted ten principles (the international "Bellagio Principles") that were used to establish criteria for identifying, organizing, evaluating, and choosing appropriate indicators. These criteria were: Defining the state of things; Relevance; Appropriate time horizon trend and spatial scale; Indicator integrity; and Understandability.

Most programs find that no single set of water indicators was useful at all scales and for all regions. In order to address this challenge the indicators in use by other current programs for aquatic resource management were reviewed and their frameworks were synthesized to develop the suite of indicators proposed for the long-term monitoring program for status and trends.

Management Strategy—Long-Term Monitoring for Bay Condition and Trend

Objective: Provide monitoring that enhances bay managers' understanding and capacity to respond to a changing San Diego Bay and make better decisions regarding natural resource conservation and sustainable uses.

Objective: Detect the extent and spatial scale of trends in critical ecosystem structural and functional attributes that contribute to the bay's important role as nursery for juvenile fish and invertebrates, as a major migratory stopover for shorebirds and waterfowl, as a breeding/nesting ground for wildlife, and for supporting endemic and rare species.

Objective: Determine the cause of detected trends, separating management effects from natural availability.

Objective: Use the trends to assess the relationship between physical and chemical factors and biological factors.

I. Select ecological indicators for long-term monitoring that together meet the above objectives.

A. The set of indicators should meet most of these criteria:

1. It should be a marker of long-term trends in ecosystem structure or process.

2. The sampling and analysis expected can be sustained in the long-term due to its cost-effectiveness.

3. The indicators can serve as an early warning for ecosystem threats, such as invasives.

4. The work has broad support and involvement by planners, managers, scientists, and the public.
5. Information supports an annual report on the state of the bay, produced in a manner useful to managers and the public, with synopses.

B. Periodically and iteratively refine objectives of long-term monitoring so that indicators can progressively define degradation of the bay in a more quantitative sense (National Research Council 1990a, 1990b, 1992).

C. Consider the contents of Table 6-4 as a preliminary set of indicator monitoring parameters, which draw on the experience of other planning efforts around the country. Refine this list of indicators with gained experience.

D. Phase the implementation of long-term monitoring based on a set of priority measures that are essential and should be accomplished at a minimum.
1. Define the types of analysis that will be conducted with these data.

II. Select target species based on a specified set of long term monitoring criteria.

A. The criteria for target indicator species include the following parameters: Exotic (E), Community Indicator (CI), Dominant Species (DS), Habitat Indicator (HI), Sensitive Species (SS), Federal or State Listed Species (LS), Economic Indicator (EI), Practical Indicator (PI), National Shorebird Conservation Priority (SP), California Special Concern Species (CSC), Multiple Species Conservation Plan (MSCP), Decline noted but no official status (D), Recreational and/or Commercial Species (RC), Endemic to Bay (BESPP), Top 10 Ecological Indicator (Top 10EI) and Tied to Bay Management Issue (M). The list of candidate target species for supporting long-term monitoring and for project planning are listed in Table 6-5.

III. Coordinate sampling to maximize the ability to establish correlations among the monitoring elements.

A. Make effective use of existing regional monitoring data to shed light on the status and trend of conditions in San Diego Bay, and to separate natural from anthropogenic change.
1. Consider the California Cooperative Fisheries Investigation, SCCWRP, NOAA National Status & Trends programs, and future studies of the type done by Fairey *et al.* (1996).
2. Expand Marine Recreational Fisheries Statistics Survey/NMFS periodic censuses (boat and dock checks, etc.); increase halibut and sand bass censuses.
3. Initiate bay-specific catch reporting of species caught for bait (ghost shrimp, anchovy, and topsmelt) to CDFG.
4. Collate site-specific studies done by academic institutions (Scripps Institute of Oceanography, SDSU, University of San Diego, etc.), consulting firms, etc.

B. Develop and adopt a means to obtain and use this information in an integrated and coordinated manner that would avoid conflict and dilution of effort, as well as maximize the ability to conduct correlations among the monitoring elements.
1. The timing and locations of the meroplankton and ichthyoplankton sampling should be coordinated with those employed for the benthic invertebrate fauna and for bay fishes. In that way, changes and long-term trends in the characteristics of these zooplankton groups can be related to those of the corresponding juvenile and adult populations. This approach will be important in helping to understand the important interrelationships between these pelagic, benthic, and demersal components of the bay ecosystem.

2. Establish a set of permanent monitoring stations throughout the bay for sediment and water column sampling, including at some storm drain outlets and river mouths, but also representative of the bay as a whole. Some of these may be useful as control sites for sediment testing for dredging projects.
3. Consider identifying and sampling for functional ecological groups meaningful to management objectives, such as fish assemblages important for bird foraging, species associated with scarce habitats, young-of-the-year or subyearling stages for commercially sought-after species, or those providing a major prey base for an endangered species. The sampling could also be stratified by season, or an indicator season might be selected. Changes in species composition or relative abundance along the length of the bay may also need to be determined, depending on management objectives.
4. Conduct certain standardized analyses. For instance, an environmental indicator variable such as salinity or temperature should be directly related back to effects on species, habitats, and communities.
5. The Technical Oversight Committee had certain priorities for long-term monitoring that fill in a prominent information gap and build on past monitoring work:
   a. A baywide avian survey was conducted in 2007. Continue to monitor migratory birds using established protocols.
   b. Continue to survey for eelgrass every five years.
   c. Every five years, conduct fish surveys with beach seines only. Adopt protocols when complete and thoroughly evaluated.

IV. Use multiple public and private jurisdictions to implement the sampling, including a citizen monitoring program to help plug gaps in coverage.

V. Apply adaptive management principles to modify the content of a comprehensive monitoring program to be more supportive of the needs of managers.

VI. Keep the Environmental Committee in place to make decisions on long-term monitoring priorities, phasing or stepwise implementation of monitoring elements, quality assurance and quality control, and effective dissemination of monitoring results to a broad audience. This committee does not make management recommendations.

Preliminary Selection of Indicators

A number of indicators were selected to be used for identification of the status and trends of the San Diego Bay's ecosystem health based on review of the programs that were currently in use. These indicators include parameters to monitor water quality, sediment quality, food web (primary production), hydrodynamic process, habitat recovery, bay biota, human use, stewardship, and climate change. A preliminary suite of proposed indicators and their respective measurable parameters are listed in Table 6-3.

Water Quality Indicator. The Water Quality Indicator measures the water quality conditions that are harmful to aquatic life and impair ecosystem function. The indicator has five parameters that each measures an aspect of water quality condition. These parameters include dissolved oxygen, salinity, turbidity, and nutrient concentrations.

Nonpoint source runoff is now commonly agreed to be “likely the principal continuing source of pollution to San Diego Bay” (SAIC 1998; SDUPD 2007a). Runoff of pollution through stormwater is the primary means of delivery of pollution to the bay. Recent studies by the San Diego RWQCB on surface water ambient monitoring programs for the Pueblo sub-watershed (SWAMP Report on the Pueblo Hydrologic Unit 2008), Sweetwater sub-watershed (SWAMP Report on the Sweetwater Hydrologic Unit 2008), and Otay sub-watershed (SWAMP Report on the Otay Hydrologic Unit 2008) will provide a valuable source of data to provide a watershed context for this parameter to be evaluated.

Table 6-3. Priority long-term monitoring "San Diego Bay Status and Trends" Indicators and Parameters.

Indicator	Parameters	
Water Quality	▪ Dissolved oxygen ▪ Salinity ▪ Turbidity ▪ Nutrients	
Sediment Quality	▪ Grain size ▪ Total organic carbon ▪ Sediment toxicity ▪ Sediment contaminants	
Food Web (Primary Productivity)	▪ Phytoplankton (Chlorophyll a) ▪ Marsh algae ▪ Rotifer Abundance ▪ % Native Copepod Abundance ▪ Average Zooplankton "Size"	
Hydrodynamic Processes	▪ Water residence time	
Habitat Recovery	▪ Historic habitat extent ▪ Restoration project evaluation	
Bay Biota	▪ Invasives ▪ Community indicator ▪ Dominant species ▪ Habitat indicator ▪ Sensitive species ▪ Protected species ▪ Economic indicator species ▪ Practical indicator	▪ National shorebird conservation priority ▪ California special concern species ▪ Multiple species conservation plan ▪ Decline noted, but no official status ▪ Recreational and/or commercial species ▪ Endemic to bay ▪ Top 10 ecological indicator ▪ Tied to bay management issue

Sediment Quality Indicator. The Sediment Quality Indicator should be based on trends detected as identified in Section 5.2.1 Remediation of Contaminated Sediments. It should use Bight '98, '03, and '08 data to establish baseline contaminant levels and trends in selected San Diego Bay seafood species. The following species should be used as described in Chapter 5 for various trend analyses related to sediment:

- Topsmelt (metals, PCBs, and DDT)
- Spotted sand bass and barred sand bass (metals, PCBs, DDTs, dioxins, and radionucliotide levels)
- Other fish species consumed in significant quantities (dioxin)
- Pacific mackerel (metals, PCBs, and DDT)

Linking species and water quality requires an understanding of how they are interconnected in San Diego Bay's ecosystem. Figure 6-1 helps depict some of the conceptual relationships between primary and secondary pollution, pathways of exposure, and receptors of pollution in the food chain (UC Davis 2003).

While this diagram was prepared as a generic site conceptual model for B Street / Broadway Piers, Downtown Anchorage, and Switzer Creek, it captures a way to identify potential biological indicators for the bay as a whole. Similarly, the USFWS offered an initial attempt to identify indicators for the bay in Figure 6-2 (USFWS 2004).

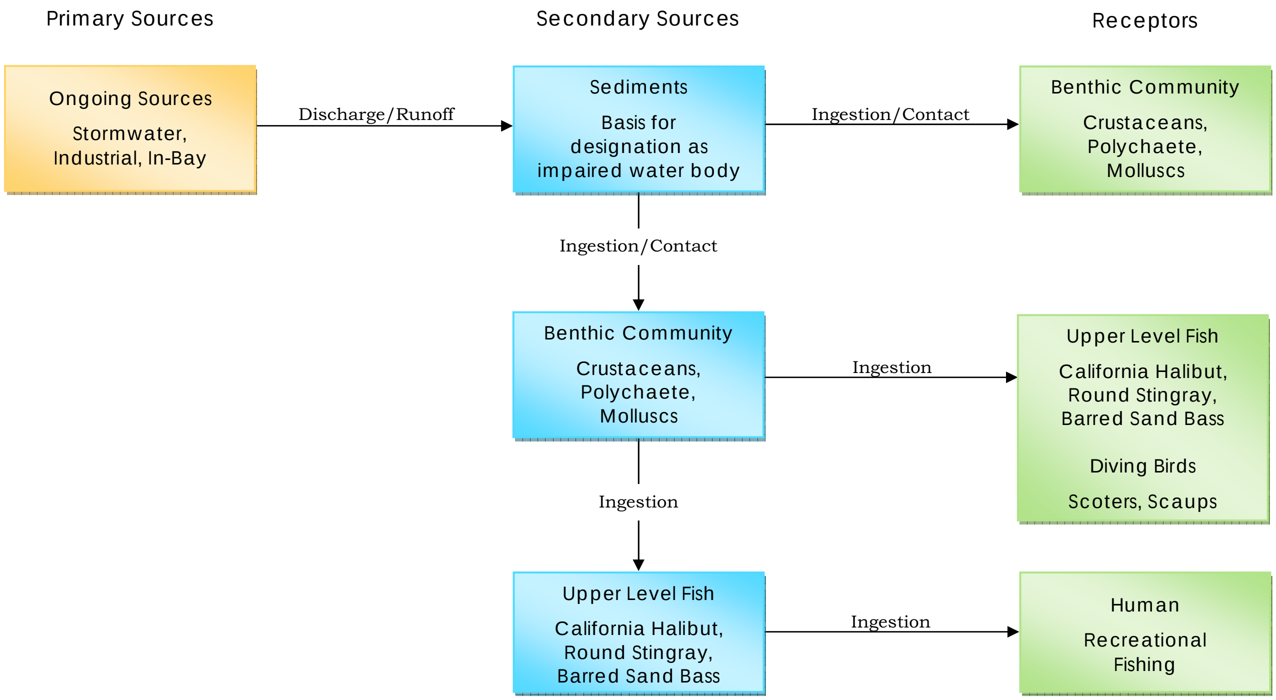

Figure 6-1. Generic site conceptual model to identify potential biological indicators for San Diego Bay.

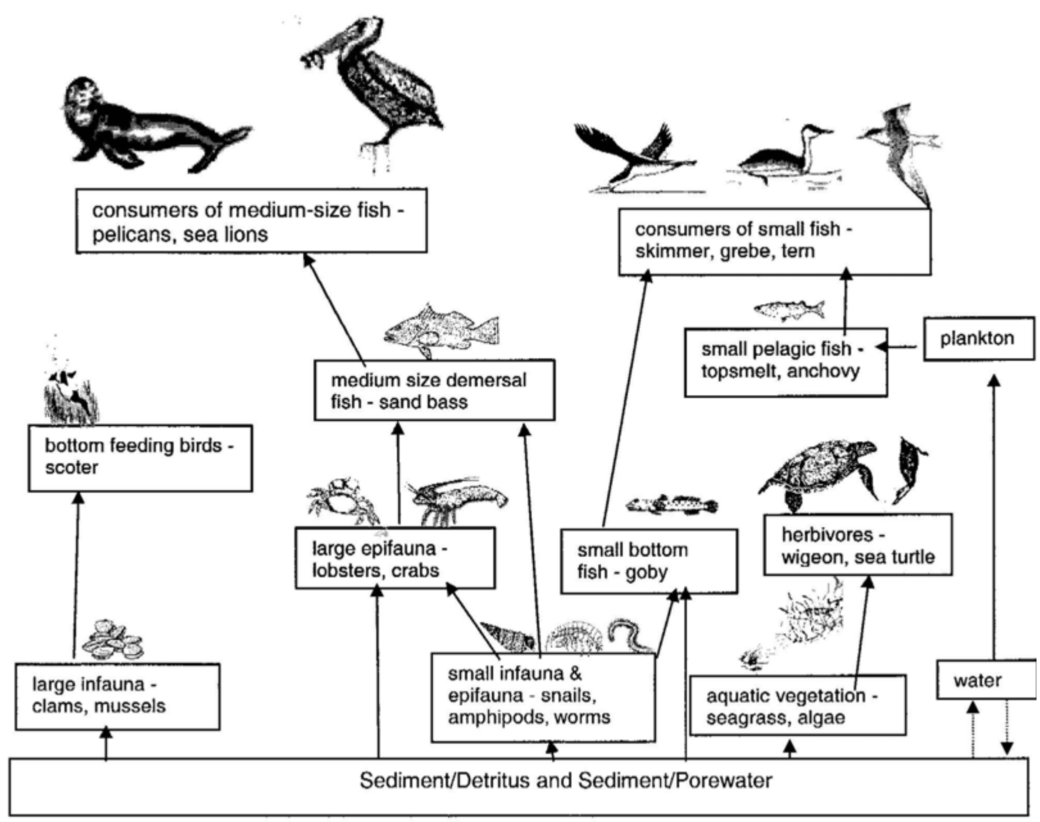

Figure 6-2. Receptor groups and routes of exposure to sediment-borne contaminants in subtidal and lower intertidal habitats in San Diego Bay.

The San Diego Bay Advisory Committee for Ecological Assessment "SB 68" Report suggested that a Biological Indicator Program consider the use of benthic community indicators and bioaccumulation data for tracking the ecological health of the bay (San Diego Bay Advisory Committee for Ecological Assessment 2005). Benthic invertebrates are considered excellent indicators of sediment quality and anthropogenic effects because they exhibit low mobility and are directly exposed for relatively long durations. While benthic invertebrates can be useful as indicators, evaluation of benthic conditions is difficult due to a high degree of variability that exists for the following reasons (SWRCB 2006): 1) biological response is dependent upon both the individual organism health and sensitivity and the bioavailability of the contaminants; 2) benthic community structure can also exhibit a high degree of seasonal and temporal variability; 3) other confounding factors include the presence of opportunistic nonindigenous species that can have a profound effect on community makeup and structure; 4) sediment toxicity test results can be influenced by other factors not directly related to *in situ* bioavailability, such as sample manipulation and disturbance.

Benthic indices measuring benthic community condition were used by the SWRCB to determine toxic hotspots and by the RWQCB to make clean up decisions for three toxic hotspots in San Diego Bay. Despite their common use, benthic indices have identified limitations. The SWRCB is studying the various benthic indices as part of its program to develop SQOs as a mechanism to differentiate sediments that are impacted or not impacted by toxic pollutants (SWRCB 2006). Five potential benthic index approaches "calibrated to California data" were evaluated for this program: Benthic Response Index; Relative Benthic Index; River Invertebrate Prediction and Classification System; and the Benthic Quality Index.

Comparing and contrasting these indices with each other and the opinions of benthic experts, the State Board staff found that none faired as well as the experts had expected, while the best was a combination of three or more indices. As a result, staff is recommending that multiple methods be used for applicable water bodies.

Relevant research on biological indicators is being performed by SCCWRP. The IBI was recently adapted for the bays and harbors of southern California in a study which included sampling at many sites in San Diego Bay (Ranasinghe *et al.* 2004). While looking promising, the IBI tool was found to need additional refinement and validation. The method is limited by three factors: 1) lack of independent data for validation; 2) insufficient data from highly disturbed sites to define the entire range of impact gradient; and 3) uncertainty in the effect of environmental variables that can affect benthic assemblage composition regardless of pollution impacts. How to best measure sediment toxicity effects on benthic organisms was the topic of another study (Bay *et al.* 2007). It concluded that five species-specific tests (three acute tests for amphipods and two sublethal tests for a polychaete and bivalve) were best suited for use in a California statewide sediment quality assessment program. Using multiple tests were suggested, since no single test ranked consistently highest for sensitivity or reliability.

The Environmental Health Coalition's 2005 Survey of Fishers on Piers in San Diego Bay provides evidence that a subpopulation of San Diego County residents engages in subsistence fishing off of piers near the shipyards and contaminated areas in San Diego Bay (Environmental Health Coalition 2005). Among this subpopulation are individuals who fish daily, who catch an average of 1.7 fish but have been recorded to catch up to 20 fish at a time, cook the fish and eat fish parts that maximize their exposure to contaminants, and who feed the fish caught in the bay to their children and families (Environmental Health Coalition 2005). These results suggest that, at the high end of the exposure continuum, a subset of fishers and their children may be eating fish once to several times weekly, eating relatively large amounts, and eating other seafood as well (Environmental Health Coalition 2005). The results also suggest that the method of fish preparation can increase exposure (Environmental Health Coalition 2005). Lastly, the survey identified that those fishers also live in communities such as Barrio Logan, Sherman Heights, Logan Heights, National City, and Tijuana that already bear a disproportionate burden of toxic exposure (Environmental Health Coalition 2005). The San Diego Union Tribune has noted that to date, the state agency responsible for issuing warnings on fish consumption, the Office of Health Hazard Assessment, has never issued an advisory for fish from San Diego Bay (San Diego Union Tribune 2005).

The San Diego Bay Advisory Committee for Ecological Assessment "SB 68" Report also recommended that "recently emerging pollutants also need to be monitored and evaluated" (San Diego Bay Advisory Committee for Ecological Assessment 2005). Determining the fate of "contaminants of emerging concern" (EC) in the environment is a relatively new issue that pertains to biological indicators and possible bioaccumulation (Battaglin *et al.* 2007). An EC is any synthetic or naturally occurring chemical or any microorganism that is not commonly monitored in the environment but has been recently detected in the environment. ECs are a potential ecological or human risk, yet little information is available to evaluate their risk. These chemicals may not be new but can now be detected at parts per trillion or, in some cases, parts per quadrillion because of advances in analytical chemistry and technology. They are usually released into the environment through household wastewater (via disposal or excretion of such products as pharmaceuticals) and can be detected in water, sediment, soil, and biota. Endocrine active chemicals, when released into water systems, can interfere with hormone systems in the bodies of animals and cause abnormalities. Such disruptions have been reported for amphibians, reptiles, fish, birds, and mammals exposed via various routes (Norris and Carr 2006). "Traditional" contaminants can also cause endocrine disruption: PCBs and perchlorate can affect the thyroid and cadmium can alter the adrenal gland.

In order to address fish contaminant concentrations and bioaccumulation, the SB 68 report recommended that the INRMP should support a program that will:

- Coordinate among local, state and federal agencies, universities, and private entities to achieve the objective above.
- Develop criteria for the selection of the most appropriate biological indicators.
- Encourage the development of conceptual models linking the relatively abundant data sets for water and sediment quality to species abundance and diversity.
- Ensure that the Bight Monitoring Program and the RHMP collect appropriate biological indicator data that can be used for long-term trend analysis of the bay's ecological condition.
- Pursue the monitoring of ECs and endocrine active chemicals in the bay and contributing drainages.
- Help carry out and coordinate a systematic sampling effort with comparable data collection protocols.
- Characterize the ecological health of San Diego Bay to help implement the recommendations of the final report of the San Diego Bay Advisory Committee for Ecological Assessment.

A potential data source for this parameter is SCCWRP General Monitoring Activities.

Food Web (Primary Productivity) Indicator. The proposed Food Web Indicator assesses the integrity of the lower trophic levels of the food web (Bay Institute 2004a). This indicator uses several parameters to measure changes in the abundance and composition of the zooplankton fauna that use San Diego Bay. Phytoplankton and zooplankton are the foundation of the bay and ocean food webs. Zooplankton is an early sentinel of ecosystem stress (Bay Institute 2004a). They are small organisms with short life cycles, which respond more rapidly than fish populations to changing conditions. It also includes measurements that affect zooplankton productivity such as chlorophyll *a* which is a widely accepted indicator of phytoplankton production in aquatic systems. The various food web indicator parameters have the potential to address hypotheses about lower trophic level relationships in the various hydrodynamic regions of San Diego Bay (Section 2.3.5. Hydrodynamic Regions of the Bay). The hypothesized stressor based food web model, Figure 6-3 Generalized Food Web, depicts generalized San Diego Bay lower trophic level food web relationships. Some proposed parameters to assess primary productivity and the bay's food web are listed in Table 6-4 Food Web Indicator Parameters.

Table 6-4. Food web indicator parameters (Source: Bay Institute 2004a.)

Parameter	Description
Phytoplankton (chlorophyll a)	A measure of phytoplankton biomass ("open water algal production")
Marsh algae	A measure of marsh algal biomass ("marsh algal production")
Rotifer Abundance	Population abundance of the smallest zooplankton species that use the San Diego Bay
% Native Copepod Abundance	Percentage of total copepods that are known to be native species
Average Zooplankton "Size"	"Annual average weight of zooplankton" (copepods and cladocerans) - an indicator of prey for fish

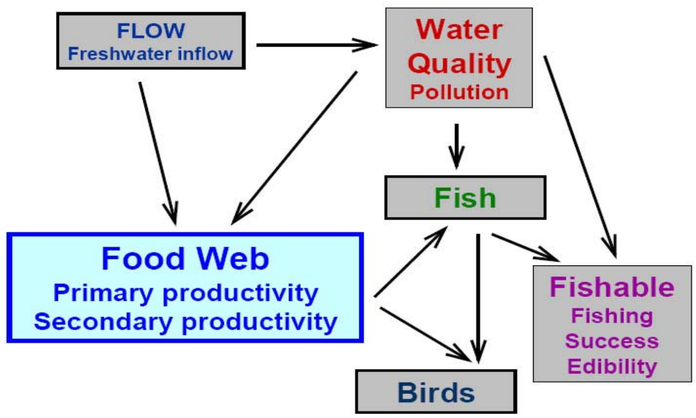

Figure 6-3. Food web trophic interactions (Bay Institute 2004a).

Habitat Recovery Indicator. A Habitat Recovery Indicator is used in San Francisco Bay's Ecological Scorecard (Bay Institute 2005). The World Bank uses a similar indicator to understand the impact of a development project's encroachment into natural habitats through the use of their Biodiversity Environmental Performance Indicator (World Bank 2002). The EPA National Coastal Condition Report III (2008) also incorporates a Coastal Habitat Index into their assessment of coastal conditions throughout the United States. There is very limited ability to recovery historic habitat conditions in San Diego Bay; however, restoration and enhancement actions recovery productivity and biodiversity in many ways only indirectly related to habitat acreage, and these could be monitored.

Bay Biota Indicator. This indicator was first proposed by the San Diego Bay Advisory Committee for Ecological Assessment which made a key recommendation in their 2005 Report (SB68) to "Implement a Biological Indicator Development Program" (San Diego Bay Advisory Committee for Ecological Assessment 2005). The Committee's hope for such a program was to:

- Better understand the link between native species abundance and diversity and indicators of water quality in San Diego Bay;
- Provide adaptive management cues;
- Help disparate programs operating under different laws and regulations to function as a more cohesive bay-wide program;
- Facilitate more effective communication with the public about the bay's status and trends;
- Add resolution to how beneficial use criteria are applied locally as they pertain to natural resources (e.g. fishing, preservation of designated biological habitats, estuarine and wildlife habitats, rare and endangered species, migration of aquatic organisms, and shellfish harvesting).

Monitoring individual species, or target species, is an important element of any program designed to assess the status and trends of an ecosystem's health. Using target species as one of several types of ecological indicators can represent a practical means at the project and programmatic level to evaluate and monitor environmental and habitat quality. The proposed San Diego Bay Indicators program builds upon this by incorporating the use of target species.

There has been ongoing debate in the scientific community about the reliability of using individual species as "ecological indicators" to interpret community and ecosystem level implications of disturbance (Patton 1987; Landres *et al.* 1988; Morrison *et al.* 1992; Marcot *et al.* 1994; Niemi *et al.* 1997). However, target or indicator species have provided and likely will continue to represent one of the most tangible, measurable approaches to environmental inventory, monitoring, and assessment (Noss 1990). The criteria and assumptions used to select these species should be clearly defined prior to the selection process to ensure the best possible candidates are selected, to avoid over-interpreting results of monitoring and project evaluations (Landres *et al.* 1988), and to ensure the entire suite of indicators selected is robust.

Target species can add an important level of detail to a time-series program and thus help to relate physical and chemical data to a species' specific dispersal or other life history needs tied to its use of the bay. The role of particular habitats or environmental factors may go undetected if at least some species are not examined at a fine, life-history scale. They are also meant to provide management a practical focus, under the assumption that managing for certain, carefully selected species of concern will take care of many others with overlapping habitat, food chain, or other ecological needs.

The use of migratory target species can be problematic because it is difficult to separate effects on the species due to problems in San Diego Bay versus anywhere else on the migratory pathway. However, support of migratory fishes, invertebrates, birds, and mammals is one of San Diego Bay's primary functions, often involving different resource issues than those that can be addressed by monitoring populations and habitats of residents. It is best to select target species that are also being monitored along the entire migratory pathway to get the larger picture necessary for revealing causes and the extent of decline. Justifications to use migratory species as ecological indicators include: 1) San Diego Bay may be part of a larger problem or it may not - this needs to be sorted out; 2) if bay activities are in fact affecting habitats and populations of migratory species, it would be difficult to understand and address this without information from ongoing population and habitat monitoring; and 3) some migratory species may be of such special interest economically, recreationally, culturally, scientifically, or from the regulatory side (listed, sensitive, etc.) to justify population and habitat trend monitoring.

The following are the proposed criteria for selecting and using suitable target management species for the San Diego Bay using recommendations from the literature (Patton 1987; Landres *et al.* 1988; Morrison *et al.* 1992; Marcot *et al.* 1994; Niemi *et al.* 1997; Bay Institute 2005; Chesapeake Ecocheck 2008; Healthy Reefs Initiative 2008; and World Bank 2002). The target management species selected should meet most of these criteria and should be highlighted in project evaluations, long-term monitoring focus, and modeling and research priorities in implementing the Bay Plan. In general the proposed criteria take the following concerns into account:

- The species relies on the bay to complete its life cycle;
- The species is sufficiently sensitive to bay disturbances that it provides a marker of environmental degradation;
- The species is a keystone upon which the diversity of a large part of a community depends;
- The species is a habitat specialists that consistently uses one habitat type or condition, or a certain combination of habitats to complete its life cycle;
- Populations are of sufficient size or density to be reasonably detected and monitored;
- The species is a year-round resident or, if migratory, is known or strongly suspected of being primarily affected by local disturbances in the bay;

- Populations are not normally sensitive to other environmental factors that would confound determination of cause-and-effect relationships (e.g. weather, predation, disease, competition);
- The species is in decline even if the cause is known to be non-bay specific.

Specifically, the criteria for target indicator species include the following parameters: Exotic (E), Community Indicator (CI), Dominant Species (DS), Habitat Indicator (HI), Sensitive Species (SS), Federal or State Listed Species (LS), Economic Indicator (EI), Practical Indicator (PI), National Shorebird Conservation Priority (SP), California Special Concern Species (CSC), Multiple Species Conservation Plan (MSCP), Decline noted but no official status (D), Recreational and/or Commercial Species (RC), Endemic to bay (BESPP), Top 10 Ecological Indicator (Top 10EI) and Tied to Bay Management Issue (M). The list of candidate target species for supporting long-term monitoring and for project planning are listed in Table 6-5.

Table 6-5. List of candidate target species for supporting long-term monitoring and for project planning.[1]

Scientific Name	Common Name	Reasons Selected	Habitat
Birds			
Limnodromus sp.	dowitchers	HI	mudflats
Aechmophorus clarkii transitionalis/	Clark's grebe	CI, HI	open water, subtidal, salt marsh
A. occidentalis var. *occidentalis*	western grebe		
Pelecanus occidentalis californicus	brown pelican	HI, SS, MSCP	subtidal, salt marsh, artificial structures
Phalacrocorax auritus	double-crested cormorant	CI, HI, SS	deep/medium subtidal, salt works, artificial structures
Egretta thula thula	snowy egret	CI, PI	upland transition, salt marsh
Branta bernicla nigricans	**black brant**	**HI, D**	**eelgrass**
Anas acuta	northern pintail	CI, HI, EI, D	shallow subtidal, shallow subtidal aquatic vegetation, salt marsh, upland transition
Aythya affinis	**lesser scaup**	**CI, HI, D, M**	**open water, deep/medium subtidal, eelgrass**
Melanitta perspicillata	**surf scoter**	**CI, HI, D, M**	**open water, subtidal, intertidal rocky, intertidal sandy**
Oxyura jamaicensis rubida	ruddy duck	CI, HI, D	open water, deep/medium subtidal, shallow subtidal aquatic vegetation, intertidal mudflat, salt marsh
Circus cyaneus hudsonius	northern harrier	HI, SS, CSC, MSCP	upland transition
Falco peregrinus anatum	peregrine falcon	CI, SS, PI, MSCP	upland transition
Rallus longirostris levipes	**light-footed clapper rail**	**CI, HI, SS, LS, PI, MSCP**	**salt marsh**
Charadrius alexandrinus nivosus	**western snowy plover**	**CI, HI, SS, LS, SP, CSC, MSCP**	**intertidal sandy, intertidal mudflat, salt marsh, salt works, upland transition**
Ammodramus sandwichensis rostratus	large-billed sparrow	HI, SS, CSC, MSCP	salt marsh
Ammodramus sandwichensis beldingi	**Belding's savannah sparrow**	**C1, H1, SS, DS, PI, MSCP**	**salt marsh**
Pandion haliaetus carolinensis	osprey	HI, SS, LS, maybe CI	open water
Larus occidentalis wymani	western gull	CI, DS	deep water, medium subtidal, shallow subtidal, aquatic vegetation, intertidal rocky, sandy, mudflat, salt marsh, salt works, artificial structure, upland transition.
Sterna antillarum browni	California least tern	CI, HI, LS, PI, MSCP	subtidal, intertidal sandy, intertidal mudflat, salt marsh, salt works, artificial structures
Sterna elegans	elegant tern	HI, SS, D, MSCP	subtidal, intertidal sandy, intertidal mudflat, salt marsh, salt works
Sterna forsteri	Forster's tern	CI, HI, PI	shallow subtidal, intertidal sandy, intertidal mudflat, salt marsh, salt works
Arenaria interpres	ruddy turnstone	CI, HI	intertidal mudflats, breakwaters
Calidris canutus roselaari	red knot	CI, HI, SS, SP	intertidal mudflat, salt marsh, salt works
Numenius americanus	long-billed curlew	CI, HI, SS, SP, MSCP	intertidal mudflat, salt marsh, salt works
Phalaropus lobatus	red-necked phalarope	CI, HI	salt works
Eremophila alpestris	coast horned lark	HI, SS	intertidal mudflat, salt marsh, upland transition
Fishes			
Urolophus halleri	round stingray	Top 10EI, CI, HI, RC, D	intertidal, nearshore, channel
Sardinops sagax caeruleus	Pacific sardine	Top 10EI, HI, RC	nearshore, channel
Engraulis mordax	northern anchovy	Top 10EI, HI, RC, DS, PI	intertidal, nearshore, channel
Anchoa delicatissima	slough anchovy	Top 10EI, BESPP, NC, SC, S	intertidal, nearshore, channel
Anchoa compressa	deepbody anchovy	BESPP, HI	intertidal, nearshore, channel

[1]Bolded items are considered highly likely candidates to be target species because of the number of criteria met. * = Exotic, CI = Community Indicator, DS = Dominant Species, HI = Habitat Indicator, SS = Sensitive Species, LS = Protected Species, EI = Economic Indicator, PI = Practical Indicator, SP = National Shorebird Conservation Priority, CSC = California Special Concern Species, MSCP = Multiple Species Conservation Plan, D= Decline noted, but no official status, RC = Recreational and/or Commercial Species, BESPP = endemic to bay, Top 10EI = Top 10 Ecological Indicator, M= Tied to Bay Management Issue.

Table 6-5. List of candidate target species for supporting long-term monitoring and for project planning.[1] (Continued)

Scientific Name	Common Name	Reasons Selected	Habitat
Leuresthes tenuis	California grunion	HI	nearshore
Atherinops affinis	topsmelt	Top 10EI, CI, HI, RC, DS, PI	intertidal, nearshore, channel
Syngnathus griseolineatus	bay pipefish	CI	intertidal, nearshore, channel
Paralabrax maculatofasciatus	**spotted sand bass**	**Top 10EI, BESPP, RC**	**intertidal, nearshore, channel**
Paralabrax nebulifer	barred sand bass	Top 10EI, RC, HI	nearshore benthic, channel benthic
Cymatogaster aggregata	**shiner surfperch**	**Top 10EI, HI, RC, DS, PI**	**intertidal, nearshore, channel**
Embiotoca jacksoni	black surfperch	HI	nonvegetated nearshore
Micrometrus minimus	dwarf surfperch	HI	intertidal, nearshore
Mugil cephalus	striped mullet	BESPP, HI	intertidal, nonvegetated nearshore, channel
Hypsoblennius gentilis	bay blenny	HI	intertidal, nearshore, channel
Heterostichus rostratus	giant kelpfish	Top 10EI, HI, VEGSPP	vegetated intertidal, nearshore
Clevelandia ios	arrow goby	BESPP, CI, HI, DS, PI	intertidal, nearshore
Hypsopsetta guttulata	diamond turbot	BESPP	unconsolidated sediment in intertidal, nearshore, channel
Paralichthys californicus	**California halibut**	**Top 10EI, HI, RC, DS, PI, EI**	**intertidal, nearshore, channel**
	fishes of artificial substrate	HI	artificial hard substrate
Reptiles			
Chelonia mydas agazzizii	green sea turtle	HI, SS	nearshore
Phrynosoma coronatum blainvillei	San Diego horned lizard	SS, MSCP	upland transition
Invertebrates			
Halichondria panicea	crumb of bread sponge	CI, HI	artificial hard substrate
Tetilla mutabilis	wandering sponge	CI, HI	unconsolidated sediment
Diadumene cf. *leucolena*	anemone	CI, HI	unconsolidated sediment, hard substrate
Pseudopolydora paucibranchiata	spionid	CI, HI, DS	tidal flat
**Neanthes acuminata*	neriid	CI, HI, DS	unconsolidated sediment
Leitoscoloplos elongatus	orbinid	CI, HI, DS	unconsolidated sediment
Capitella capitata	capitellid	CI, HI, DS	eelgrass, unconsolidated sediment, marsh channels
Megalomma pigmentum	sabellid	CI, HI, DS	unconsolidated sediment
Fabricia limnicola	sabellid	CI, HI, DS	eelgrass, unconsolidated sediment
Euphilomedes carcharodonta	ostracod	CI, HI	eelgrass
Parasterope barnsei	ostracod	CI, HI, DS	eelgrass, unconsolidated sediment
Acuminodeutopus heteruropus	aorid	CI, HI, DS	unconsolidated sediment
Plankton	Add planktonic indicators as they can be identified and prioritized.		
Caprella mendax	skeleton shrimp	CI, HI, DS	eelgrass, unconsolidated sediment
Euphilomedes carcharodonta	seed shrimp	CI, HI, DS	unconsolidated sediment
Crangon franiscorum	crangonid shrimp	HI, PI	eelgrass
Cancer antennarius	common rock crab	HI, PI	unconsolidated sediment, hard substrate
Hemigrapsus oregonesis	mudflat crab	CI, PI	eelgrass, unconsolidated sediment
Portunus xantusi	swimming crab	CI, PI	unconsolidated sediment
Callianassa californiensis	**ghost shrimp**	**CI, PI, RC**	**eelgrass, unconsolidated sediment**
Panoquina errans	wandering skipper	CI, PI, MSCP	salt marsh
Cerithidea californica	California horn shell	HI, DS, PI	unconsolidated sediment, vegetated salt marsh
****Musculista senhousia***	**Japanese mussel**	**CI, HI, DS**	**eelgrass, unconsolidated sediment**
**Tapes japonica (semidecussata)*	venerid clam	HI, DS, PI	unconsolidated sediment
Tagelus californianus	jackknife clam	CI, HI, DS	eelgrass, unconsolidated sediment
Macoma nasuta	bent-nosed clam	CI, HI	eelgrass, unconsolidated sediment
Crangon franiscorum	crangonid shrimp	HI, PI	eelgrass
	mussels, barnacles	HI, PI	artificial hard substrate
Plants			
Spartina foliosa	cord grass	HI, D	salt marsh
Cordylanthus maritimus maritimus	salt marsh bird's beak	LS	salt marsh
Nemacaulis denudata var. *denudata*	coast woolly-heads	CI, SS	coastal dune
Lotus nuttallianus	Nuttall's lotus	CI, SS	coastal dune
Zostera marina	eelgrass	HI	eelgrass

[1]Bolded items are considered highly likely candidates to be target species because of the number of criteria met. * = Exotic, CI = Community Indicator, DS = Dominant Species, HI = Habitat Indicator, SS = Sensitive Species, LS = Protected Species, EI = Economic Indicator, PI = Practical Indicator, SP = National Shorebird Conservation Priority, CSC = California Special Concern Species, MSCP = Multiple Species Conservation Plan, D= Decline noted, but no official status, RC = Recreational and/or Commercial Species, BESPP = endemic to bay, Top 10EI = Top 10 Ecological Indicator, M= Tied to Bay Management Issue.

The candidates considered highly likely to be target species because of the number of criteria met include the following species listed in Table 6-6.

Table 6-6. Candidates considered highly likely to be target species

Scientific Name	Common Name	Reasons Selected
Birds		
Branta bernicla nigricans	Black brant	HI,D
Aythya affinis	lesser scaup	CI, HI, D, M
Melanitta perspicillata	Surf scoter	CI, HI, D, M
Rallus longirostris levipes	Light-footed clapper rail	CI, HI, SS, LS, PI, MSCP
Charadrius alexandrinus nivosus	Western snowy plover	CI, HI, SS, LS, SP, CSC, MSCP
Ammodramus sandwichensis beldingi	Belding's savannah sparrow	CI, HI, SS, DS, PI, MSCP
Sterna antillarum browni	California Least Tern	CI, HI, LS, PI, MSCP
Fishes		
Paralabrax maculatofasciatus	Spotted sand bass	Top 10EI, BESPP, RC
Cymatoaster aggregate	Shiner surfperch	Top 10EI, HI, RC, DS, PI
Paralichthys californicus	California halibut	Top 10EI, HI, RC, DS, PI, EI
Invertebrates		
Callianassa californiensis	Ghost shrimp	CI, PI, RC
Musculista senhousia	Japanese mussel	CI, HI, DS

Climate Change Indicator. Anthropogenic climatic forcing is mediated primarily by greenhouse gas (predominantly CO_2) emissions (Harley *et al.* 2006). Together, elevated CO_2 and the resultant increases in global mean temperature is expected to result in a cascade of physical and chemical changes in marine ecosystems (Harley *et al.* 2006). Figure 6-4 illustrates important abiotic changes in marine ecosystems associated with climate change (Harley *et al.* 2006).

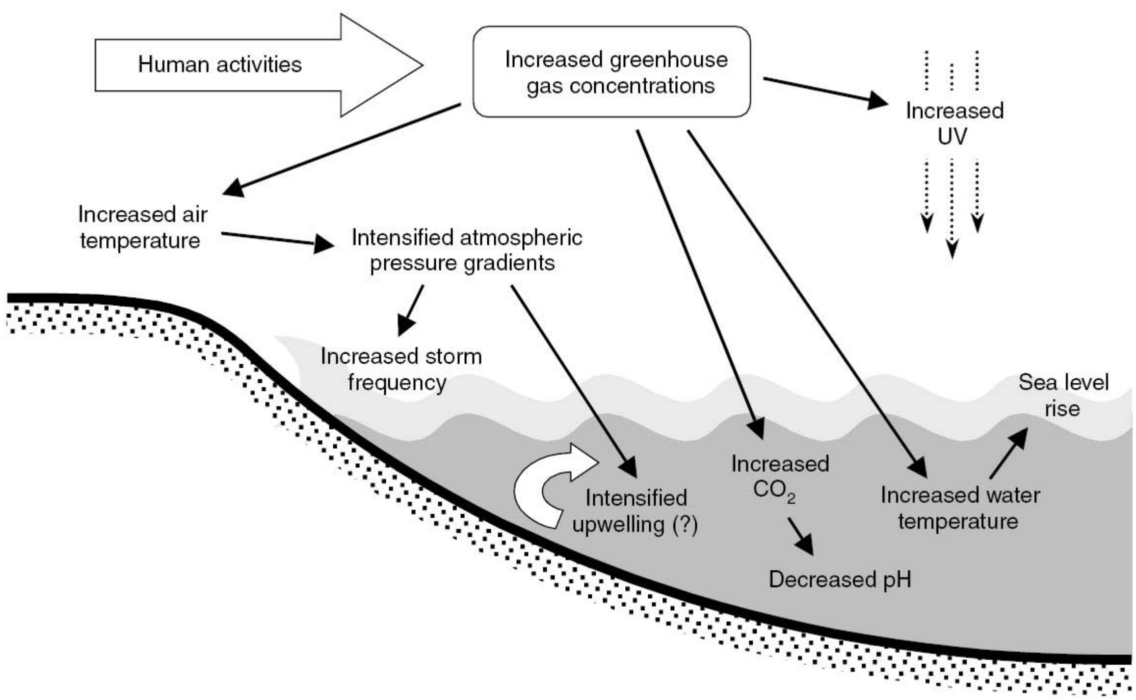

Figure 6-4. Abiotic changes in marine ecosystems associated with climate change, source: Harley et al 2006.

The proposed Climate Change indicator for San Diego Bay has three parameters that collectively assess the abiotic physical and chemical changes in marine systems linked to anthropogenic climatic forcing (Harley *et al.* 2006). These parameters include tracking water temperature, water pH, and sea level rise.

The warming trends for sea surface temperatures also have implications for other abiotic variables such as sea level (IPCC 2001, 2007; Harley *et al.* 2006). As a result of warming seawater the world oceans are expanding (IPCC 2001, 2007; Harley *et al.* 2006). Coupled with freshwater input from ice-melt, thermal expansion of the oceans is causing sea level to rise at approximately 2 mm per year (IPCC 2001, 2007; Harley *et al.* 2006). The San Diego Foundation predicts that if current trends continue, then in 2050 the sea level will be 12-18 inches higher in the region (Focus 2050 Study 2008). Sea level change is expected to have the following implications to the region's coastal environment:

- Beaches will shrink and some will disappear completely;
- Fragile sea cliffs will collapse;
- Coastal properties will be flooded with increasing regularity;
- More frequent high waves and rough surf will increase the potential for significant damage;
- Existing tide pools will be destroyed;
- Coastal wetlands will lose their capacity to filter polluted runoff and keep beaches clean.

In San Diego Bay specifically, when a high tide occurs during a large storm, particularly in El Niño winters, flooding will threaten homes, businesses, and hotels in low-lying coastal communities such as Imperial Beach and Coronado (Focus 2050 Study 2008). The U.S. Navy, Port, and San Diego International Airport may also be affected by these changes in sea level (Focus 2050 Study 2008).

Roughly half of the CO_2 released by human activities between 1800 and 1994 is now stored in the ocean (Sabine *et al.* 2004), and about 30% of modern CO_2 emissions are taken up by oceans today (Feely *et al.* 2004; Harley *et al.* 2006). Continued uptake of atmospheric CO_2 is expected to substantially decrease oceanic pH over the next few centuries, changing the saturation horizons of aragonite, calcite, and other minerals essential to calcifying organisms (Kleypas *et al.* 1999; Feely *et al.* 2004; Harley *et al.* 2006).

Model estimates of pH reduction in the surface ocean range from 0.3 to 0.5 units over the next 100 years and from 0.3 to 1.4 units over the next 300 years, depending on the CO_2 emission scenario used (Caldeira and Wickett 2005; Harley *et al.* 2006). While many marine organisms have adapted to thermal fluctuations in the last few million years, the expected changes in pH are higher than any other pH changes inferred from the fossil record over the past 200-300 million years (Caldeira and Wickett 2003; Feely *et al.* 2004; Harley *et al.* 2006). The findings from recent studies on ocean acidification indicate that conditions detrimental to high-latitude marine ecosystems could develop within decades, not centuries as suggested previously (Orr *et al.* 2005).

This parameter is intended to track water pH in the bay in order to provide information as to the status of the pH of the bay's water at any given time. The collection of this water chemistry data provides a means to evaluate the trend of this variable over time.

6.2.3 Project Monitoring

Current Management

Most monitoring is done in response to permit requirements for discharges or construction or maintenance projects. Discharge permits are administered by a number of agencies and there had been no attempt to coordinate among them until the SCB Regional Program organized by the SCCWRP as described above. However, this regional monitoring program is oriented toward tracking pollution rather than broader ecological questions.

Most other ecological monitoring in San Diego Bay is conducted by project proponents, as mandated by regulators, and tends to be limited in its ability to provide management guidance. It is narrowly defined and completed within parameters of the permitting process and the project proponent's cost constraints. It tends to be poorly standardized, although eelgrass monitoring requirements have been established for some time and are an exception to this rule.

Evaluation of Current Management

Bay managers meet routinely; however, design review of projects is still insufficiently early to facilitate better projects for habitat and the ability for bay managers to learn from project implementation. The existing approach still suffers from being too piecemeal, nonstandardized, and generally not disseminated beyond the project proponent, the immediate agency in charge, and the consulting firm contracted to perform the monitoring. Project-oriented monitoring often provides little predictive insight because species abundance and diversity are inherently variable at many scales. Such monitoring typically does not allow for adequate experimentation or sampling to make it useful as a baseline for future or related studies. Furthermore, it does not provide any indication about whether the bay as a whole is being affected by cumulative effects of the multitude of projects implemented within it.

Management Strategy-Monitoring Related to Project Implementation

Objective: Improve the ability to build on existing and new project monitoring experience to make the bay healthier and more sustainable.

I. Obtain useful information from each restoration and enhancement project and use projects to test new ideas.

- *A.* Integrate the use of pilot projects for innovation in restoration design and construction.
- *B.* Standardize methods and protocols to enable comparison among projects, as well as between short-term and long-term monitoring programs at a reasonable cost.

II. Provide quality control and assurance for monitoring data and their interpretation.

- *A.* Assess existing monitoring efforts in San Diego Bay.
- *B.* Establish a network of reference sites that can be used to monitor background variation in populations of target species of fish and wildlife and their habitats in relatively undisturbed areas.

III. Improve the effectiveness of monitoring related to permits so that it may provide insight on avoidance, minimization and mitigation priorities and protocols beyond the scope of the project for which it is implemented.

- *A.* Encourage formalization of design review for bay projects by interagency managers early in project development in order to achieve the most benefit for habitats and bay health.
- *B.* Encourage public-private partnerships to research the design, implementation, and monitoring of mitigation projects and avoidance and minimization measures.
- *C.* Restoration projects should, where possible, involve the community, i.e. not on easily damaged sites.
- *D.* Sponsor studies that support protocols and conditions for out-of-kind mitigation and mitigation banking.
- *E.* Assess success of mitigation projects and avoidance and minimization measures and use results to improve implementation.

IV. Make monitoring results readily available to agencies and the public.

- *A.* Integrate project monitoring with regular reporting on the bay's natural resources through a "San Diego Bay Status and Trends Report."
- *B.* Report on the contributions to the goal and objectives of this Plan.

C. An independent organization should manage the monitoring program, data archiving, and making data available to interested parties.

V. Supplement project-related monitoring with focused research on such topics as:

- The relative importance of habitat at a certain location compared to a neighboring area, to support evaluation of project placement/alternative sites;
- The strength of dependencies among habitats and organisms (productivity, physical material transport, tidal circulation, and biological linkages such as migration and feeding dependencies, etc.), in order to better define the area of influence of a project and cumulative effects;
- Quantified area of influence;
- Quantified response time scale; and
- Quantify changes in organism abundance and community structure.

VI. Evaluate project success based on priority goals and objectives of this Plan.

A. Consider success ranking based on the following:

- To what extent will the project restore functioning of natural processes (e.g. hydrology)?
- Will the project result in an increase in habitat acreage?
- Will the improvements be self-sustaining? What level of on-site management or maintenance will be required?
- To what extent is the site physically and ecologically connected to other natural upland transition habitats?
- To what extent is the site hydrologically and ecologically connected to marine habitats?
- To what extent will the project benefit marine and intertidal resources?
- What is the site's function and value from a regional perspective, including sensitive species habitat, use by migratory birds, fisheries support, and biodiversity?

B. Identify a predisturbance reference condition to help evaluate success.

C. Where possible, restore processes instead of structural habitat features, in order that the work be self-sustaining. Emphasis should be on process-based ecosystem restoration, such as those processes that naturally sustain marshes, channels, mudflats, etc.

6.2.4 Research to Support Management Decisions

In contrast to monitoring, research constitutes problem-solving and hypothesis-testing, and focuses on mechanisms. It requires articulation of an explicit conceptual model to evaluate its relevance to the concerns of bay managers.

Current Management

Current research programs are sponsored by individual organizations with a specific interest relative to their use of the bay and which are usually related to compliance with environmental laws. This Plan summarizes much of the past and current research in Chapter 2.

Recent studies that pertain to the San Diego Bay are currently underway and are funded by the Port's Environmental Fund include the following (SDUPD 2009):

- SDSU, in conjunction with NMFS, has begun to use isotopes and element analysis to understand the impact of trophic structure and contaminants on threatened and endangered species, such as sea turtles, in San Diego Bay.
- AMEC Earth & Environmental is conducting a pilot study for used oil and oil filter bins for boaters at a marina in San Diego Bay.

- M.H Systems, Inc. and Scripps Institution of Oceanography is testing ballast water treatment options with inert gas on the oceanographic research vessel, RV Melville.
- SDSU is conducting research on maintaining healthy eelgrass beds, looking at fishes, trophic diversity, and ecosystem function.
- SDSU is assessing the eelgrass habitat function for recreationally important fish species.
- A student grant recipient studied predator manipulation and effects of habitat structure/complexity on diversity and abundance.
- Fish structures used at an enhancement site are monitored.
- The Port and Navy both contribute to green sea turtle tracking with GPS, satellite, and data recorders.
- TDI, in collaboration with SPAWAR, is using automated “Ocean Sensors” to monitor water quality at fixed stations.
- The light-footed clapper rail propagation program at the Chula Vista Nature Center provides methods and monitoring data.
- Scripps Institute of Oceanography is studying the magnitude and extension of copper pollution effects on benthic faunal communities in San Diego Bay.
- A geotechnical and fault study is underway for San Diego Bay.

Evaluation of Current Management

While there are decreasing trends of some metals and PAHs in the open bay sediments and waters, toxicity still exists in some areas of the bay. Some of the newer pollutants are not being monitored. Pollutant levels tend to be higher in areas of industrial uses and urban runoff. Lower native species abundance and diversity and higher invasive species numbers are found at these sites.

Dissolved copper levels exceed chronic, and sometimes acute, water quality criteria. Shoreside areas in north and north-central regions contain the highest levels, while the lowest are in the open bay area.

Specified industrial stormwater permits include acute toxicity standards (for U.S. Navy, shipyards, and boatyards). However, similar standards are not included in the Municipal Stormwater Permit for the cities and county, nor in other NPDES permits in county. To date, the impacted industrial permittees have not identified a reliable, permanent means of complying with the toxicity provision of their permit. Considerable effort and funds have been expended to try to comply with these toxicity standards. Both successes and failures have occurred in trying to meet toxicity standards with available treatment technologies.

Research on the bay suffers from the same problems already identified in previous sections of this chapter. It is conducted piecemeal and project by project. Much of it falls in the “gray literature” and is poorly disseminated to interested parties. Furthermore, much of it is not peer-reviewed.

A systematic program is needed that is designed to fill gaps in data and technology as these are prioritized by managers, rather than following the past project-by-project, opportunistic approach.

Table 6-7 is a list of priority research interests identified by the TAC during the production of this INRMP.

Table 6-7. Research topic interests.

Artificial Habitats

What can be done to make man-made structures and altered habitats in the urbanized areas of the bay more habitable by diverse, native species without compromising the effectiveness of the structures?
What affects do artificial hard substrates have on adjacent soft bottom or other natural habitats?
What are the ecological consequences of replacing native soft substrates and habitat with anthropogenic hard substrates?
What role do artificial substrates have in supporting invasive species?
What affect do filter feeders living on artificial substrates have on water quality?

Contaminants

What are the effects of toxic constituents in bay sediments on benthic infauna?
What is the pollutant input from urbanized watersheds (e.g. Chollas Creek)?
What are the effects on fish and invertebrate communities?
How do the industrial bay users (shipbuilding) affect biological communities?
What is the pollutant input?
How can sediment remediation be accomplished?
How can important habitats be safeguarded from sources of contaminants?
What is the relationship of contaminated sediments and water to fish tissue levels in migratory species?
What part does pollution play in habitat loss or degradation?
How can causes of pollutants from nonpoint sources be determined, and their effects?
What is the effect of fuel and oil from pleasure craft and small boats on water quality, benthic communities, pelagic communities, or on seabird communities?

Cumulative Effects

How is armoring the shoreline with riprap and continually covering open water areas with structures (i.e. wharves, docks) changing biological, fish, and invertebrate communities?
What are the cumulative effects?

Disturbance

What are the anthropogenic disturbances on animal populations in the bay (population pressure, boats, recreation)?
How should an adequate survey of bay surface users be conducted?
How can design criteria to adequately buffer impacts at the urban interface be determined, i.e. render adjacent impacts compatible with proper natural system functioning to guarantee long-term productivity of target species and habitats (noise, light, pollution, water quality, exotic/invasive species)?

Ecological Dependencies

What physical and chemical conditions affect bay phytoplankton and zooplankton?
What is the contribution of bay ichthyoplankton to juvenile and adult diversity, biomass, and productivity in the bay / nearshore ocean?
What is the ecological and productivity value of the benthic algae masses (*Gracilaria* sp.) in the bay?
How are they formed, what allows them to remain and what would cause them to be disrupted?
What is the relationship between fish biomass/productivity in north/central bay in summer, and south/central in January?
What physical (and biological) components best explain this?
How should utilization of tidal flat (both mud and sand) by marine resources and linkages with adjacent subtidal and upper intertidal habitats be assessed?
What is the relationship between anchovy biomass/productivity and California least tern nesting success?

Ecosystem Processes

Can we identify markers of ecosystem function: what are the organisms, rates, and communities?

Enhancement Planning

How can planned or potential development areas vs. future enhancement needs be identified in advance and made compatible?

Invasives

Is natural population succession of created habitats affected by invasive species?
How should populations be tracked?
What habitats or systems are most susceptible to invasion by invasives and what species are most likely to invade San Diego Bay and cause significant damage to the ecosystem?

Habitats

What is the ecological function and value of unvegetated, shallow habitat?
What is the ecological function and value of intertidal habitat for shorebirds and marine fish?
What tidal elevations seem to be most highly utilized?
What species are dependent upon these areas?
What species of benthic invertebrates are present, and what are the numbers of organisms by tidal elevations?
How should trends in habitat extent be identified, and habitat maps updated?
What is the extent of eelgrass?
What portion of existing habitat is degraded due to direct impacts and indirect impacts such as fragmentation, sediments, disturbance, edge impacts?
How do different habitats interact and how does habitat fragmentation affect ecosystem function?
What has been the effect of the loss of needed interrelating rivers, marshes, subtidal, and mudflats, to habitat value?
What threats may result in additional habitat losses?
How can shoreline erosion be determined/addressed, and sand replenishment be accomplished?
What wetland habitat and upland transition loss is due to development?

Table 6-7. Research topic interests. (Continued)

Mitigation/Restoration
What are the important habitat areas to be conserved by way of sales of mitigation credits? What is the benefit of using a mitigation bank? What are new or revised avoidance, minimization, and mitigation strategies that will improve and replace diminished habitats? What research can be done to aid the success of tidal mudflat and wetland restoration projects? How should success be evaluated? Is tidal wetland restoration in San Diego Bay successful? What are the relationships between shoreline topography and elevation along the bay and tidal wetland plant communities?
Monitoring
How can we make specific pre- and postproject implementation surveys useful for comparison data (including relating system functionality to wildlife use) in an ecological restoration-related monitoring program? What should be the effectiveness measures (criteria) for intertidal flat and marsh conservation programs? How can baseline monitoring be accomplished in the long term?
Populations
How does the power plant operation (or nonoperation) affect the green sea turtle population and ecology? What research should be done into the ecology of the green sea turtle population? Is there a shorebird population decline? What are the causes? What improvements to south bay forage fish production/populations can be made? Shorebird survey for the entire San Diego Bay shoreline (what are the species, numbers, and distribution patterns?). Update the waterbird survey of San Diego Bay (a second survey). How should an adequate comprehensive survey of birds be accomplished (i.e. shorebirds separate from rafting birds, and full access to all bay locations for observers)? Where are California least tern populations and nesting locations in South America? How can gaps in the clapper rail breeding survey/census be filled?
Regional Growth
How should regional population growth issues be addressed? How can continued development pressures be anticipated and planned for? How might different cultural attitudes from multi-ethnic communities located in different parts of the bay watershed contribute to ecosystem improvement or degradation? How might cultural diversity in local multi-ethnic communities impact the ecosystems, diversity, or specific species of San Diego Bay? How does ethnic and socio-economic diversity affect the marine resource use of various sub-populations in local multi-ethnic communities?

Objective: Support management decisions by conducting research on the mechanisms and processes that provide value to the bay as an ecosystem.

The following list of recommendations provides a plan and a series of tasks to coordinate the activities of bay researchers and managers so that many of the questions identified in the previous table may be able to be answered in the future.

Management Strategy—Research to Support Management Decisions

I. Prioritize research using the following Bay Biota Indicator criteria:

- *A.* Invasive (I)
- *B.* Community Indicator (CI)
- *C.* Dominant Species (DS)
- *D.* Habitat Indicator (HI)
- *E.* Sensitive Species (SS)
- *F.* Federal or State Listed Species (LS)
- *G.* Economic Indicator (EI)
- *H.* Practical Indicator (PI)
- *I.* National Shorebird Conservation Priority (NSCP)
- *J.* California Special Concern Species (CSC)
- *K.* Multiple Species Conservation Plan (MSCP)
- *L.* Decline noted but no official listed status (D)
- *M.* Recreational and/or Commercial Species (RC)
- *N.* Endemic to Bay (BESSP)
- *O.* Top 10 Ecological Indicator (Top 10EI)
- *P.* Tied to Bay Management Issue (M)

II. Link Management to Research.

A. Ongoing work must address a specific, acknowledged management need. Research is directly linked to management objectives that are identified and ranked by managers.

B. The protocols, methods, and results of research must be presented in a form useful to managers.

C. Research is linked with, continues, or augments accepted past and current monitoring programs.

D. Work must be done in the context of a disturbed ecosystem, requiring that projects focus on impact dynamics rather than on traditional ecology alone. However, the work could compare disturbed and undisturbed functions.

E. Research must be done at a scale applicable to management.

F. The work must provide insight into the strength and dependencies of one habitat or community upon another, and structure and function of the ecosystem. The work supports technically sound decisions about the relative quantities (habitat balance) desirable for San Diego Bay.

G. Research addresses highly ranked items on a Priority Problem List, which is agreed upon by consensus of the TAC, Science Panel, and stakeholders. If there is disagreement, then managers carry the day. The list is reconsidered every year, based on adaptive management principles. The criteria for making the list are (1) prevention of new problems or threats to the bay's ecosystem; (2) helps resolve conflict with bay uses; (3) reduces an ecosystem-wide impact or provides an ecosystem-wide benefit; (4) improves conditions of the most impaired habitats or species in the bay; or (5) relatively cost-effective for achieving the goal and objectives.

III. Conduct water and sediment quality monitoring and research to support management decisions.

A. Perform study on turbidity effects from vessel traffic, construction and dredging projects on biological resources.

B. Perform seasonal (winter/spring) water quality monitoring to evaluate spatial distributions and long-term trends. Includes surface mapping and vertical profiles of salinity, temperature, TSS (turbidity), chlorophyll-a, pH, dissolved oxygen, and at least discrete samples analyzed for COCs: (e.g. copper, zinc, PAH, PCB, pesticides) and toxicity. This should build upon data collected from Regional Harbor Monitoring Plan.

C. Perform biannual sediment quality monitoring to evaluate spatial distributions long-term trends. Include measures of COCs, toxicity, benthics, and bioaccumulation into bivalve tissues. Relate the effects of toxics and their severity to health of infaunal assemblages, and associated substrate or water quality conditions.

D. Perform a detailed assessment of the fate and transport of contaminants in storm water runoff once they reach the bay. Determine the extent of impacts to bay sediments in and around Navy facilities and to the bay as a whole.

E. Perform a study on the use of untreated (i.e. plastic, concrete, etc.) pier pilings in the bay. The study should include an inventory of existing treated and untreated pilings in the bay, an estimate of reduced pollutant loading realized by replacing treated pilings and affects on receiving water concentrations.

F. Establish a guidance document with information on low impact development technologies with a goal to maintain pre-development hydrological conditions. Develop a training program for government planners/designers on low impact development.

G. Develop linked watershed-hydrodynamic model similar to that developed under ENVVEST in Puget Sound that can be used to assess fate and transport of COCs and to predict how changes impact bay water, sediment, and ecosystem health. This could also be used for partial or bay-wide TMDL efforts.

H. Use the Navy's hydrodynamic model of the bay to create results for multiple oil spill scenarios as readily available “look up tables” that can be used by the regional Navy Operation and Support Centers during spills. This will provide quick views of the likely transport of oil under a variety of conditions for quicker response.

I. Develop a San Diego Bay specific copper criterion by collecting the appropriate amount and type of data for computing a Water Effects Ratio. Combine this effort with the Biotic Ligand Model development for marine waters.

J. Minimize risks to wildlife species by monitoring topsmelt for bioaccumulation, ensuring that monitoring programs account not only for acute but also for chronic and teratogenic effects, and conducting autopsies within 24 to 48 hours on birds that are found dead in the bay area.

K. Use the new GIS layers of bay natural resources to support spill response preparedness planning. Add water quality and sediment quality data/layers to GIS.

L. Sediment quality objectives are being developed and adopted by the SWRCB. They are in progress for a limited set of pollutants and primarily for protection of bottom-dwelling biota.

   1. Objectives need to also be established for emerging pollutants and which address aquatic vegetation, fish, wildlife, and human health.

   2. In the interim, widely accepted and peer-reviewed risk assessment protocols should be used. Decisions by managers will need to be made on a project-by-project basis until formal adoption of sediment quality objectives.

M. As part of NRDA monitoring, look at expansion and contraction of algae and trends in benthic invertebrates as evidence of water quality trend, and since it is tied to food chain concerns.

IV. Establish a committee of scientists, managers, landowners, and users, and the involved public to prioritize research needs. The purpose of the Research Committee will be to set research priorities in relation to management concerns, decide what management concerns make the Priority Problem List and rank issues on the list, ensure the quality of research conducted and tie-in to management, and communicate research results effectively to a broad audience.

A. The committee should develop, maintain and update conceptual models of how species groups use the bay in order to: improve communication about how the ecosystem works, help identify research and monitoring priorities, and provide a framework within which to identify and test key processes.

V. The broad purpose of a research program will be to:

A. Increase understanding of physical/chemical processes in the bay that support fish and wildlife use and that relate to management actions.

B. Help relate information from long-term and project monitoring into conceptual models about bay functions on multiple scales from individual species life history to the bay as a whole.

C. Test cause-and-effect relationships identified in conceptual models.

D. Reduce scientific uncertainty with respect to management decisions.

E. Conduct baseline, whole-bay characterization studies. Fill critical information gaps needed to understand the functional relationships among habitats and communities well enough to provide guidance for impact assessment and enhancement priorities.

   1. Give priority to baseline studies that will be taken up in the long-term monitoring program, except when the results of the study are expected to suffice for an extended time (such as sediment characterization).

   2. Establish baseline data sets for community abundance and distribution, emphasizing lower trophic levels or physical factors that have predictive value for organisms.

      a. Sediment characterization (grain size, toxics)

b. Temperature and salinity
c. Phytoplankton
d. Zooplankton
e. Algae
f. Benthic invertebrates
g. Larval fishes
h. Shorebirds
i. Water birds

3. Use correlation among the relevant variables as a guide for more focused studies.

F. Conduct focused studies on the effects of natural and anthropogenic disturbance that test conceptual models.
   1. Conduct studies to better characterize the fish species assemblages associated with different artificial or man-made habitats in San Diego Bay.
   2. Waterfowl as a guild might be monitored for susceptibility to boat traffic.
   3. Research the scope and impact of nonindigenous invasions of San Diego Bay.

G. Conduct studies on ecosystem function and process. Improve understanding of the essential elements of habitat and environmental quality necessary to support the potential productivity, abundance, and diversity of biological resources in San Diego Bay.
   1. For example, investigate subyearling use by fish and crustaceans in mid- and upper-intertidal areas.
   2. Conduct studies on the feeding dependencies of declining bird species.
   3. Research structural surrogates of ecological function that are easier to monitor than functions themselves (such as the height of cordgrass and its suitability for clapper rail use).
   4. Develop a method to determine reference conditions for the four different bay regions.

H. Conduct pilot projects that expand restoration science or technical understanding. Examples are:
   1. Optimal design, configuration, and management of shoreline armoring to maximize its habitat value.
   2. Optimal design, configuration, and management of salt ponds to support shorebirds, waterfowl, and marsh birds in the absence of commercial salt production.
   3. Effective and affordable methods for controlling nonnative invasive plants.

VI. Facilitate cooperation among involved organizations, including integrated and collaborative actions, and collaboration of relevant scientific and engineering disciplines.

6.3 Data Integration, Access, and Reporting

Background

Success of the approaches undertaken in this Plan for management, research, and monitoring depend upon public confidence. There is a broad public perception that the bay is environmentally degraded. To ensure accurate public understanding and well-placed concern and support for the bay's resources, consistent and accurate communication from bay managers and researchers about extraordinarily complex natural ecosystem processes is needed. Such effective reporting of monitoring and research results, as well as progress in Plan implementation, will help keep the Plan strong, relevant, and responsive.

Current Management

Historical and current information on the bay's natural resources is scattered throughout regional libraries as well as agency, installation, and consultant offices. In many cases, few copies of reports funded by the Navy or the Port are in circulation. Newspaper articles appear sporadically and tend to be tied to a specific event.

Evaluation of Current Management

Existing data on the bay are not in a form that gets used by bay managers. Complex problems such as those described as key management questions are interdisciplinary and require interfacing across disciplines and agencies.

There should be better synthesis and analysis of the monitoring data presented to public agencies and better communication of that analysis to the public (National Research Council 1990a), so that it will be used effectively as a basis to target resources.

Management Strategy—Data Integration, Access, and Reporting

Objective: Ensure the most effective integration, analysis, and dissemination of monitoring and research on San Diego Bay, and communication of this information to all concerned, so resources are targeted effectively for bay ecosystem health.

I. Set up a central clearinghouse for data, reports, and publications on the bay's natural resources that is accessible to a broad range of users, both technical and nontechnical.

- *A.* The criteria for selection of an institution for managing a data clearinghouse should include longevity, objectivity, ability to work with the public, and cost benefit.
- *B.* Develop and adopt a means to catalog and access this information that would avoid conflict and dilution of effort.
    - *1.* Establish or use an existing website for San Diego Bay natural resource information that is designed to be useful to the general public, agency, and academic users.
    - *2.* Establish a standardized format for submitting data or reports to the clearinghouse.

II. Organize events to promote data sharing, technology transfer, and communication for a broad range of involved parties.

- *A.* Develop a newsletter to report on progress in implementing this Plan and other bay activities.
- *B.* Produce a biannual report on the results of long-term monitoring and other research in a format accessible to the involved public.
- *C.* Promote biennial workshops or conferences on ongoing research and monitoring, and management planning for the bay.
- *D.* Develop shared field programs that will promote cross-disciplinary working relationships.
- *E.* Target reporting and communication in conjunction with neighboring "estuarine" systems: Tijuana Estuary, Mission Bay, Los Penasquitos, etc.
- *F.* Integrate data with other bays and estuaries on the west coast including information on shorebirds from Point Reyes Bird Observatory and San Francisco Bay Bird Observatory.
- *G.* Ensure outreach to and participation by cities.

III. Seek standardization of the approach to communicate research and monitoring results so that the format is accessible to a broad audience, through the two separate committees established to manage the research and the long-term monitoring programs.

- *A.* "Bundle" sets of indicators for reporting to management and the public so that the monitoring results are more comprehensible.

See also project descriptions for tracking cumulative effects of projects, including sea level rise, in Section 5.5 Cumulative Effects.

IV. Enhance data compatibility and standardization of study methods so that data may be more effectively integrated.

A. Ensure that GIS data are collected and delivered in a standard format so that layers are compatible among studies, such as in the federal government's Tri-Services format

B. Develop a web-based database to track projects affecting the San Diego Bay natural resources. A database should be developed specific for San Diego Bay to help evaluate cumulative effects of projects and effects over time to natural resources. This database should be public information for all to access to keep the public well informed of projects and any public commenting periods. The California Department of Toxic Substances has a web-based database that could be used as a model.

C. Integrate San Diego Bay GIS with related GIS databases (e.g. there is a large one for the Tijuana Estuary Watershed and for inland southern California).

V. San Diego Bay Status and Trends Report with indicators on ecosystem health

A. Report on INRMP goals and objectives achievement / Navy metrics and Navy partnership metrics.

B. The San Diego Bay Status and Trends Report should include all the priority long term monitoring indicators. Further work to refine the Indicators to promote an ecosystem approach to adaptive management for the bay is needed.

7.0 Implementation Strategies

To successfully attain the Plan's goal and objectives, the measures proposed in Chapters 4 through 6 need to be prioritized, assigned to institutions, and prepared as projects for various funding processes. For many, funding mechanisms will need to be developed or innovated as they do not currently exist.

As identified in Chapter 1 and by the TAC, a key issue for this INRMP is the capacity to implement its strategies. The health of San Diego Bay is, as stated in the White House's EO of 19 July 2010 for all United States' coasts, "intrinsically linked to environmental sustainability, human health and well-being, national prosperity, adaptation to climate and other environmental changes, social justice… and national and homeland security." Without the capacity to implement, these goals will fall short.

There will be multiple pathways to implementing this INRMP. Some of the objectives can be achieved with projects funded through existing institutional structures and processes, while others will require organizational change and innovation, including funding mechanisms that are not currently working in the bay. Many projects are difficult to implement due to their size, inter-jurisdictional boundaries, or the lack of a well-defined legal driver to take them on within existing funding constraints; they will require partnerships across agencies and non-governmental organizations. They will also require innovation in how agencies interact and how funding is allocated and prioritized. Agency work plans, incentive structures, budgets, and evaluation protocols may need to be transformed.

The health of San Diego Bay is "intrinsically linked to environmental sustainability, human health and well-being, national prosperity, adaptation to climate and other environmental changes, social justice… and national and homeland security." Without the capacity to implement, these goals will fall short.

The recommendations of the INRMP are organized into a detailed implementation table at the end of this chapter. However, they may be condensed into a set of seven initiatives, summarized in Section 7.2: Seven Major INRMP Initiatives.

7.1 What's Accomplished and New Since the 2000 INRMP

Much work has been implemented since the INRMP process ended in 2000 and finalized in 2001. The INRMP has been cited in many important venues, from the SB 68 Report, to the State of the Bay 2007 Report, to agency documents and journals. It earned participants the Coastal America Partnership Award in 2001. Below is a synopsis of what has been accomplished and what has changed.

Regulatory

- USFWS-DOD MOU on implementing compliance with the MBTA and issuance of the DoD Migratory Bird Rule on 28 February 2007.
- EO 13423 on Sustainability issued in 2007 affects all federal agencies.

- EO 13547 (19 July 2010) on Coast and Ocean Stewardship created the National Ocean Council to oversee national ocean policy. In addition, it directed federal agencies to conduct coastal and marine spatial planning using collaborative, transparent processes to ensure the protection, maintenance, and restoration of the health of coastal ecosystems and resources; enhance the sustainability of ocean and coastal economies; preserve our maritime heritage; support sustainable uses and access; provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification; and coordinate with our national security and foreign policy interests.
- New conditions on Municipal Stormwater Permit in 2001 and in 2007 when reissued.
- Total Maximum Daily Loads completed for Diazinon in Chollas Creek and for Copper in Shelter Island Yacht Basin. For Chollas Creek, TMDLs were completed for lead, copper, and zinc. In 2007, a TMDL was adopted for the shoreline segment at Shelter Island Shoreline Park in San Diego Bay (Resolution No. R9-2008-0027 and Basin Plan amendment).
- Local Stormwater Manuals and Ordinances adopted and implemented for San Diego Bay's Watershed.

Planning

- The San Diego Bay NWR has completed its own CCP with a focus on the former South Bay saltworks.
- The Port has established an Environmental Fund and Environmental Advisory Committee composed of a broad spectrum of San Diego Bay stakeholders who advise on environmental issues and on priorities for funding.
- A SB 68 Report to the Legislature on the State of the Bay and INRMP Implementation was issued.
- LID measures are becoming a component of new development projects by cities, the County, Port, and Navy.

Habitats

- Restoration has begun of almost 300 acres of tidal flats, salt marsh, subtidal, and native uplands in and around south San Diego Bay. These areas include the western-most salt ponds located adjacent to State Route 75, the CVWR, and the western edge of Emory Cove. Once construction is complete, the levees will be breached in order to re-introduce natural tidal flows and the ensuing natural recruitment of native species (USFWS 2010).
- Fifteen acres of shallow subtidal habitat was created by filling in a former deep-water borrow pit in South Bay (Port).
- An eight-acre intertidal mudflat was created in addition to shallow subtidal habitat with a new island in the bay, combining both enhancement and offsetting mitigation for impacts of the Navy’s nuclear carrier homeporting project (Navy).
- The Port is funding a $5 million Environmental Fund and offering grants for habitat enhancement in the bay.
- Eelgrass mapping of the bay is funded every five years (Navy-Port).
- EFH is currently undergoing an analysis and mapping refinement. A study on artificial habitats is currently underway to characterize their range of habitat values (Navy).
- Fisheries enhancement was implemented by installing fish structures to increase both recreation and commercial fish populations, allowing fish shelter from predators. The project will conduct quarterly monitoring of the reefs to study fish recruitment biodiversity and abundance for a year (Port).
- Restoration of the salt marsh at J Street off the South Bay Power Plant included removal of shopping carts, tires, and other debris to improve habitat for birds and wildlife and increase vegetation (Port).

- An assessment of the abundance, diversity, and biomass of fish occupying artificial habitats started in 2007.
- New fish habitat was created in a former borrow pit by placing A-jacks reef structures (Port).
- A scholarship was awarded to a Scripps Oceanography Institute student to study habitats (Port).

Populations and Special Status Species

- Fish abundance and diversity surveys are sponsored every three to five years (joint Navy-Port).
- Nesting platforms for raptors, specifically ospreys, were placed in each member city around San Diego Bay. Interpretive signs were placed at each platform to educate the public regarding the importance of these species (Port).
- An Eastern Pacific Green Sea Turtle tracking study was begun. Devices to track the endangered turtle movements in the bay were installed using matching funds from the U.S. Navy and Port. This project will assist with the protection of the turtles and understanding of areas to be protected based on their movements (joint Port-Navy).
- The San Diego Natural History Museum Bird Atlas survey added to the bird observations for the bay.
- Support was provided to the light-footed clapper rail propagation program at the Chula Vista Nature Center Port).
- The Port contributed to the Oceans Foundation raising white seabass (Port).
- Habitat was expanded for the federally endangered salt marsh bird's beak (Port).
- The Navy and USFWS extended the Memorandum of Understanding Between U.S. Fish and Wildlife Service and the U.S. Navy Concerning Conservation of the Endangered California Least Tern in San Diego Bay, California (Navy).
- Baywide waterbird and shorebird survey was started in 2006 (joint Navy-Port).

Water Quality

- Urban runoff control measures were carried out by all co-permittees on the Municipal Stormwater Permit for the San Diego Bay Watershed on new and existing development, including annual reports of wet and dry weather monitoring results (cities, the County, Port).
- Storm drain labeling by the Port is nearly complete. San Diego Bay drains are marked with a phone number (Port).
- To improve water quality in south bay, environmental debris was removed from the A-8 anchorage including engine blocks, fuel tanks, batteries, generators, and electronic equipment (Port-NMFS).
- A pilot study with General Services was begun to install mesh filters on storm drains in the Seaport Village area to prevent trash from entering the bay. This included a study to evaluate the types and amount of debris collected (Port).
- Funding for water quality monitoring was approved at five sites in 2001, now repeating with addition of other metrics (joint Port-Navy).
- Conducted research on non-toxic hull paints (Port).
- The Navy continues to implement a program to replace all treated pier pilings (creosote, arsenic) with non-polluting piling systems (concrete, recycled plastic) (Navy).
- SCCWRP continued its monitoring in the bay, the Bight monitoring program in 2003 and 2008, and the RHMP (Port, the County, cities).
- Scholarships were offered for studies in water and sediment quality (Port).
- The “Think Blue” campaign is becoming well known among city residents (Port).

Sustainability

- LID and LEED certification is being promoted by the Port, City of San Diego, and the County of San Diego.
- To improve air quality in the region, a pilot study with General Services was sponsored to determine the best alternative fuel vehicles appropriate to eventually replace the Port fleet of cars. Price would include the difference between leasing five standard vehicles versus alternative fuel vehicles for five years. In addition, training of Port staff to maintain the vehicles plus any special tools required. Ten cars were funded (Port).
- A pilot study was sponsored regarding the use of solar energy for Port buildings including use for the boiler at the Port Administration building. This project will reduce air impacts to the San Diego region (Port).
- A $10,000 scholarship was offered to in the air quality/sustainability field (Port).

Watersheds

- San Diego Bay WURMP and Annual Monitoring Program were implemented (cities, the County, Port).
- The Otay River Watershed Management Plan and SAMP was initiated.
- The Chollas Creek Enhancement Program was adopted and is being implemented (Proposition 13, City of San Diego, Jacobs Foundation).
- The Paradise Creek Enhancement Plan is being implemented by National City, an effort that originated and is led by community volunteers in a low-income neighborhood, and implemented in a stepwise fashion (many sponsors).
- The Annual Creek-to-Bay Cleanup, is sponsored by I Love a Clean San Diego in April. Since 2003, this event has collected over 217 tons of trash and recyclables. See *www.creektobay.org*.
- The CCC sponsors an Annual Coastal Clean Up Day.

Oil Spill/NRDA Planning

- A plan for NRDA was funded and will help update the Oil Spill Contingency Plan for spill response (Navy).

Environmental Education and Public Awareness

- San Diego Bay eco-tours were sponsored through a partnership with the Birch Aquarium at Scripps and San Diego Harbor Excursion. The tours ran from April 27, 2007 through June 16, 2007 and focused on the history, ecology, and environmental health of San Diego Bay (Port).
- A free lecture series on the bay included a focus on seabirds, sea turtles, and restoring the light-footed clapper rail (Port).
- A boater environmental brochure was published and distributed through the marina inspection program to educate boaters regarding bay pollution. The Port's Boater's Guide was expanded to explain the need to avoid eelgrass, rafting birds, green sea turtles, and marshes (Port).
- An annual K-6 grade education program includes trips to the Chula Vista Nature Center, Green Machine, Aquatic Adventures - Wetlands Avengers, San Diego Maritime Museum, Resource Conservation District, Birch Aquarium, Habitat Heroes, Project SWELL, ProPeninsula- turtles, Wildcoast - turtles, ORCA website - kids education about the bay, and Kids in Canyons program (Port).
- The Zoological Society of San Diego featured a news article on eastern Pacific green sea turtles of the bay.
- New interpretive signs along the bikeway at Coronado and at Chesapeake Fish Company are in place (Navy, Port, Chesapeake Fish Company).

7.2 Seven Major INRMP Initiatives

7.2.1 San Diego Bay Restoration Partnership

A San Diego Bay Ecosystem Restoration Partnership would foster the collaboration needed to apply for and manage funds from multiple sources and to execute the consensus-based strategy developed in the INRMP, especially for projects that achieve multiple public objectives. A proposal for such a newly structured partnership is shown in Section 7.6: Proposed Organizational Structure. Legislative support may be necessary.

Such a formalized partnership would help the Port, Navy, resource agencies, and others take on in a structured way the cross-jurisdictional ecosystem work, the bigger work, and work that has a watershed connection. This is work that is better done together than by separate entities. No mechanisms exist for coordinating management effort when (even agency-specific) projects can derive benefit from the context of work undertaken by others. While the Port's "Beyond Compliance and Mitigation" initiative and its newly established Environmental Fund are helping to accomplish needed work that has not had a consistent funding avenue in the past, there are still limitations to the Port's purview based on its mission and jurisdiction. The Navy's requirement to implement INRMPs is constrained in its funding capacity for work that is not directly driven by regulation or work outside of its jurisdictional control. While efforts to address upstream issues such as urban runoff and watershed protection are being worked through cross-jurisdictional coordination (e.g. NPDES permit and watershed plans), within-bay work lacks a mechanism for coordinating bay-wide ecosystem management. For example, water quality improvement, cleanup of contaminated areas, and habitat conservation are often managed separately even when they overlap. When funding for habitat enhancement is so short, it is possible that such coordination could lead to meaningful habitat enhancement at relatively low cost.

The coastal stewardship EO of 19 July 2010 calls for Regional Ecosystem Protection and Restoration as a national priority, targeting a strategy that is "science-based and aligns conservation and restoration goals at the federal, state, tribal, local, and regional levels."

7.2.2 San Diego Bay Ecological Indicators

As stated in the SB 68 Report to the Legislature, there is a need to invest in understanding the link between native species abundance and diversity and indicators of water and sediment quality that is specific to the resources of San Diego Bay (see Section 6.1.1: Key Management Questions). An Ecological Indicator Development Program would address four main aims.

1. Provide adaptive management cues and improve the scientific basis of natural resources actions undertaken by integrating the monitoring and assessment of ecological and environmental indicators with management practices.
2. Help disparate programs operating under different laws and regulations function as a more cohesive bay-wide program that achieves multiple public objectives. Most monitoring funds are currently tied to compliance with specific water and sediment quality requirements. More effort is needed to monitor ecological beneficial uses. It would add resolution to how beneficial use criteria are applied locally as they pertain to natural resources: fishing (commercial and sport); preservation of designated biological habitats; estuarine and wildlife habitats; rare and endangered species; migration of aquatic organisms; and shellfish harvesting.
3. Ensure that monitoring is scientifically-based, conducted at the appropriate geographic scale, able to detect trends, and cost-effective for applied management through integrated modeling, quantitative data sets, and selection of a short list of key indicators. This committee would ensure that survey plans and schedules are integrated so that independent surveys can be correlated. For example, certain water quality data requirements can be fulfilled while conducting fish surveys, such as checking for fish with lesions and checking for bioaccumulation such as PCBs. Surveys should also be integrated with NRDA data retrieval sites. Joint projects, such as identifying spatial patterns and trends in sediment quality, would also be facilitated.

4. Facilitate more effective communication with the public about environmental status and trends. By cross-linking objectives for water/sediment quality/watersheds/sustainability/living resources, data sets could eventually be condensed to key indicator suites for reporting across multiple scales and resources. Such indicator sets are designed to be scientifically rigorous and relevant both for natural resources management and public education.

A Committee on Ecological Indicators would be in charge of issuing a joint Navy-Port "State of the Bay" every two years as recommended in the 2001 INRMP and carried over in this one.

7.2.3 Sustainability

The new initiative on sustainability is intended to strengthen the approach to sustainability by establishing unified, coordinated leadership and an overarching framework for ensuring resources that underlie the functioning of the missions of both the Port and the Navy are sustained. This includes climate change. This joint initiative towards sustainability is driven by both the current business and regulatory climates. Anticipating future resource liabilities and constraints now is key to the imperative of sustainability so that the Port's and Navy's mission will continue uncompromised.

A new sustainability work group, a cooperative effort between the Port and the Navy, would review all uses of resources identified in EO 13423 and examine requirements of AB 32 "Global Warming Solutions Act" for potentials to improve sustainability. In addition, the Navy would join the Port in its new 'Clean Port Initiative'. This committee would necessarily be multi-disciplinary and facilitate communication regarding resource use from alternative perspectives and jurisdictions. The work group would seek to establish cooperative planning from the initial phase of a program (or project) along with an analysis of its life cycle to improve efficiency, reduce total costs, and preempt downstream conflicts and externalities. The work group would provide for and take part in training in sustainable practices, such as environmental engineering and low-impact design (such as the LEED program and LID), environmental management systems, and greenhouse gas reduction. The work group would review interagency efforts made towards sustainability and award project and program leads for the implementation of innovative and progressive solutions. The committee would publish the results of sustainability programs biannually on line.

The following represent key focus areas for the committee on sustainability:

- Energy Use: The work group would seek solutions to improve energy efficiency and greenhouse gas reductions. All sectors of energy use would be evaluated and then ranked according to the ease at which reductions could be made with the aid of life-cycle analysis.
- Water Consumption: The work group would advance LID structures and create standards for water conservation measures through xeriscape landscaping, renovation with water conserving plumbing, the use of grey water, etc. The use of water for habitat enhancement in combination with storm water management and other water quality goals would be integrated.
- Environmental Design: The work group would advance LEED certification and expand these guidelines for renovation and new construction based on design standards for high performance buildings and infrastructure. The guidelines would be expanded to incorporate more habitat values for structures in the shoreline environment.
- Training in Sustainable Project Design and Best Practices: The work group will develop sustainability training and education programs that highlight new approaches, technologies, funding sources, and certification programs.
- Military and Port Missions: Ensuring sufficient latitude for the military mission to be fully sustained and adapt to changing requirements is the final focus area of the committee.

7.2.4 Habitat Enhancement

It will take many avenues to improve the habitat value of intertidal mudflats and shorelines. Shoreline structures should achieve multiple objectives besides shore stabilization, such as provide habitat for organisms that are native to the bay; contribute to sustainability with respect to non-point source pollution prevention; avoid harboring predators of sensitive birds; provide access for wildlife viewing; and accommodate the expected rise in sea level. Designs that support terrestrial predators (rats, cats, raccoons, etc.) of nesting birds should be avoided and corrected if already in existence. A design criteria template should be established for new and renovated structures.

To support this, finer-scale mapping of habitat values is needed. This mapping would contrast patterns in the invertebrate community as correlated with tidal prism and sediment grain size; partitioning of shorebird foraging in mudflats; fish nursery locations by species; zooplankton biomass in vegetated versus unvegetated areas; and productivity of habitats based on size and shape. It would help prioritize enhancement efforts based on fish and bird productivity and support of the bay's core values (section 1.3) and indicator species. This habitat mapping would build on that currently in progress to support consultation on EFH. It would support a recommendation of the 2001 INRMP to develop local guidance on unvegetated shallows and mudflats. Regulatory matters associated with armoring the shoreline or creating intertidal habitat through filling of deeper water sites will need to be resolved.

Of the 29 habitat enhancement projects identified in the 2011 INRMP, two are highlighted here as examples because they would accomplish many public and ecosystem objectives which cross regulatory and jurisdictional boundaries. These projects also encompass nearly all the problems of INRMP implementation in that they involve multiple landowners, are too large for any one jurisdiction to take on, and involve habitats which are historically the most impacted and severely depleted in San Diego Bay. They are:

Two habitat enhancement projects are highlighted here because they would accomplish many public and ecosystem objectives, which cross regulatory and jurisdictional boundaries. However, they also encompass nearly all the problems of INRMP implementation, in that they involve multiple landowners, are too large for any one jurisdiction to take on, and involve habitats which are historically the most impacted and severely depleted in San Diego Bay.

- *Restore the Mouth of Chollas Creek.* With property owned by the Navy, Port, and the City of San Diego, this project requires partnership among three major jurisdictions and community restoration groups. Restoring and enhancing the natural functions of this creek mouth represents one of the few opportunities for recovering salt marsh, brackish habitat, and freshwater filtering functions. Chollas Creek is listed by the Regional and State Boards as water quality impaired. One of the added incentives for watershed planning is the need to accomplish TMDL compliance for all waters that are listed as impaired under CWA §303(d). Chollas Creek contributes copper, lead, zinc, and bacteria to the bay. The site is one corresponding to regions of the bay that were affected historically by sewage sludge and industrial waste discharges and are now affected by stormwater discharges.
- *Restore the Lower Sweetwater River Flood Control Channel.* This flood control channel should be de-channelized and allowed to perform a more natural role. The natural connection (now isolated by a riprap channel) to softened floodplains and shorelines should be restored and invasive species controlled. Stakeholders include the city of Chula Vista, National City, USFWS Refuges, USACE, and the Port.

7.2.5 Water and Sediment Quality

This INRMP addresses water and sediment quality to a greater degree than the 2001 INRMP, but continues to emphasize the link to habitats and natural resources rather than clean-up, which has an established process. The Ecological Indicator initiative will help provide a natural resources focus to the water and sediment quality work. The emphasis will be on studies that support how to prioritize and allocate efforts to make the most benefit to the bay on a food web/ecosystem level and that which may require a partnership for best implementation.

The first focus of this initiative will be to evaluate the spatial distribution and trends of physical and biological parameters on a wet season/dry season basis. Protocols would generally build on those of the RHMP and SCCWRP's Bight-wide monitoring. SCCWRP is a good but infrequent program, and with data from 2003 work not summarized by 2007, it is unhelpful as a practical feedback mechanism to management efforts in San Diego Bay. It needs to be supplemented by a more continuous program that integrates the mandatory TMDL requirements and NPDES permit requirements for water quality. Only benthics are used for "biological integrity" indicators under those permits. Elements would include temperature, salinity, plankton, turbidity, compound-of-concern, benthics, bioaccumulation in bivalves and other indicator species. Comparisons should be made by the four bay regions and by depth, such as comparing deep water to moderately deep to shallows.

The second focus will be to integrate the data sets with hydrodynamic and oil spill response modeling so that existing modeling technologies are more applicable for managers. A linked hydrodynamic-watershed model similar to that used in Puget Sound could help evaluate the fate and transport of storm water contaminants, sort out sediment toxicity clean-up responsibilities and priorities, influence TMDL decisions, support oil spill quick-response, and predict future watershed changes' effects on San Diego Bay.

Questions would have to be resolved about who contributes to sediment cleanup when multiple parties are responsible for contamination and complete control over sources is unlikely.

Information on background turbidities will help assess turbidity effects of vehicle traffic on biological resources. Establishing the natural/background turbidity in a mudflat will affect the location of equipment and silt fences that may cause turbidity. The existing dilution models do not help prioritize where to do work; they are based on flushing. For example, a project may be located to get one tidal flush/day. The above would build on the current study conducted by the Navy for locating their second new nuclear carrier (CVN II) and included studies for Homeport Island and NEMS V.

Questions would have to be resolved about who contributes to sediment cleanup when multiple parties are responsible for contamination and complete control over sources is unlikely.

7.2.6 Invasive Species Detection and Response

An invasive species vulnerability analysis is needed to focus how the bay should be monitored for invasives and to set priorities to prevent invasion. Likely vectors should be analyzed for introduction of invasives and their potential damage to vulnerable habitats.

To be effective, detection and control of invasive species must be vigilant and under unified, coordinated leadership. Much can be addressed in the context of doing other work that has a regulatory driver, such as searches during Caulerpa surveys, sampling NRDA transects, or conducting eelgrass monitoring. There is a need to conduct a vulnerability analysis to help focus how the bay should be monitored for invasives and to set priorities for a prevention program. The analysis should combine an evaluation of likely vectors for introduction of invasives and their potential damage to vulnerable habitats. It should provide a Watch List for San Diego Bay, high risk areas (similar to what is done at Point Mugu), and protocols for reporting both detections and negative results. For example, NOAA would like negative results reported when Caulerpa surveys are done; results are put in a database managed under contract. Emerging problem invasives should be noted and put on the Watch List. With an increasing number of nonnative aquatic nuisance species detected, the bay's ecological integrity is under challenge.

7.2.7 Data Management and Reporting to Improve Information Access

There is a need for a central clearinghouse for data, reports, and publications on the bay's natural resources that is accessible to a broad range of users, both technical and non-technical. One of the primary objectives of the library would be to support a consistent approach to cumulative effects analysis in bay-related environmental documentation. Water and sediment quality and stormwater data sets should be more accessible and interpreted with GIS overlays. Hydrodynamic modeling should be linked to these datasets. To start, the clearinghouse could be built from established databases such as the Point Loma Ecological Conservation Area database. The database could be expanded to the bay as a whole.

7.3 Achieving Successful Implementation

The desire of all who have worked long and hard on this Plan is that it be "successful." This chapter specifies some options and ingredients for implementation.

Beginning in Chapter 1, the Plan's vision for San Diego Bay is outlined. The current state of the ecosystem is described in Chapters 2 and 3, spelling out the existing baseline from which managers and users can measure progress. Chapter 4, Chapter 5, and Chapter 6 lay out a pathway to change for proceeding toward the Plan's goal and vision. They develop a progression not towards the historical bay, because we cannot return to that, but towards one that is wilder, with softer shorelines, richer, and more abundant in native life. They also describe a bay that, while used for thriving urban, commercial, and military needs, has an increasing proportion of uses that are passive. It is moving towards a place with more opportunities for public access, recreation, education, and enjoyment of the myriad benefits of a healthy, dynamic ecosystem. Finally, the bay's managers and stakeholders will make sounder decisions because of positive collaboration, a clearer understanding of the cumulative effects of their actions, and information from focused research, long-term monitoring, and effective communication.

Attaining the Goal and Objectives

Achieving success means certain expectations must be met. These expectations include the Plan's "enduring, visionary description" of where its supporters want to go. The Plan's goal is repeated here:

Ensure the long-term health, recovery, and protection of San Diego Bay's ecosystem in concert with the bay's economic, Naval, recreational, navigational, and fisheries needs.

Objectives are specific statements that describe a desired condition. The Plan presently contains 27 Ecosystem Management Objectives (Chapter 4), 10 Compatible Use Objectives (Chapter 5), and 6 Monitoring and Research Objectives (Chapter 6).

Fulfilling Its Purpose and Intent

The Plan is intended to be used as both a reference tool and as a strategy by its audience. Chapter 1 also lists nine specific needs that the Plan is intended to meet for the Navy and the Port, as well as the regulatory community.

Beyond these statements of intent are the following questions: Why *would* anyone implement the Plan? Why *should* anyone implement it? Some answers include:

- Much work for the bay is better done together than separately. The TAC was composed of members whose professional and personal experience provided a "reality check" on the material and ideas used to ensure that sustainable, ecosystem-based strategies were considered in institutional, social, and economic contexts to validate the Plan's approach.
- Without this Plan, a bay-wide strategy vacuum would exist, which can lead to uncertainty on the part of management and increasing potential for legal challenges to uses and users of the bay's resources.
- Pooling of financial resources for implementation will spread the costs of restoration, enhancement, monitoring, and research.
- Project mitigation will be more beneficial and efficient because it is based on a consensus of prioritized need.
- Funding institutions, as well as regulatory agencies, can determine their own role in contributing to the Plan's success.
- This INRMP was developed in a collaborative, transparent process. Positive relationships, partnerships, and goodwill can result among all participants in the bay community by fostering understanding and collaborating on a common goal. The public is provided a consistent message that is an accurate reflection of the status and management of the bay.
- A more consistent and reliable regulatory process is better for everyone.

Much work for the bay is better done together than separately. The TAC was composed of members whose professional and personal experience provided a "reality check" on the material and ideas used to ensure that sustainable, ecosystem-based strategies were considered in institutional, social, and economic contexts to validate the Plan's approach.

Achieving Commitments

At the minimum, expectations for commitment to the Plan's implementation are that the Navy and the Port will carry it out and use the Plan as (a) guidance for decisions; (b) a basis for budgeting their needed projects and programs; (c) a reference tool; and (d) their responsibility to maintain and update the Plan under their own specific mandates and guidelines. Commitments from other agencies and organizations to carry out the Plan are another level of expectation. Their commitments can be at different tiers, dependent on their ability to implement. Options to accomplish these partnerships and multiple efforts are described below.

7.4 Components of Implementation

The basic components of implementation come down to identifying the Who, How, and When:

- Institutional Resources—Who
- Financial Resources—How
- Priority Setting—When

7.4.1 Institutional Resources

Institutions are governmental and nongovernment organizations that have a structure and function to enable accomplishment of their missions. This Plan will need numerous, varied institutions to help implement it. Already existing are many institutions with missions that overlap or complement the goal of this Plan. If interested and able, these organizations could be used to implement portions of the Plan's strategies. For some of the strategies, implementation may also require the formation of a new institution if existing ones are not capable of fulfilling the scope or purpose of the strategy.

7.4.1.1 Existing Organizations

Existing institutions that can help implement the Plan include four sectors: governmental, academic, private, and nonprofit. While the Navy and the Port can implement pertinent portions of the Plan, they cannot ensure implementation beyond their jurisdictions. To be effective, the strategies will need the combined efforts of many entities working in the bay and within its watershed.

Table 7-1 lists specific as well as general organizations in the region that may be available for implementation assistance. All of the Plan's TAC member organizations are included in this list.

7.4.1.2 Potential New Institutions and Mechanisms

Linking institutional needs to financial needs is critical to ensure success of the Plan. A mechanism to organize stakeholders for collaborative problem-solving and priority-setting as well as coordinate funding is needed, and this can take a number of forms. Some options are listed in Table 7-2, along with a few advantages and disadvantages of each. This Plan proposes a new Stakeholders' Committee as an implementation tool, described in Section 7.3: Achieving Successful Implementation.

*Table 7-1. Existing institutions to implement the plan (Technical Advisory Committee members noted with *).*

Type	Name
Government—Federal	■ U.S. Navy * ■ U.S. Army Corps of Engineers * ■ U.S. Fish and Wildlife Agency */National Wildlife Refuges * ■ National Marine Fisheries Service * ■ U.S. Coast Guard* ■ Environmental Protection Agency
Government—State	■ California Coastal Commission * ■ California Department of Fish and Game * ■ Regional Water Quality Control Board, San Diego Region * ■ State Lands Commission ■ State Water Resources Control Board ■ California Coastal Conservancy ■ California Department of Parks and Recreation ■ California Department of Boating and Waterways
Government—Local	■ Port of San Diego * ■ County of San Diego ■ Cities along bay: Chula Vista, Coronado, Imperial Beach, National City, San Diego ■ Cities within bay's watershed
Government—Regional	■ San Diego Association of Governments * ■ San Diego Bay Interagency Water Quality Panel—Monitoring Subcommittee ■ San Diego Bay Watershed Task Force and Sub-Basin Watershed Groups ■ Resource Conservation District of Greater San Diego County ■ Harbor Safety Committee for San Diego Bay
Academic	■ Universities and Colleges in region ■ University of California, San Diego Cooperative Extension/Sea Grant Program ■ K–12 Schools in the bay's watershed
Private Sector	■ Port tenants and leaseholders ■ Chambers of Commerce/Visitor's Bureaus ■ Businesses in the bay's watershed ■ Consultants
Nonprofit Organizations	■ Conservancies ■ Friends of San Diego Wildlife Refuges ■ Zoological Society of San Diego ■ Environmental groups or consortiums such as the San Diego Bay Council ■ Recreational groups ■ Natural history, aquarium, museum, and other educational and research centers

Making Implementation Official

Various formal and informal mechanisms are available as implementation tools for public and private institutions. For example, strategies recommended within this San Diego Bay INRMP could be included as part of another jurisdiction's plans, such as the South Bay NWR's CCP, or a revised and updated general plan for Silver Strand State Beach. Informal or formal partnerships among agencies or between public and private organizations are another way to continue the coordination and communication for this Plan's development.

Examples of the types of institutional mechanisms that are available to help implement the Plan are listed in Table 7-3.

Tracking Implementation

To track the progress of each of the Plan's strategies, a spreadsheet program (e.g. Paradox, Access) should be constructed and maintained. Fields can be included to help (a) build queries; (b) track progress by location, type, sponsor, year, etc.; and (c) provide different types of reports. The GIS database established for this Plan should be maintained to track updates on various implementation activities, such as results of resource inventories, and locations of restoration projects. The Navy and Port are logical entities to be in charge of tracking implementation. However, they could delegate this function to a third party, if desired. A website for the Plan can be developed to help. Public accessibility to the Plan and its maps would be enhanced and public participation could be encouraged through the site.

Table 7-2. Evaluation of new organization options for plan implementation.

New Institution/Purpose	Advantages	Disadvantages
Joint INRMP TAC and Work Groups: A group like the TAC to oversee implementation of the Plan; Could function under a Joint Powers Agreement or MOU	▪ Communication, coordination, and neutral forum for issue discussion among diverse interests would be continued. ▪ Continuity would be provided. ▪ Serves as focal point and identity for the bay's ecosystem, including ability to attract funding.	▪ Staff may not be available to implement Plan between meetings. ▪ No new funding available to sustain oversight efforts.
San Diego Bay Ecosystem Restoration Partnership: A public-private partnership of entities doing habitat projects, studies, research, and monitoring for bay restoration. Program alternative would become a 501(c)(3) to be able to draw contributions.	▪ Ability to focus on the state-of-the-art of restoration techniques through workshops, forums, conferences, publications. ▪ Bring together agencies, universities, and citizen groups to share information.	▪ May not be needed if bay Ecosystem Committee above can cover this function and focus.
San Diego Bay Conservancy: A nonprofit (501[c][3]) private foundation to receive tax deductible donations and to award grants for bay projects.	▪ Unique focus on funding San Diego Bay projects. ▪ Ability to attract local funding and reinvest in bay community.	▪ Need to find a dedicated Board of Directors to oversee and solicit funds. ▪ May be seen as competing with existing foundations for funds.
San Diego Bay Invasive Species Task Force: A partnership of public and private entities focused on protecting the bay from invasive marine and coastal invasive species, per Plan Section 4.4.1: Invasive Species.	▪ Ability to focus solely on controlling invasive species invasions in the bay. ▪ A means to implement an early warning system for new species that does not already exist. ▪ Can share information with other groups in other bays.	▪ New funding and staffing may be needed to implement efforts effectively.
Marine Managed Areas: State managed marine areas designed to protect, conserve, and manage marine habitat and species. Also called marine refuges, reserves, sanctuaries, ecological reserves (see Table Table 7-5).	▪ May help implement Plan Section 4.2.1: Protected Sites for intertidal or subtidal habitats. ▪ Underprotected habitats and species within central and north bay may benefit from additional protection.	▪ Another restriction would be placed on certain portions of the bay. ▪ National Wildlife Refuges already cover a large part of bay and more protection may not be needed.
National Estuary Program: A national program designed to encourage local communities to take responsibility for managing their own estuaries, with decisions made by representatives of local, state, federal agencies and the public. Federally funded through EPA.	▪ This Plan may be able to serve as the National Estuary Program required Comprehensive Conservation and Management Plan. ▪ Full-time paid staff available to help accomplish tasks. ▪ Funding available for restoration, monitoring, and education projects, enabling local funds to stretch farther. ▪ Baywide and watershed approach encouraged. ▪ Research and innovative projects are promoted.	▪ Previous two attempts to designate bay for National Estuary Program failed due to local fear of potential for additional regulations, control by EPA and another layer of government. ▪ Possible loss of local control over bay management. ▪ Emphasis is on water quality, with ecosystem a secondary issue. ▪ Reporting and grant writing requirements could be burdensome. ▪ Funding depends on whims of federal budgeting and overhead costs must be met locally.

Table 7-3. Examples of formal and informal institutional mechanisms for implementation .

Mechanism and Purpose	Examples (general and specific)
Interagency Agreements. To identify areas of agreement among different agencies for implementing a general or specific mutual need.	Joint Powers Agreement; MOU; Memorandum of Agreement.
Partnerships. To formally or informally agree to work together, often among different levels of government and/or between public and private sectors.	Coastal America (federal); Southern California Wetlands Recovery Project (federal-state).
Land Use Plans. To guide land use locations and development standards within local jurisdictions.	City and County general plans, LCPs, and specific plans; Port Master Plan and area plans; Navy facility master plans.
Programmatic Species Conservation and Management Take Permits.	MSCP which includes portions of San Diego Bay and key dependent species (federal-state-local-private);
Natural Resource Management Plans. To guide the protection, restoration, and management of natural resources within a jurisdiction.	Navy Facility INRMP; NWR CCP; CDPR general plan; San Diego MSCP; Endangered Species Recovery Plans.
Ordinances. To give specific rules for implementing local government policies and plans.	Port Ordinances; County Resource Protection Ordinance; City Zoning Ordinances.
Regulations. To make a rule with the force of law by the executive authority of government.	California Fish and Game Code; State Water Code.
Policies. To guide and determine present and future decisions.	Southern California Eelgrass Mitigation Policy.
Laws. To formally enact policy as a statute by the legislative branch of government.	Federal ESA; CWA.

7.4.2 Funding Resources

Many of the Plan's strategies, though not all, will require special funding to implement. Strategies can probably be carried out through annual agency budgets or presently available public and private funding sources, while others may require the creation of new sources. Sustaining adequate funding levels is always a challenge but need not be a distracting or permanent obstacle.

A funding strategy is a key element of a resource management plan. Alternative financing mechanisms include a wide range of options, ranging from traditional mechanisms (e.g. fees, grants, voluntary donations) to more innovative ones (e.g. economic incentives, public-private partnerships) (Henkin and Mayer 1996). Direct government appropriation is a sometimes-overlooked approach, and was used successfully to support an ongoing, community-based restoration project at Paradise Creek (Taylor 1999).

Estimating costs of Plan implementation is an important step once strategies are agreed upon. Some actions will involve capital costs over a short period of time, while other strategies involve ongoing operating costs continuing over a period of years. Types of financial management techniques useful in identifying the types and extent of Plan-related costs include (a) capital budgeting; (b) workload analysis; and (c) categorical cost (e.g. price tag) estimates (Henkin and Mayer 1996).

7.4.2.1 Existing Sources

A list of existing funding sources that are available to institutions involved with the natural resources of the bay can be found in Table 7-4. These funds are usually available in the form of project grants and can often be obtained by agencies, academic institutions, or nonprofit organizations. Some programs are very narrow in their eligibility requirements while others are very broad. Matching funds (cash and/or in-kind) are frequently required. The level of annual funding varies considerably for each program, with national programs usually more competitive than state or local ones. Programs that are targeted solely for states for internal state agency purposes are not included.

Federal Sources: Examples

Coastal America Partnership

Description

Coastal America is a partnership that began in 1992 among federal, state and local governments and private alliances to address environmental problems along the nation's coasts. Federal partners include the following departments and offices, with specific INRMP federal participants noted in parentheses: USDA, Air Force, Army (USACE), Commerce (NMFS), Defense, Energy, Housing and Urban Development, Interior (USFWS), Navy, Transportation (USCG), EPA, and the Executive Office of the President.

San Diego Bay is within the area of the Southwest Region Implementation Team of the Coastal America Partnership. Its emphasis is on projects that address the preservation and restoration of tidally influenced wetlands in California. Other targets are the development of restoration projects associated with transportation infrastructure and corridor modification, and with educational outreach on coastal preservation and restoration. The National Implementation Team takes action on project recommendations from the Regional Teams to help fund projects and provides a variety of information to Regional Teams.

Potential Implementation Assistance

- Endorsement of bay restoration projects, particularly those within or directly affecting the intertidal zone, by the Regional and National Implementation Teams, which should help improve and expedite the ability to obtain federal funding for the requesting federal agency.
- Assist in resolving conflicts among federal agency members over restoration methods or strategies; also assist agencies to "develop crosswalks" between conflicting statutes.
- Support for the watershed approach to aquatic ecosystem restoration (see existing publication) of San Diego Bay.
- Better coordination among federal agencies involved in coastal restoration in the San Diego region by recognizing potential impediments to successful collaboration and developing a clearinghouse for this information.

Table 7-4. Available primary funding sources for plan implementation.

Source/Program	Purpose—By Category/Level of Available Funding (see caption above)
Federal	
▪ Direct appropriation	All/varies
▪ Federal agencies' (see Table Table 7-1) budgets	All/varies
▪ Department of Defense—Corps of Engineers—WRDA §206 Aquatic ecosystem restoration/and §1135 project modification	2/Medium
▪ Commander Naval Region Southwest budgets	All/varies
▪ EPA—Wetlands Development Grants	1, 2, 3, 5/Medium
▪ EPA—Clean Water Act programs	(see below: State/SWRCB/RWQCB)
▪ EPA—Environmental Education Grants Program	4/Medium
▪ EPA—Water Quality Cooperative Agreements (CWA §104[b][3])	1, 4, 5/High
▪ EPA—National Estuary Program	2, 4, 5, 6/Medium
▪ Multiple—Coastal America Partnership	2, 4/Low?
▪ National Sea Grant College—Aquatic Nuisance Species Program and Special Initiatives Program	4, 5/Low
▪ NOAA—Ocean Resources Conservation and Assessment Program	1, 5/Low
▪ NOAA—Coastal Service Center Cooperative Agreements	1, 2, 4/Medium
▪ USFWS—Clean Vessel Act Grant Program	(see below: State/Department of Boating and Waterways)
▪ USFWS—National Coastal Wetlands Conservation Grants	2/Medium
▪ USFWS—North American Wetlands Conservation Act Grant Program	2, 6/High
▪ USFWS—Wetlands Protection Development Grants	2/Medium
State	
▪ Direct appropriation	All/varies
▪ State agencies' (see Table Table 7-1) budgets	All
▪ SWRCB and RWQCB: CWA Nonpoint Source Grant Programs (Planning §205[j], Implementation §319 [h])	1, 2, 6/High
▪ SWRCB and RWQCB: State Revolving Fund Loan Program	1, 2/High
▪ RWQCB: Clean-up and Abatement Account (legal fines)	?/varies
▪ Coastal Conservancy: Watershed Enhancement Program	2, 6/
▪ Southern California Wetlands Recovery Project	2, 5/Medium
▪ Wildlife Conservation Board	2/High
▪ Department of Education: Environmental Education Grant Program	4/?
▪ Department of Boating and Waterways: Clean Vessel Act Grant Program	1, 4/Medium
▪ Department of Parks and Recreation: Habitat Conservation Fund	2/Medium
▪ Department of Water Resources: Urban Streams Restoration Program	2/Medium
Local	
▪ Port budget and Environmental Fund	/varies
▪ Local agencies' budgets (see Table Table 7-1).	All
▪ Local fine monies (from ordinance violations, etc.)	/varies
▪ County Fish and Game Advisory Commission: Fine monies	2, 3, 4, 5/Low
Private	
▪ National Fish and Wildlife Foundation: Challenge Grants	1, 2, 4, 5/Medium
▪ Packard Foundation: Conservation Program, West Coast of North America	1, 2, 5, 6/High
▪ Other Foundations, such as the local Oceans Foundation	varies/Low to High

Categories: 1—Management Practices and Mitigation; 2—Restoration, Enhancement and Remediation; 3—Regulation, Permitting, and Enforcement; 4—Education, Outreach and Training; 5—Monitoring, Assessments and Research; 6—Planning and Coordination. Levels of Annual Program Funding: Low=<$1 million; Medium=$1–20 million; High=>$20 million.

- Education and outreach assistance to teachers and schools on coastal environmental issues through the nearest designated Coastal Ecosystem Learning Center (Monterey Bay Aquarium); also by designating the Stephen Birch Aquarium in La Jolla and/or the Chula Vista Nature Center as an official Coastal Ecosystem Learning Center.
- Promotion of the consensus-building process involving stakeholders at local and regional levels to address environmental problems, such as with the Bay Ecosystem Plan, perhaps involving and integrating the work of existing advisory boards (such as the San Diego Wetlands Advisory Board).

Role in Bay to Date

Coastal America endorsed the San Diego Bay INRMP during its conceptual stage, when Navy legacy funds were being sought for some of the original field studies. In October 1998, the INRMP's progress was described to the Regional Team.

North American Wetlands Conservation Act Grant Program

Description

The North American Wetlands Conservation Act grant program promotes long-term conservation of North American wetland ecosystems, and the waterfowl and other migratory birds, fish, and wildlife that depend upon such habitat. It was created as a result of the 1989 North American Wetlands Conservation Act (as amended) and the Coastal Wetlands, Planning, Protection, and Restoration Act (as amended). In Fiscal Year 2008, the funding level was about $82.4 million. The USFWS issued project grants through cooperative agreements and contracts.

Potential Implementation Assistance

- Funding for acquisition, enhancement, and restoration of wetlands and wetlands-associated habitat.
- Support for voluntary, public-private partnerships by creating an infrastructure and providing a source of funding.

Role in Bay to Date

USFWS awarded a North American Wetlands Conservation Act grant for restoration of D Street Fill.

National Estuary Program

Description

The National Estuary Program was established in 1987 by amendments to the CWA (§320) to identify, restore, and protect nationally significant estuaries of the United States. The Program is designed to encourage local communities to take responsibility for managing their own estuaries, with each National Estuary Program made up of representatives from local, state, and federal government agencies and members of the community. While funds are administered by the EPA, program decisions and activities are carried out by the local committees based on their Comprehensive Conservation and Management Plan. This Bay Ecosystem Plan must address environmental problems as well as the economic and social values of the estuary.

Estuaries designated as NEPs in California are San Francisco Bay, Morro Bay, and Santa Monica Bay. The Governor must nominate the bay/estuary for inclusion in the National Estuary Program to Congress during designated nomination periods. The Program has not been reauthorized by Congress since 1994, when Morro Bay was added.

Potential Implementation Assistance

National Estuary Program funds can be used to carry out such tasks as:

- Gathering and analyzing data, and acquiring new data as needed to address priority problems;
- Increasing public understanding of the problems and complexity of an estuary and engaging local citizens in the decision-making process;
- Developing and implementing corrective actions to address the most significant problems.

Role in Bay to Date

No role is known in San Diego Bay. A past attempt to designate the bay as a National Estuary Program was defeated by local industry and uncertainty about the role of another federal program.

If and when the National Estuary Program nomination process opens, the TAC believes an application should be pursued for inclusion of San Diego Bay.

State Sources: Examples

Southern California Wetlands Recovery Project

Description

The goal of the Recovery Project is to develop and implement a regional strategy for acquisition, restoration, and enhancement of southern California's coastal wetlands, which will result in a long-term increase in the quantity and quality of the region's wetlands. As a partnership of public agencies working cooperatively, the Recovery Project uses a nonregulatory approach and an ecosystem perspective. It hopes to increase the pace and effectiveness of these efforts by securing and pooling funding, establishing priorities, and identifying who will coordinate the construction and monitoring of projects. The state contributed $6 million for Fiscal Year 1998–1999 and again for Watershed URMP 1999–2000. The state also provides $10 million for Fiscal Year 1999–2000 in a program not specific to the Recovery Project but from which the Project can draw, with the funds administered by the California Coastal Conservancy. A Wetlands Managers Group and a Public Advisory Committee advises the Governing Board of 14 members (ten state and four federal resource management agencies). The use of mitigation funds is not the central purpose or function of the Recovery Project, though it could develop projects that may provide mitigation credits.

Potential Implementation Assistance

- Wetland restoration and enhancement projects in San Diego Bay are a high priority to the Recovery Project.
- Potentially a source of funds for implementation of the Plan, with no minimum or maximum grant amount per proposal.
- An agency working on both the Recovery Project and the Plan (which includes at least six agencies) would need to take the lead in identifying potential Recovery Project projects from the Plan and presenting them to the Recovery Project Wetlands Managers Group.
- Science and feasibility criteria must be used in evaluating and prioritizing projects.

Role in Bay to Date

The California Coastal Conservancy purchased property to augment the South San Diego Bay NWR's establishment where the Otay River enters the former salt works area. Also, the Conservancy is trying to complete portions of its California Coastal Trail in south San Diego Bay in the area where its purchase is located, through the Refuge, and to link the trail to the Tijuana Estuary. The California Coastal Trail, once completed, will extend 1,200 miles from Oregon to Mexico. The Trail's recent history began in 1972 when Proposition 20 recommended that a trails system be established along or near the coast. In 1999, the California Coastal Trail was designated at the state and federal level as Millennium Legacy Trail, and in 2001 state legislation called for its completion. Today, roughly half of the California Coastal Trail is complete.

CALIFORNIA COASTAL TRAIL

7.4.2.2 Port Environmental Committee

The Port's Environmental Committee advises the BPC on funding of environmental projects through the Port's Environmental Fund. Since 2006, the Environmental Fund has established itself as a major source of funding for natural resources projects in San Diego. The Committee also advises the BPC on significant ecosystem and environmental issues relating to San Diego Bay. Participants include representatives from government, academia, port tenants, and the environmental community. A Charter and Policy have been established for the Committee. The Committee provides advice on new or emerging issues, including: remediation of contamination; enhancement of habitat for native fish and wildlife; increasing native fish and wildlife populations; controlling and eliminating pollutant discharges, and eliminating air emissions.

7.4.2.3 Potential New Sources

Competition and unstable levels for federal and state sources of funding could leave too little funds available for ecosystem management implementation in the bay. Some new and unique sources of funding may be very helpful. Ideas identified to date are listed in Table 7-5.

Table 7-5. Ideas for new funding sources for bay ecosystem management.

Sector	Potential Source
Federal	▪ Special Appropriation
State	▪ Special Appropriation
Local	▪ San Diego Bay Endowment Fund (from penalties, pollution fines, donations, etc.) ▪ Ecotourism tax on ecotours in bay ▪ Special Bay Bond measure ▪ "Bay Project or User Tax" for users (like the "bed tax") ▪ "Adopt a Tideland" certificate for donation ▪ San Diego Bay Harvest Management Endowment Fund (Section 4.4.3.1: Harvest Management")
Private	▪ Bank card income from special local charge card directed at coastal resources (like San Diego Zoo card)
Public-Private	▪ Public-Private Partnership Fund for Bay

Other ideas may be worth pursuing. For example, a MOU between the Navy and regulators can serve as a means for the Navy to commit funds to a project covered by the MOU, rather than a competing project. The Port has been successful in generating a significant public art fund by charging a 1/4% tax on certain activities. A similar concept could be used for bay management activities. Some significant monitoring surveys have been accomplished by pooling funds from the annual monitoring requirement of major waste dischargers under their NPDES permits. Finally, oil spill response management and reporting (and to a certain extent ecological risk assessment conducted under CERCLA) can be a driver to fund long-term monitoring.

7.4.2.4 Volunteer Contributions

The value of using volunteers to assist with implementation is not overlooked or unappreciated. Volunteer efforts can provide a significant contribution to carrying out portions of the Plan. Ongoing volunteer efforts in the bay already include cleanup debris days, bird counts, invasive plant removal, and educational tours at nature centers and wildlife reserves. Volunteers could probably have the most impact in the areas of restoration, education, and monitoring.

For example, volunteer estuary monitoring is a popular and successful program used in estuaries throughout the country. Following training workshops, volunteer monitoring leaders return home to establish or improve their local water quality monitoring operations. For government agencies with limited funds for monitoring, these volunteer programs can provide high-quality, reliable data to supplement their own water quality monitoring programs.

Volunteer efforts can provide a significant contribution to carrying out portions of the Plan.

While volunteer efforts can save money, their work often requires adequate supervision to sustain quality control. Supervisors must have adequate time and funding to oversee the volunteer programs. In addition, volunteer committees can suffer from "burn-out" over time if adequate recruitment and personal reward do not occur.

The bay is a public treasure and the public wants to be able to participate in its care.

Although the Plan should not be overly dependent on volunteer labor, the contributions of volunteers should be actively encouraged. Considerable local talent, dedication, and energy can and should be engaged. The bay is a public treasure that the public wants to be able to participate in its care.

7.5 Priority Setting

Of the hundreds of individual strategies recommended within the Plan, which ones should be the top priority? Which should be implemented first? That question will continue to be asked throughout the Plan's lifespan. Everyone understands that it is not possible to get all of the strategies done immediately.

Setting implementation priorities for the Plan's strategies is different than setting priorities for project selection or monitoring or research. Each of these has a different set of criteria. Chapter 6 lists criteria to establish priorities for monitoring and research needs.

7.5.1 Criteria for Ranking Priority Strategies and Projects

The following criteria are proposed to help rank (1—high, 5—low) each of the strategies in the Plan. Priorities will change over time, just as these criteria might change over time.

- Prevents new problems or threats to the bay's ecosystem;
- Helps resolve conflicts among bay uses;
- Reduces an ecosystem-wide impact or provides an ecosystem-wide benefit;
- Improves conditions of most impaired habitats or species in the bay;
- Relatively cost-effective for achieving the goal and objectives.

Each strategy, or group of strategies (e.g. II.A.1, 2 and 3), needs to be evaluated and ranked on a 1-to-5 scale based on the above criteria. Each strategy could then be presented in a spreadsheet, in order to facilitate implementation tracking. Those of similar rank can then be sorted together.

7.5.2 Sorting Project Work by Funding Program and Appropriate Criteria for Project Ranking

This is a natural resources budget guidance document as well as a natural resources management plan. Successful implementation depends upon not only standards and guidelines established, but how well these are translated into performance work statements (who will do what and with what funding), project lists and scopes, and work load planning.

Some proposed strategies involve specific actions that may need cooperative funding. However, other strategies suggest changes that do not necessarily require direct funding to implement (e.g. EA methods or criteria for habitat conservation). Whatever the case, cooperative efforts are essential to ensure complete implementation of this Plan. Signature approval by the Port and U.S. Navy as well as by other agencies and organizations provides an authority for implementation.

Navy Natural Resources Project Ratings, Priorities, and Funding Classifications

Four programming and budgeting priority levels are detailed, as shown below. Implementation of the strategies and projects described in this INRMP from the Navy perspective is guided by how budget priorities are assessed for environmental work on DoD installations. This is described in DoDI 4715.3 (May 3, 1996) *Environmental Conservation Programs*, which implements policy, assigns responsibilities, and prescribes procedures for the integrated management of natural and cultural resources on property under DoD control. Budget priorities are also described in OPNAVINST 5090.1C, Environmental and Natural Resources Program Manual 2007, and by Commander Naval Installations policy (Table 1-5, *Programming And Budgeting Priorities For Conservation Programs* from Chief of Naval Operations Funding Guidelines from the Program Objective Memorandum Fiscal Year 2004 Naval Environmental Requirements Guidebook).

Budget priorities for regulatory compliance such as under the CWA, or for threatened and endangered species terms and conditions of Biological Opinions, receive the highest possible budgeting priority. This INRMP supports the need to avoid critical habitat designations under §4(b)(2) of the ESA, or §4(a)3 of the ESA (exemption from critical habitat designations for national security reasons).

The SAIA specifically requires that there be "sufficient numbers of professionally trained natural resources management and natural resources enforcement personnel to be available and assigned responsibility" to implement an INRMP.

DoD Priorities

The budgeting plan for the INRMP is based on programming and budgeting priorities for conservation programs described in DoDI 4715.3 *Environmental Conservation Program.* Funds will be requested for tasks within the INRMP, with priority given to Class I, II, and III projects, in that order, based on this guidance. The DoDI 4715.3 document defines four classes of conservation programs; compliance activities fall into the first three classes and stewardship activities fall into the fourth class. Accordingly, the projects recommended in this INRMP have been prioritized based on compliance and stewardship criteria. Four programming and budgeting priority levels are detailed, with the first three classified as "Compliance" (Class 0 - *Recurring Natural and Cultural Resources Conservation Management Requirements;* Class I - *Current Compliance;* and Class II - *Maintenance Requirements*). The fourth category is "Stewardship" (Class III - *Enhancement Actions, Beyond Compliance*). Funding is routinely programmed three years in advance of project implementation.

Navy Assessment Levels for Assigning Budget Priorities

The Navy breaks the DoD categories further down by assigning an additional assessment level to projects to assist in recognizing appropriate funding sources in their Environmental Program Requirements (EPR) budget process for projects. The following descriptions of Navy Assessment Levels are summarized from the Navy Environmental Requirements Guidebook (Chief of Naval Operations 2004 Memo). After each description is the approximate equivalent DoD Class.

- **Level 1 (Federal and State Regulation).** Level one requirements are those prescribed by existing laws, regulations, and EOs. These projects/ongoing efforts include responding to applicable federal, state and local laws and regulations. Level one also includes costs of ongoing compliance, such as: manpower, training, travel, and program management. [same as DoDI 4715.3 Classes 0 & I]
- **Level 2 (Navy Policy).** Requirements derived from DoD or Navy policy. These projects/proposed efforts are not mandated by law or other federal, state or local regulations/orders, but reflect implementation of Navy and DoD policy decisions and initiatives (e.g. PCB elimination). [same as DoDI 4715.3 Class I]
- **Level 3 (Pending Regulation).** Requirements derived from pending federal, state or local regulations under development (where publication is scheduled), using, if available, model state regulation/permit standards. [same as DoDI 4715.3 Class I]

- **Level 4 (Future Requirements).** Requirements derived from future potential federal, state or local legislation. These requirements are speculative in nature. [same as DoDI 4715.3 Class II]
- **Level 5 (Leadership Initiatives).** Requirements based on local proactive Navy initiatives not mandated by law, regulation, EO or policy. [same as DoDI 4715.3 Class III]

Budget priorities for threatened and endangered species management, especially compliance with Biological Opinions, receive the ***highest possible*** budgeting priority, and supports the Navy's need to avoid critical habitat designations under §4(b)(2) of the ESA (based on three criteria described in Section 1.9.4.1), or §4(a)3 of the ESA (exemption from critical habitat designations for national security reasons).

Environmental Readiness Program Assessment Database

EPRs cover multiple subject matter or "business lines" aside from natural and cultural resources. EPRWeb is an optimized online database used to define all programming for the Navy's environmental requirements. EPRWeb records data on project expenditures, and provides immediate, web-based access to requirements entered by the multiple Navy environmental programs, including Environmental Compliance, Pollution Prevention, Conservation, Radiological Controls, and Range Sustainment as related to environmental costs on military ranges. It is the Navy's policy to fully fund compliance with all applicable federal, state and local laws; EOs; and associated implementing rules, regulations, DoD Instructions and Directives, and applicable international and overseas requirements (OPNAVINST 5090.1C October 2007).

All natural resources requirements are entered into the EPRWeb and that they are available for review/approval by the chain of command by the dates specified in the Guidance letter that is provided annually by the Chief of Naval Operations (N45). This database is the source document for determining all programming and budgeting requirements of the Environmental Quality Program. EPRWeb is also the tool for providing the four Environmental Readiness Level (ERL) capabilities used in producing programming and budgeting requirements for the various processes within the budget planning system.

Four Navy environmental readiness levels have been established to enable capability-based programming and budgeting of environmental funding, and to facilitate capability versus cost trade-off decisions. ERL4 is considered the absolute minimum level of environmental readiness capability required to maintain compliance with applicable legal requirements. The definitions of ERL1 through ERL4 follow:

a) Environmental Readiness Level 4

- Supports all actions specifically required by law, regulation or EO (DoD Class I and II requirements) just in time.
- Supports all DoD Class 0 requirements as they relate to a specific statute such as hazardous waste disposal, permits, fees, monitoring, sampling and analysis, reporting and record keeping.
- Supports recurring administrative, personnel and other costs associated with managing environmental programs that are necessary to meet applicable compliance requirements (DoD Class 0).
- Supports minimum feasible Navy executive agent responsibilities, participation in Office of the Secretary of Defense sponsored inter-department and inter-agency efforts, and Office of the Secretary of Defense mandated regional coordination efforts.

b) Environmental Readiness Level 3

- Supports all capabilities provided by ERL4.
- Supports existing level of Navy executive agent responsibilities, participation in Office of the Secretary of Defense sponsored inter-department and inter-agency efforts, and Office of the Secretary of Defense mandated regional coordination efforts.

- Supports proactive involvement in the legislative and regulatory process to identify and mitigate requirements that will impose excessive costs or restrictions on operations and training.
- Supports proactive initiatives critical to the protection of Navy operational readiness.

c) Environmental Readiness Level 2

- Supports all capabilities provided under ERL3.
- Supports enhanced proactive initiatives critical to the protection of Navy operational readiness.
- Supports all Navy and DoD policy requirements.
- Supports investments in pollution reduction, compliance enhancement, energy conservation and cost reduction.

d) Environmental Readiness Level 1

- Supports all capabilities provided under ERL2.
- Supports proactive actions required to ensure compliance with pending/strong anticipated laws and regulations in a timely manner and/or to prevent adverse impact to Navy mission.
- Supports investments that demonstrate Navy environmental leadership and proactive environmental stewardship.

7.6 Proposed Organizational Structure

The INRMP TAC's core charge is to ensure the sound basis of management decisions toward the INRMP goal, including their scientific and ecosystem basis.

Four jointly staffed (Port-Navy) Working Groups are proposed to make recommendations to the TAC (Table 7-6). They are shown in Figure 7-1.

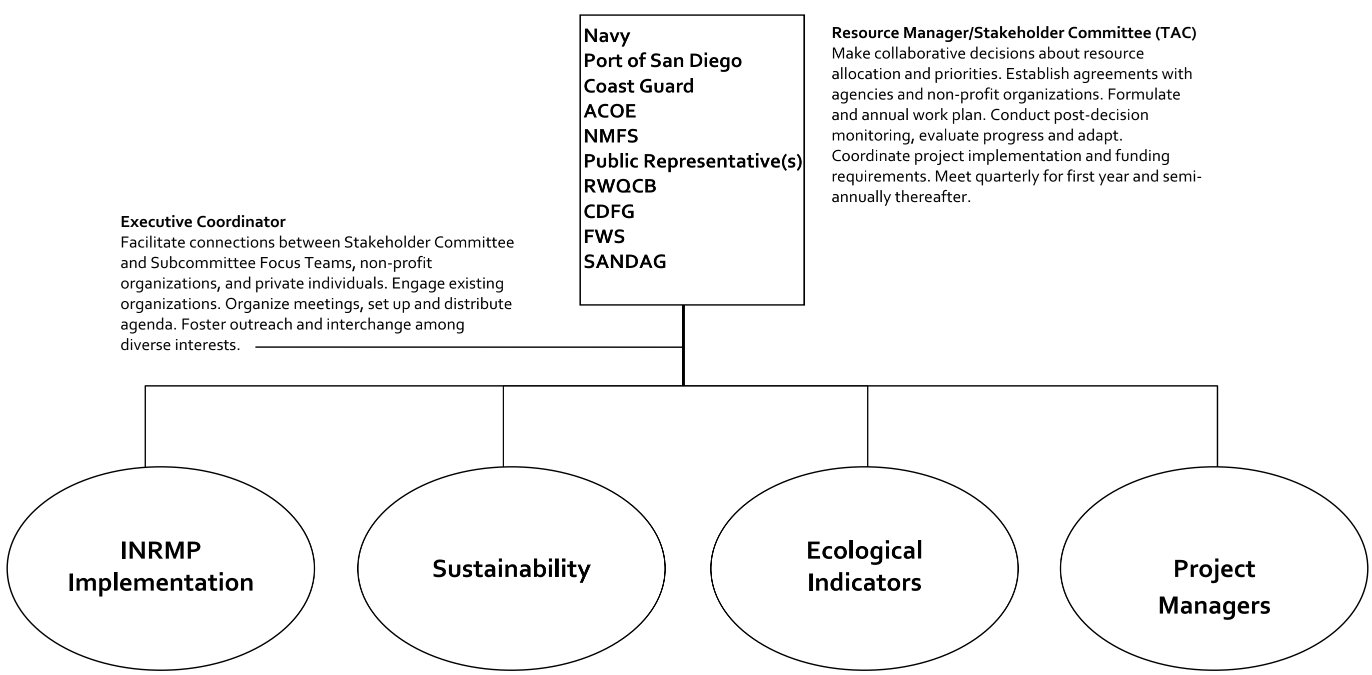

Figure 7-1. Proposed Technical Advisory Committee and Work Groups organizational structure. Each Work Group should be interdisciplinary and cross-jurisdictional.

Table 7-6. First-year priorities for Joint INRMP Technical Advisory Committee and Work Groups.

Resources Agency/Project Managers Work Group

- Obtain sign off signatures from the Navy, Port and regulatory and resource agencies for implementation of this INRMP.
- Address invasive species threats in the context of projects. Conduct a vulnerability analysis to help focus how the bay should be monitored for invasives and to set priorities for a prevention program. The analysis should combine an evaluation of likely vectors for introduction of invasives and their potential damage in vulnerable habitats.

INRMP Implementation Work Group (make decisions on appropriate funding venues)

- Make recommendations on appropriate funding venues and ensure grants are solicited to build the capacity of habitat restoration work.
- Define site-specific habitat restoration / enhancement priorities for bay properties to benefit shorebirds (mudflats, Salt Works), river mouth and floodplain, upland transition, and fish nursery functions based on the locations identified in Table 3-14.
- Define site-specific habitat conservation priorities for bay properties. Identify the mechanism and source of funding for this conservation at each site.
- Establish a new or build on an existing community-based restoration program, in cooperation with non-profit groups already involved in the bay or environmental education.
- Set up a central clearinghouse for data, reports and publications on the bay's natural resources that is accessible to a broad range of users, both technical and non-technical.
- RWQCB should address the general problem with access, collation, and interpretation of storm drain and water quality data in San Diego Bay.

Ecological Indicators "State of the Bay" Work Group

- Develop an implementation strategy for the first year - where funding is to come from, who does the monitoring.
- Set priorities, decide about phasing or stepwise implementation of monitoring elements, quality assurance and quality control, and information dissemination.
- Implement the baseline, minimum elements of the program:
  Collect water column samples of temperature, dissolved oxygen, salinity, turbidity, and chlorophyll *a* at permanent locations throughout the bay.
  Every five years, assess habitat changes.
  Every five years, conduct fish surveys.
- Conduct a comprehensive and recurring bay-wide shorebird and waterbird inventory about every five years, to coincide with fish surveys. Also conduct interim monitoring at a reduced level.

Sustainability Work Group

- Develop joint design guidelines for projects.
- Administer an award for achievement in sustainability design and implementation.

- Ecological Indicators (improved "State of the Bay" monitoring, data management and reporting, biennial conference)
- Project Managers (listed species, permits, project design review, shoreline management plan, invasive species detection and rapid response, resource agency collaboration)
- Sustainability (energy and water use efficiency [LEED and LID], water and sediment quality, climate change)
- Implementation (partnerships, outside grant management, watershed restoration connections and groups, etc.)

Figure 7-2 shows how the TAC and Work Groups would operate in the Port-Navy funding environment. As shown in that Figure, an institutional element of implementation appears to be missing in order to accomplish larger projects that are not directly tied to regulatory compliance. For example, the Joint Powers Agreement that the Port, County and two cities signed to do the Otay Watershed Management Plan together is an option for this INRMP implementation (See http://www.projectcleanwater.org/pdf/otay/jepa-final.pdf?wp_ml=0). Figure 7-3 is a Draft Charter for such a group.

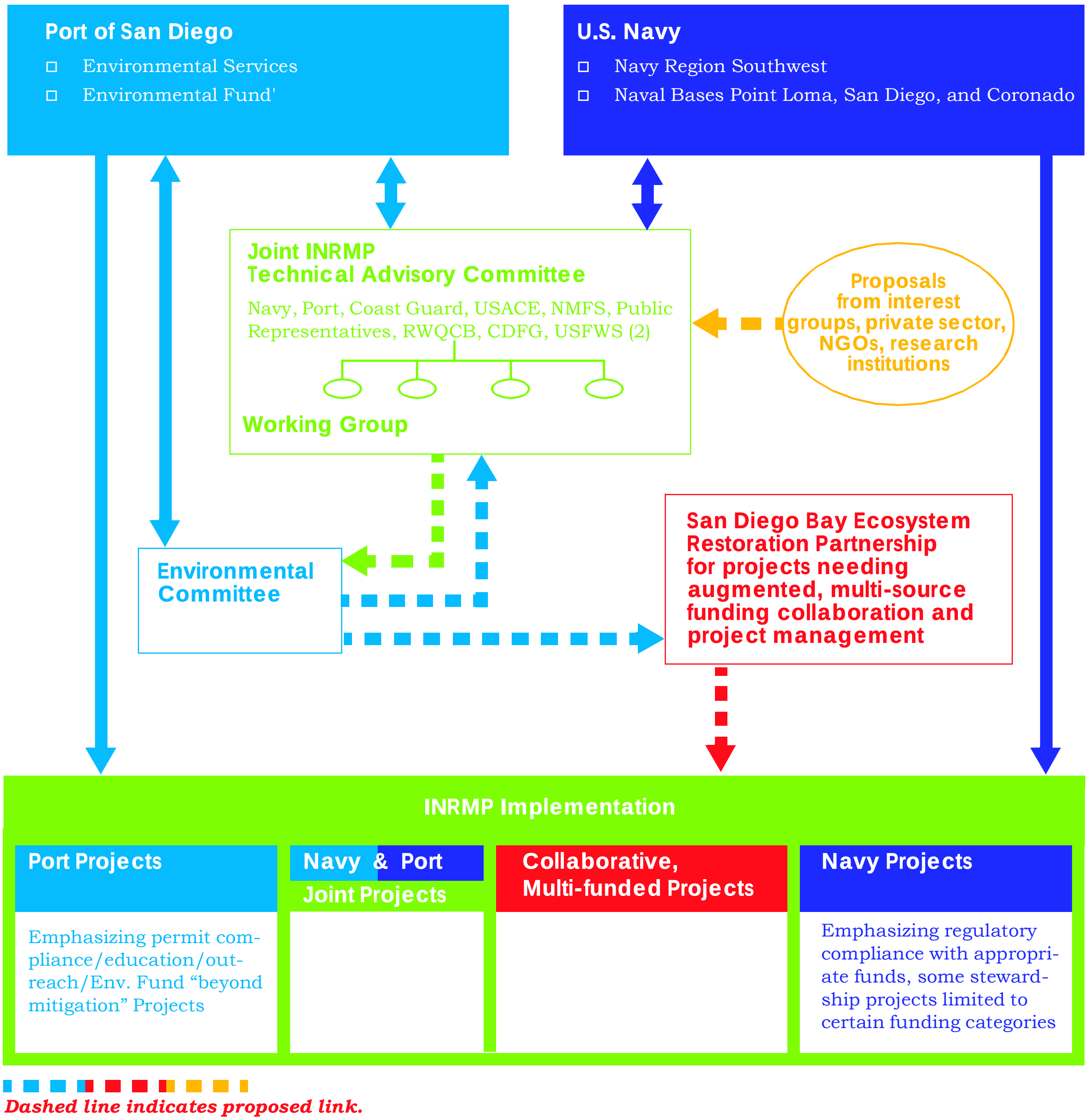

Figure 7-2. Operation of Technical Advisory Committee and Work Groups in a Port-Navy funding environment.

SAN DIEGO BAY ENHANCEMENT COUNCIL
DRAFT CHARTER

This is One bay, but we are fractured into many parts that work separately. Without a sufficient or shared information base, without an effective means to apply for grants, with project implementation that is segmented and opportunistic, there have been many missed opportunities that could have made the bay ecosystem healthier, even with the existing investment. We know there is a better way of doing the business of making San Diego Bay a more productive and biodiverse ecosystem. A way that links government, business, and the private citizen.

This Council is founded in order to implement the San Diego Bay INRMP. The INRMP is a long-term strategy sponsored by two of the major managers of the San Diego Bay: the U.S. Navy and San Diego Unified Port District. The ecosystem approach reflected in the INRMP looks at the interconnections among all of the natural resources and human uses of the bay, across ownership and jurisdictional boundaries. San Diego Bay is viewed as an ecosystem rather than as a collection of individual species or sites or programs. The INRMP's intent is to provide direction for ensuring the long-term health, restoration, and protection of natural resources, while also supporting the ability of the Navy and Port to meet their missions and continue thriving within the bay, in concert with other commercial, recreational, navigational, and fisheries needs.

MISSION:

Our mission is to:

- Preserve, Enhance, and Restore the natural resources of San Diego Bay as described in the INRMP.
- Develop synergy among a broad range of investment sources.
- Identify and energize work toward the most critical needs and the most productive opportunities first.

ROLE

The role of the Council and its membership is to implement the Mission and ensure that natural resources of the San Diego Bay ecosystem are conserved, enhanced, and restored. To accomplish this role, it has the agility to:

- Provide an information clearinghouse about the natural resources and water quality of San Diego Bay.
- Seek and receive funds and leverage investment from multiple sources to improve San Diego Bay through enhancement and restoration.
- Facilitate, coordinate and prioritize the implementation of enhancement and restoration projects.
- Improve the natural resource benefit provided by individual mitigation projects in the bay, such as through coordinating timing, location, and costs.
- Support research projects that help make decisions about allocating funds to the most critical needs and most productive opportunities.

In no way is the organizational mission or its member roles to be construed to diminish or in any way affect the decision-making authority of the member organizations.

FUNCTIONS

The Executive Leadership (or its committee) will:

- Develop and implement ranking criteria and methods for prioritizing enhancement and restoration projects. Some of the factors should be: level of community support, consistency with INRMP objectives, enhances scarcest habitats, supports indicator species.
- Put in place an institutional and financial framework for collaborative, ecosystem-based problem-solving and decisions.
- Encourage balanced implementation, and provide for tracking and assessment of program progress.
- Provide the public a consistent message that is an accurate reflection of the status and management of the bay.
- Assure the use of sound science in project implementation. Conduct research and long-term monitoring that supports sound decisions.
- Assure public involvement and outreach.
- Encourage integration, consistency, and continuity among agency and jurisdiction planning processes, especially between water quality and natural resource programs.

GOVERNING BODY

Executive Leadership Group of no more than 11 voting members with advisory committees, to include the Port, Navy, resource agencies (NMFS, USFWS, RWQCB, CDFG), National Park Service, public representative(s) from the environmental community, Port tenants association, small business or recreational communities (or a combination).

Project Managers Team includes a Local Government Liaison and a Collaborative Planning Coordinator (in charge of internal and external communication among a diverse community of interests, and takes direction from the Executive Leadership).

Stakeholder Forums and Potential Work Groups, such as: Finance and implementation (grant-seeking); Invasive Species; Data Management and Reporting; Ecological Restoration; Education; Watershed/Stormwater; Sediment Quality; Threatened/Endangered Species; Recreation/Access; Long-term monitoring, Ecological Assessment, and Bio-indicator Development for Protecting Beneficial Uses.

Figure 7-3. Bay Ecosystem Enhancement Council Draft Charter.

Many ecosystem-based efforts have succeeded in developing a collaborative organizational process as a stepping stone to effective management. The main purpose of a new organizational structure is to facilitate implementation by providing proper communication among the parties that can execute these management strategies. It would facilitate the needed network of communication and problem-solving, matching the bay's administrative or political boundaries to its ecosystem-wide problems. The following organizational process is proposed to kick off implementation of the bay Plan. It includes a primary decision-making committee of resource managers and stakeholders, including at least one public representative. The core strategies are broken down into topic-specific focus team subcommittees, shown in Figure 7-1 below. Rather than have a separate Implementation subcommittee, each group takes on project concept development, prioritization, and implementation responsibilities. An Executive Coordinator is in charge of internal and external communication among a diverse community of interests, and takes direction from the Stakeholder Committee.

The Joint Ocean Commission Initiative (2009) recommended that local leaders implement an integrated approach for ecosystem management of areas such as San Diego Bay. This is to be done in part by "establishing coordinating mechanisms" for citizens, agencies, and stakeholders across jurisdictions and sectors in identifying and implementing strategies to achieve multiple ecosystem goals.

The public representative(s) could be drawn from the environmental, small business or recreational communities (or a combination), as they were for the MSCP process. Alternatively, a public representative could be selected from a standing bay-wide organization, such as the Harbor Safety Committee. This is a voluntary group mandated by the California Oil Spill Prevention and Response Act of 1990. The "Safety" is for the safe transportation of oil. Members include pleasure/recreational groups, sport fishermen, harbor pilots, Port, CCC, State OSPR, Navy and USCG. They cooperate in the drafting of a Harbor Safety Plan, coinciding with the separate ACP which addresses oil spill response and cleanup.

7.7 Project Implementation Table

Table 7-7. Integrated Natural Resources Management Plan Implementation Summary, including the assignment of priorities based on legal driver behind each project .

INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
7.2.1 San Diego Bay Restoration Partnership Initiative									
4.1 Ecosystem Approach 4.2 Mitigation and Enhancement	Joint–Port and Navy	00242NR044- San Diego Bay Natural Resources Restoration Business Plan	**Restoration Business Plan.** Develop a coordinated, inter-jurisdictional business plan for implementing restoration projects that achieve the goal and objectives of this INRMP, with an implementation schedule and funding mechanisms. The plan should identify staffing, and specifically take on cross-jurisdictional projects that require leveraging of multiple funding sources.	ERL 4	TAC Top Nine	1/ESA, CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	Updated annually	2012-2014: 25 K first year and each additional thereafter 2015-2023: 25 K each year	1. INRMP Project Implementation Number of co-sponsored efforts consistent with Guiding Principles of Ecosystem Management in DoDI 4715.03 Increase in shallow water and intertidal habitats, “Living Shoreline” examples of erosion/sedimentation control with habitat values
4.1 Ecosystem Approach 4.2 Mitigation and Enhancement 5.3.2 Storm Water Management 5.4.1 Contaminated Sediments	Navy	0024208052- Storm Water Permitting SW Region Installations 00245TMDL1- Chollas Creek TMDL Monitoring	**Chollas and Paleta Creek Restoration.** Restore the mouth of Chollas Creek (on Navy property) and its historic filtering, remnant salt marsh, shoreline, and creek functions. Restore historic filtering, remnant salt marsh, shoreline, and creek function. Work with landowner upstream to shallow banks as they lead into the bay (on Navy property).	ERL 3	N/A	2/CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11988, 11990, 13112, 13186, DODI 4715.03	As needed	2014	1. INRMP Project Implementation 6. Ecosystem Integrity
7.2.2 Ecological Indicators Initiative									
5.4.1 Contaminated Sediments 6.1.1 Biological Indicators 6.2.1 Coordinated Long-term Monitoring	Joint–Port and Navy	00242SSCP3- San Diego Bay Water Quality Spatial Mapping	**San Diego Bay Sediment and Water Quality Indicator Species Selection Committee.** Implement indicator species monitoring for focusing bay-wide management, trend assessment, and reporting. This program is needed to understand the link between native species abundance and diversity and indicators of water and sediment quality, specifically in San Diego Bay. It would add resolution to how beneficial use criteria are applied locally as they pertain to natural resources: fishing (commercial and sport); preservation of designated biological habitats; estuarine and wildlife habitats; rare and endangered species; migration of aquatic organisms; and shellfish harvesting. This project is part of the Bight Regional Monitoring Program.	ERL 3	TAC Top Nine	1/CWA, MSA, EO 12962	Every 5 years	2013	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.4.1 Contaminated Sediment 6.1.1 Biological Indicators 6.2.1 Coordinated Long-term Monitoring	Joint–Port and Navy	00242NR012- San Diego Bay Fisheries Inventory	**Early Indicator Species (Bird and Fish) Monitoring.** Monitor topsmelt for bioaccumulation, including monitoring for acute, chronic, and teratogenic effects. Conducting autopsies within 24 to 48 hours on birds that are found dead in the greater bay area. Incorporate indicator species in project and other bay monitoring work.	ERL 2	N/A	CWA, ESA, MSA, EO 12962	Every 3-5 years	2016	1. INRMP Project Implementation 6. Ecosystem Integrity
7.2.3 Sustainable Ecosystem Initiative									

Note: EPR = Environmental Program Requirements, ERL = Environmental Readiness Level, N/A = Not Applicable, TAC = Technical Advisory Committee

Federal Executive Orders:
11988 - Floodplain Management; 11990 - Protection of Wetlands; 12962 - Recreational Fisheries; 13112 - Invasive Species; 13186- Protection of Migratory Birds; 13423 - Strengthening the environmental, energy, and transportation management of federal agencies in the United States; 13547 - Stewardship of the Ocean, Our Coasts, and the Great Lakes; 13514 - Federal Leadership in Environmental, Energy, and Economic Performance

Other Instructions and Federal Laws:
ASN Memo 2007 - Assistant Secretary of Navy Memorandum (2007) on use of Low Impact Development Technology for Stormwater Management; CERCLA - Comprehensive Environmental Response, Compensation and Liability Act; CWA - Clean Water Act; CZMA - Coastal Zone Management Act; DODI 4715.03 - Department of Defense Instruction March 2011: Natural resources Conservation Program; DQA - Data Quality Act; ECWA - Estuaries and Clean Water Act of 2000; ESA - Endangered Species Act; EsPA - Estuary Protection Act; FWCA - Fish and Wildlife Coordination Act; MBTA - Migratory Bird Treaty Act; MMPA - Marine Mammal Protection Act; MSA - Magnuson Stevens Fishery Conservation and Management Act, as amended through 2007; NAISA - National Aquatic Invasive Species Act; NAVFACINST 10110.45 - Naval Facility Command Instruction Regional Planning Instruction on Sustainable Development; NAWCA - North American Wetlands Conservation Act; NMBCA - Neotropical Migratory Bird Conservation Act; OPA - Oil Pollution Act of 1990; OPNAVINST 5090.1D - Office of the Chief of Naval Operations Instruction Natural Resources Management; PPA - Plant Protection Act; SAIA - Sikes Act Improvement Act

Table 7-7. Integrated Natural Resources Management Plan Implementation Summary, including the assignment of priorities based on legal driver behind each project (Continued).

INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
5.1 Sustainable Ecosystem 4.3.7 Artificial Shoreline Structures 5.2.3 Shoreline Construction	Joint–Port and Navy	N/A	**Conduct a pilot project using 2-6 treatments on a riprapped shoreline.** This project will provide the basis for the Sustainable Shoreline Stabilization and Habitat Enhancement Plan.	N/A	TAC Top Nine	1/ESA, CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	One-time occurrence	Ongoing since 2012	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.1 Sustainable Ecosystem 4.3.7 Artificial Shoreline Structures 5.2.3 Shoreline Construction	Joint–Port and Navy	00242NR045- San Diego Bay Sustainable Shoreline Stabilization and Habitat Enhancement Plan	**Sustainable Shoreline Stabilization and Habitat Enhancement Plan.** This plan will allow resource agencies to view the bay as an ecosystem when planning restoration work. Design criteria that improve habitat values provided by necessary artificial shoreline structures. Identify through interdisciplinary approach design criteria that enhance desired habitat values while preventing the occupation of shoreline stabilizing structures by terrestrial predators such as rats. Implement criteria for design review of project proposals to meet sustainability objectives. Ensure design review by engineers, water quality specialists, and marine biologists at all major phases of intertidal and subtidal construction project development. Identify, map and rank opportunities for shoreline structure enhancement. Consider wave energy, tidal position of structures, and other hydrologic criteria. Criteria and ranking should be the consensus of coastal engineer, marine biologist, and other natural resources professionals.	ERL 3	TAC Top Nine	1/ESA, CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	Annually	2016	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
7.2.4 Habitat Values Enhancement Initiative									
4.2.2 Mitigation/Enhancement	Joint–Port and Navy	N/A	**Restoration and Enhancement Site Mapping.** Identify and map all potential restoration and enhancement sites in the bay. Identify target acreages for each of the four bay eco-regions for functional habitat enhancement on a landscape level, and indicate appropriate restoration procedures for each site.	N/A	TAC Top Nine	1/ESA, CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	Update as needed	2010	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
4.2.2 Mitigation/Enhancement	Joint- Port and Navy (on Navy property where this is an issue)	00246J100H- NBC CLT & WSP Predator Control	**Predator Control for Threatened and Endangered Species Through Landscape Modification.** Implement predator control programs in areas where introduced predators are a constraint to maintenance and restoration of native populations. Where found possible, expand connections among marine, coastal, and upland natural habitat remnants while guarding against increases in unwanted predator-prey interactions especially for listed species.	ERL 4	N/A	2/ESA, EO 11990, 13112	Annually	Ongoing	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 6. Ecosystem Integrity

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Table 7-7. Integrated Natural Resources Management Plan Implementation Summary, including the assignment of priorities based on legal driver behind each project (Continued).

INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
4.2.2 Mitigation/Enhancement	Joint- Port and Navy	00242NR012–San Diego Bay Fisheries Inventory 00242MAR04–San Diego Bay Plankton Inventory 00242MAR05–San Diego Bay Benthic Community Inventory 00242MR106–San Diego Bay Automated Biological System 00242NR013–San Diego Bay Waterbird Survey	Value Determination of Shallow Subtidal Unvegetated Habitat. Fund a study to describe seasonal patterns of temperature, salinity, plankton, invertebrates, fish and birds for in-water habitats.	ERL 3	TAC Top Nine	1/CWA, EPA, MSA, ECWA	Every 3-5 years	Ongoing	1. INRMP Project Implementation 6. Ecosystem Integrity
4.2.2 Mitigation/Enhancement	Joint- Port and Navy	00242NR012–San Diego Bay Fisheries Inventory	Bay Community Characterization. Improve understanding of the inhabitants of vegetated shallows within the bay. Identify fish nursery locations by species and bird use of beds throughout the bay at a scale useful for project planning.	ERL 4	N/A	1/CWA, EPA, MSA, ECWA	Every 3-5 years	Ongoing since 1994	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 5. Team Adequacy 6. Ecosystem Integrity
4.2.2 Mitigation/Enhancement	Navy	00246NR047- Intertidal Restoration at Alpha Beach/Crown Cove on Navy land leased from State	Intertidal Restoration at Alpha Beach/Crown Cove on Navy land leased from State. Lessen the slope to widen the beach and enhance for intertidal mudflat, while filling in on interior side to replace lost eelgrass, designing for no interim loss.	ERL 4	TAC Top Nine	1/ESA, CWA, MSA, NAWCA, NMBCA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	One-time occurrence	2016	1. INRMP Project Implementation 6. Ecosystem Integrity
4.2.2 Mitigation/Enhancement	Navy	00246NR024- Dune and Strand Restoration to Support CLT & WSP	Delta Beach Upland and Intertidal Restoration. Reconstruct and enhance habitat value of the North Delta/NAB/ least tern nesting site as an alternative use for dredge spoils.	ERL 4	N/A	1/CWA, ESA, SSTC EIS ROD	Annually	Ongoing	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
4.2.2 Mitigation/Enhancement	Joint- Port and Navy	00242NR046- San Diego Bay Intertidal Mudflat Mapping	Intertidal Mudflat Mapping. Delineate the locations of all intertidal mudflats within the bay based on a commonly agreed upon definition and at a project-planning scale (1 inch = 600 feet). Add other vegetation and algae to eelgrass maps, add other special aquatic sites.	ERL 3	N/A	ESPA, CWA, ECWA, NMBCA, EO 11990	Every 5-10 years	2016	1. INRMP Project Implementation 6. Ecosystem Integrity

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INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
4.2.2 Mitigation/Enhancement	Navy	00246NR024- Dune and Strand Restoration to Support CLT & WSP 00246NR101- Invasive Plant Control for Listed Species	**Bay Shoreline Structures & Habitats Project.** Around San Diego Bay, improve the habitat value of the varied intertidal structures, could remove old boat ramp, or old seaplane ramp. Dune and other upland transition enhancement, control exotics, conserve foraging and loafing value for birds, remove parking lot, recontour cliff to historic conditions, fill in and build up beach.	ERL 3	N/A	2/SAIA, PPA, MBTA, MSA, EO 13186, DODI 4715.03	One-time occurrence	2016	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
4.2.2 Mitigation/Enhancement	Joint- Port and Navy	N/A	**General Intertidal/Shallow Subtidal Enhancement.** Fill in deeper habitats opportunistically (i.e., beneficial use of dredge fill).	N/A	TAC Top Nine	2/CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	As needed	Ongoing	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity
4.2.2 Mitigation/Enhancement	Joint- Port and Navy	00242MAR02- SD Bay INRMP Artificial Fish Structure Surveys	**Fish Use of Artificial Structures.** Assess the abundance, diversity, and biomass of fish occupying artificial habitats of varying material in the bay. Conduct a quantitative study to assess the recreational fishery and food gathering by ethnic groups.	ERL 4	N/A	2/MSA	One-time occurrence	2016	1. INRMP Project Implementation 6. Ecosystem Integrity
4.2.2 Mitigation/Enhancement	Port	N/A	**South Bay Power Plant Decommissioning and Habitat Improvement.** Decommission the South Bay Power Plant, including subsurface structures, in a manner that allows habitat improvements to be performed at the site. Set aside this property for intertidal habitat enhancements and/or mitigation purposes. Create additional upland transition, intertidal and subtidal habitat. Support the green sea turtle.	N/A	TAC Top Nine	1/ ESA, CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	One-time occurrence	2013	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.4.6.5 Salt Marsh Bird's Beak	Joint- Port and Navy	00246NR100- NBC Salt Marsh Bird's Beak Management	**Expand Salt Marsh Bird's Beak Habitat.** Plant seeds in suitable habitat.	ERL 4	N/A	2/ESA	As needed	Navy: ongoing (management) Port: 2004-2008 (planting)	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.3.6 Salt Marsh	Port	N/A	**Purchase Uplands to create wetlands or salt marsh.** Find a willing seller with viable land then construct wetlands habitat.	N/A	N/A	2/ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	As needed	Opportunistically	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity

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Table 7-7. Integrated Natural Resources Management Plan Implementation Summary, including the assignment of priorities based on legal driver behind each project (Continued).

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4.3.6 Salt Marsh	Port	N/A	**Extend Salt Marsh into Buffer Zone Chula Vista Bay Front Master Plan.** A 200 to 400 feet buffer is required for the Chula Vista Bayfront Master Plan. Salt Marsh to be created within the buffer, currently uplands.	N/A	N/A	2/ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	One-time occurrence	2020	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
5.2.3 Shoreline Construction	Port	N/A	**Emory Cove Shoreline Enhancement.** Remove invasive plant species and replant with native species.	N/A	N/A	2/ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	As needed	2009	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.3.4 Vegetated Shallows	Port	N/A	**Enhance Convair Lagoon.** Extend the fill to the east and west of the riprap berm around the cap to increase the shallow water area for eelgrass habitat, (e.g., by disposal of fill). Protect shoreline for use by loafing marine birds.	N/A	N/A	2/MSA, EO 11990	As needed	2015-2020	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Enhance National City Marina/Marine Terminal.** Soften shoreline, crenulate (make more irregular) and less steep on western face, for example. Look for alternative that at least does not steepen the slope.	N/A	N/A	2/SAIA, PPA, MBTA, MSA, EO 13186, DODI 4715.03	One-time occurrence	2015-2020	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement 4.3.6 Salt Marsh	Port, USFWS, & San Diego Natural Wildlife Refuge	N/A	**Restore F, G, and J Street marshes, Connector Marsh, and associated mudflats and low-lying salt marsh and upland transition located immediately adjacent to SDG&E on J Street.** Ephemeral tidal marsh at F Street and poorly flushed saltwater marsh on G Street, both serviced by a small, ineffective culvert. Enhancement potential: An additional channel, refuge islands, secondary tidal channels, and bayward expansion of the marsh. Needs improved flushing, possibly by new enlarged culvert and channel between culvert and bay. Needs clearing of sediment, trash. Should close to recreational all-terrain vehicle traffic.	N/A	N/A	2/CWA, ESA, ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	One-time occurrence	2015-2020	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Enhance CVWR.** Create additional intertidal wetlands. Improve wetland-upland transition. CVWR could be expanded on the south, west, or north sides of the present Reserve. Reduce water-born debris. Establish tidal channel system. Tern nesting could be expanded or improved by addition of a sand cap.	N/A	N/A	2/CWA, ESA, ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	One-time occurrence	2020-2025	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity

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							Frequency	Year	
4.2 Mitigation and Enhancement	Port	N/A	**Enhance Emory Reserve.** Area of degraded wetlands and transitional uplands. Convert peripheral uplands to wetland habitats. Fence and excavate small area (0.1 to 0.2 acre) for salt marsh enhancement. Control trash.	N/A	N/A	2/CWA, ESA, ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	One-time occurrence	2015-2025	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Enhance Emory Cove Boat Basin and Channel.** Restore the ten acre area of subtidal open water habitat surrounded by intertidal mudflats by filling in channel or expanding intertidal.	N/A	N/A	2/CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186 DODI 4715.03	One-time occurrence	2025-2030	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Navy	00246NR024- Dune and Strand Restoration to Support CLT & WSP	**Restore Coastal Strand Dunes.** Remove invasive species, revegetate with natives, and restore dunes on Navy-owned property.	N/A	TAC Top Nine	2/PPA, MBTA, EO 13186	As needed	2014	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 5. Team Adequacy 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
4.2 Mitigation and Enhancement	Port	N/A	**Improve Grand Caribe Isle South/Coronado Cays.** Board of Port Commissioners has set this area aside for mitigation. Fill in northern arm. Excavate beach to create intertidal habitat.	ERL 4	N/A	2/CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	One-time occurrence	2015-2025	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Navy	00246NR024- Dune and Strand Restoration to Support CLT & WSP	**Enhance Crown Cove and Navy land (leased).** Organize a beach cleanup, construct a boardwalk and launch dock to avoid disturbance of marsh habitat to improve beach and open water habitats. Enhance remnant salt marsh and dunes.	N/A	TAC Top Nine	2/PPA, MBTA, EO 13186	One-time occurrence	2014	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Navy	63406NR005- NBPL Invasive Plant Control 63406NR034- NBPL Erosion Control Plan & Implementation	**Protect and Restore Shoreline between SUBASE and fuel pier.** This area is a disturbed dune system which needs to be restored to protect foraging and loafing value for birds. Restoration should include: removal of invasive plants; removal of parking lot and replace with porous pavement and trees; re-contour the cliff to historic configuration; fill in and build up beach; and protect the beach and restore the uplands.	ERL 3	N/A	2/PPA, MBTA, EO 13186	One-time occurrence	2016	1. INRMP Project Implementation 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Navy	00246NR021- NBC Erosion Control Plan & Implementation	**Enhance NASNI shoreline.** The shoreline currently varies from beach to rubble to rock revetment. Enhance shoreline structures or remove boat ramp, old seaplane ramp.	ERL 3	N/A	2/SAIA, PPA, MBTA, MSA, EO 13186, DODI 4715.03, ASN Memo 2007	One-time occurrence	2016	1. INRMP Project Implementation 6. Ecosystem Integrity

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							Frequency	Year	
4.2 Mitigation and Enhancement	Port	N/A	**Enhance Coronado bayfront.** Shoreline is too narrow for effective shorebird use. Enhance habitat value of artificial hard substrate and broaden the shoreline and existing mudflat for improved intertidal habitat. Combine erosion control with ecologically beneficial shoreline treatment. Portions can be filled without retaining wall.	ERL 2	N/A	2/SAIA, PPA, MBTA, MSA, EO 13186, DODI 4715.03, ASN Memo 2007	One-time occurrence	2025-2030	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Enhance Coronado golf course shoreline.** Enhance shoreline without affecting boat channels, and without riprap or walls.	N/A	N/A	2/SAIA, PPA, MBTA, MSA, EO 13186, DODI 4715.03, ASN Memo 2007	One-time occurrence	2035-2040	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Enhance South Bay Power Plant site.** Integrate project with plans for CVWR. Enhance intertidal and shallow subtidal habitat for green sea turtle and other species.	N/A	N/A	1/ ESA, CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11990, 13112, 13186, DODI 4715.03	One-time occurrence	2013	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Restore Sweetwater River Mouth and Flood Control Channel.** Reconnect the stranded channel (now isolated by a riprap channel), and soften the shoreline. Restore natural connection and riparian habitat, including east of I-5. Remove pampas grass and shore up shoreline.	N/A	TAC Top Nine	2/CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11988, 11990, 13112, 13186, DODI 4715.03	One-time occurrence	2040-2050	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 5. Team Adequacy 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Enhance Port's Rohr site.** Enhance salt marsh remnant.	N/A	N/A	2/EO 11990, 13186	One-time occurrence	2020	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Port	N/A	**Enhance Mudflat off of Sweetwater National Wildlife Refuge.** Protect and enhance mudflat values for snowy plovers.	N/A	N/A	1/MSA, EO 11990	One-time occurrence	2010	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
7.2.5 Water and Sediment Quality Initiative									
5.3 Watershed Approach 5.3.2 Storm Water Management 5.3.3 Freshwater inflow management	Port	N/A	**Reroute Nestor Creek.** The current creek configuration causes flooding. Reroute to improve flow and avoid flooding.	N/A	N/A	2/CWA, EO 11988	One-time occurrence	2015	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity

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INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
5.3.2 Storm Water Management	Joint–Port and Navy	00242MR106- San Diego Bay Automated Biological System	**San Diego Bay water monitoring.** Water quality parameters should include temperature, pH, turbidity, dissolved oxygen, and salinity with Ocean Sensors APV.	ERL 3	N/A	1/CWA	Annually	2014	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 6. Ecosystem Integrity
5.3.2 Storm Water Management	Joint–Port and Navy	00242SSCP3- San Diego Bay Water Quality Spatial Mapping	**Water Quality GIS Database Layer Development.** Use the new GIS layers of bay natural resources to support spill response preparedness planning. Add water quality and sediment quality data/layers to GIS.	ERL 3	N/A	1/CWA, DQA	Every 2 years as new data are available	Ongoing	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity
5.3.2 Storm Water Management 5.2.2 Receiving Water Monitoring & Trend Analysis Water and Sediment Quality	Joint–Port and Navy	0024208052- Storm Water Permitting SW Region Installations	**Receiving Water Quality Monitoring.** Perform seasonal (winter/spring) water quality monitoring to evaluate spatial distributions and long-term trends. Includes surface mapping and vertical profiles of salinity, temperature, TSS (turbidity), chlorophyll-a, pH, dissolved oxygen, and at least discrete samples analyzed for COCs: (e.g. copper, zinc, PAH, PCB, pesticides) and toxicity.	ERL 4	N/A	1/CWA	Annually	2014	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.3.2 Storm Water Management 5.2.2 Receiving Water Monitoring & Trend Analysis (Water and Sediment Quality)	Joint–Port and Navy	0024208052 Storm Water Permitting SW Region Installations 00245TMDL1- Chollas Creek TMDL Monitoring 0024208059- TMDL Waste Load Assessment and Reduction Studies	**SD Bay Copper Criterion Establishment.** Develop a San Diego Bay specific copper criterion by collecting the appropriate amount and type of data for computing a Water Effects Ratio. Combine this effort with the Biotic Ligand Model development for marine waters. Criterion should focus on water and sediment quality, not just stormwater management.	ERL 3	N/A	1/CWA	As needed	Ongoing since 2005-2025	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
5.2.2 Receiving Water Monitoring & Trend Analysis (Water and Sediment Quality)	Joint–Port and Navy	N/A	**Development of less toxic and non biocidal anti-fouling paints for boat hulls.** Request field demonstration/pilot projects of promising nontoxic coatings on ships and boats to evaluate effectiveness of durability, bonding, and repellency (of fouling organisms) under local conditions.	N/A	N/A	1/CWA, EO 13514	One-time occurrence	Ongoing since 2010-2013	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.3.2 Storm Water Management	Port	N/A	**Remove debris in A-8 anchorage.**	N/A	N/A	1/CWA	As needed	Ongoing since 2010-2013	1. INRMP Project Implementation 6. Ecosystem Integrity
5.3.2 Storm Water Management	Joint–Port and Navy	0024208052- Storm Water Permitting SW Region Installations	**Install storm water filters to catch debris.** Filter installation on respective Port and Navy properties.	ERL 3	N/A	1/CWA	One-time occurrence	2014	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity

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							Frequency	Year	
4.1 Ecosystem Approach 4.4.2.2 Invertebrates 4.4 Birds 5.3.2 Storm Water Management 5.4.1 Remediation of Contaminated Sediments	Joint–Port and Navy	00242MAR05- San Diego Bay Benthic Community Inventory	**Benthic Study.** Detect changes in the quality of the benthic invertebrate assemblage, especially with respect to food for shorebirds, water quality and toxics, and overall ecosystem health. Monitor for introduction of invasive exotic invertebrates, and populations of those already occurring in the bay. Conduct a baseline inventory of the bay's benthic invertebrates, with emphasis on functional groups and developing indices of health, or on identification of "keystone" species that may be used for long-term monitoring of habitat and ecosystem health. Conduct studies on a seasonal basis. Support Regional Monitoring studies investigating the relative importance of attributes of sediment and water quality compared to predation and other factors should be funded to facilitate better management of invertebrates. This information could also be used to help make invertebrate assemblages an early indicator of ecosystem problems.	ERL 4	TAC Top Nine	1/ESA CWA, MBTA, ECWA, ESPA, MSA, SAIA, NAISA, EO 12962	Every 5 years	Ongoing since 2010	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
4.1 Ecosystem Approach	Joint–Port and Navy	00242NR047	**Bay Hydrographic GIS Tool.** Examine the ecological significance of the changes in bay circulation, velocity, tidal flushing, subsurface erosion, and sediment movement caused by deeper dredging and lengthening of deep bay channels.	ERL 2	N/A	2/SAIA, ESPA, ECWA, DQA, DODI 4715.03	One-time occurrence	2016	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
7.2.6 Invasive Species Initiative									
4.4.1 Invasive Species	Joint–Port and Navy	00242NR015- San Diego Bay Marine Invasive Species Plan & Implementation	**San Diego Bay Invasive Species Watch List and Photo Vouchers.** Develop a watch list for species that are invasive in SD Bay or those that are a potential threat for distribution to public or to those performing research/projects in the bay.	ERL 2	N/A	1/EO 13112, SAIA, CWA, NAISA	As needed	2014	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.4.1 Invasive Species	Joint–Port and Navy	00242NR015- San Diego Bay Marine Invasive Species Plan & Implementation	**Invasive Species Monitoring and Detection Program & Protocol Development for Reporting and Response to Detection.** Pursue detection measures to monitor for invasion of bay habitats by nonindegenous invasives such as Spartina densiflora, Caulerpa spp. Conduct a pilot project to demonstrate rapid response to new invasions of aquatic species.	ERL 2	TAC Top Nine	1/PPA, SAIA, EO 13112, California NAIS laws	Annually	2014	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
7.2.7 Data Management and Reporting/Improved Information Access Initiative									

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6.3 Data Integration, Access, and Reporting	Joint–Port and Navy	00242MR090- SW Regional Marine Resources Plan	**San Diego Bay On-line Database.** Create a centralized location to support a consistent approach to analyzing the cumulative effects of projects, including sea level rise. A central database that includes GIS Layers from all research projects should be created for multiple users to help distribute data for future projects and analysis. Could link to existing databases. Make publications and report monitoring results readily available to agencies and public. Identify an independent organization to manage data archiving and make data available. A central clearinghouse should be set up for reports and publications on the bay's natural resources, and water and sediment quality, that is accessible to a broad range of users. Develop a web based or other central repository for data sets and summary reports about the bay to facilitate access for students and environmental educators.	ERL 2	N/A	2/ SAIA, DQA, EO 13547, DODI 4715.03	Annually	2016	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 5. Team Adequacy 6. Ecosystem Integrity
6.3 Data Integration, Access, and Reporting	Joint–Port and Navy	00242MR114- San Diego Bay Outreach Symposium	**San Diego Bay Symposium.** Biennial conference on San Diego Bay health and research, including ecological Indicators, "State of the Bay" monitoring, and studies.	ERL 2	N/A	2/SAIA DODI 4715.03	Biennial	Navy-hosted: 2009 Port-hosted: 2012	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity
Projects Not Part of an Initiative but Addressing INRMP Objectives in Order of Listing in Chapters 4-6									
6.2.1 Long Term Monitoring Bay Condition and Trend	Joint–Port and Navy	00242NR014- San Diego Bay Eelgrass Monitoring and Mitigation Bank Plan	**Long-term Trend Eelgrass Habitat and Bank Monitoring.** Conduct bay-wide eelgrass mapping every 3-5 years.	ERL 4	N/A	1/CWA, MSA	Every 5 years	Ongoing since 1994	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
4.2 Mitigation and Enhancement	Joint–Port and Navy	N/A	**Cooperative Mitigation Management and Banking Plan.** Conduct the necessary pre-planning and develop agreements with regulators whereby mitigation for a series of projects may be combined for the purpose of accomplishing a larger or more ecologically effective project. This is a form of mitigation banking.	N/A	TAC Top Nine	1/CWA, ECWA, FWCA, EO 11990, DODI 4715.03	One-time occurrence	2012	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity

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							Frequency	Year	
4.4.2 Plankton	Navy	00242MAR04- San Diego Bay Plankton Inventory	**Bay Plankton Community Baseline, Primary Production Monitoring & Trend Analysis.** Long term investigations of bay plankton should be conducted in a way that allows integration with plankton studies in coastal waters and those of other bays. Studies to investigate plankton population dynamics, productivity, and human impacts in the bay should be funded to increase knowledge that could be applied to effective management. Because of the dependence of the bay food web on plankton, filling this knowledge gap is considered a critical need.	ERL 3	N/A	2/ESPA, DODI 4715.03	Every 5 years	2011	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
4.4.2.1 Algae 4.4.2.2 Invertebrates	Navy	00242MR104- San Diego Bay Algae Management Plan	**Algae: Ecological and Bay Productivity Role Analysis.** Fill in important information gaps that contribute to understanding algae's contribution to ecosystem health. Combine invertebrate studies with quadrat sampling for algae or seek to improve the understanding of the relative importance of the role played by algae in salt marsh productivity. Investigate alternative structure designs to compare abundance and diversity of invertebrate and algae populations.	ERL 2	N/A	2/ESPA, MSA, EO 11990, DODI 4715.03	Every 5 years	2016	1. INRMP Project Implementation 6. Ecosystem Integrity
4.4.3 Fishes	Joint–Port and Navy	00242NR012- San Diego Bay Fisheries Inventory	**Fish abundance, health, and habitat monitoring with implications for recreational fisheries.** Continue 5 year inventories and successful management strategies, and implement others, for habitats that function as nurseries for fish. Assess the abundance, diversity, and biomass of fish occupying various habitats including artificial structures.	ERL 3	TAC Top Nine	1/MSA, SAIA, EO 11990, 12962, DODI 4715.03	Every 3 years	Ongoing since 1994	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.4.3.1 Harvest Management	Joint–Port and Navy	00242MR116- San Diego Bay Marine Resources Outreach	**Fishery Education & Outreach.** Support effective enforcement of existing state and federal fishery management regulations by supporting better public education about the need for fishing regulations and by supporting improved publicity and deterrents.	ERL 3	N/A	3/SAIA	As needed	2013	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.3.4 Birds	Joint–Port and Navy	00242NR013- San Diego Bay Waterbird Survey	**SD Bay Avian and Habitat Monitoring Survey.** Establish a long-term standardized population and habitat monitoring program throughout the bay in coordination with current local, regional and national bird surveys and conservation initiatives. Habitat monitoring should consist of a comprehensive habitat classification system that clearly defines habitat subsets used on a recurring basis by bay birds. It should help prioritize bird species groups and associated habitats most in need of future management and conservation. Avian and habitat monitoring and bay-wide efforts should be conducted every 3 or 6 years.	ERL 3	N/A	1/MBTA, MSA, SAIA, ECWA, ESPA, EO 11990, 13186, 13547	Every 3 years	Ongoing since 1995	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity

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							Frequency	Year	
4.3.5 Marine Mammals	Navy	63406NR019- San Diego Bay Marine Mammal Survey	**SD Bay Mammal Use Analysis and Monitoring Program.** Asses the population, distribution, and time of use over a four- to five-year period for bottlenose dolphins, grey whale, Pacific harbor seal, and California sea lion; reevaluate their status in the bay every 3-5 years. Describe haul out sites, rest areas, feeding areas, and patterns of use for pinnipeds and feeding and rest area patterns for dolphins.	ERL 4	N/A	2/MMPA, SAIA	Annually for 4-5 years; reevaluated every 3-5 years	2007	1. INRMP Project Implementation 6. Ecosystem Integrity
4.4.6.1 Green Sea Turtle	Joint–Port and Navy	00242MR117- San Diego Bay Green Sea Turtle Monitoring	**East Pacific Green Sea Turtle Joint Research Program.** Determine the population status in the bay and identify the turtles' seasonal and migratory movements within and outside the bay. Conduct presence/absence study to determine whether turtles are foraging in IR sites or adjacent to operational areas. Monitor using GPS, satellite and data recorders.	ERL 3	N/A	1/ESA, SAIA	Annually	2007	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 5. Team Adequacy 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
6.2.1 Long Term Monitoring Bay Condition and Trend	Navy	00242SWC11- San Diego Bay Gull Billed Tern Management	**Gull-billed Tern Foraging Analysis.** Analyze gull-billed tern foraging in the bay, especially in reference to the California least tern, and including a management plan that addresses predation on the least tern.	ERL 4	N/A	1/ESA	As needed	2011	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
4.4.6.2 California Least Tern	Joint–Port and Navy	00246J100G	**Conduct a Population Viability Analysis for the California Least Tern.**	ERL 4	N/A	1/ESA	As needed	Ongoing	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
5.3 Watershed Approach 5.3.2 Storm Water Management	Joint–Port and Navy	00245EC002- Storm Drain Markers NBSD 00246DF001- Storm Drain Markers NBC 63406SDTAG- Storm Drain Labeling NBPL	**Storm Drain Labeling.** Support the completion and maintenance of storm drain stenciling around the bay's watershed including on Navy properties to alert the public of the endpoint of any dumping in storm drains.	ERL 4	N/A	2/CWA	As needed	Ongoing since 2002	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.6 Environmental Education	Joint–Port and Navy	00242MR115- San Diego Bay Green Sea Turtle and CA Least Tern Sign 00242MR116- San Diego Bay Marine Resources Outreach	**Mid-San Diego Bay Interpretive Center.** Develop outreach displays that explain the economic benefits of a healthy bay to the public and decision makers. Use Chesapeake Fish Company and nearby sites for Interpretive Facility.	ERL 3	N/A	3/SAIA, DODI 4715.03	As needed	2009	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use

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5.6 Environmental Education	Port	N/A	Kids in Canyons watershed and pollution prevention education.	N/A	N/A	3/CWA	As funding provides	2006-2010	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 5. Team Adequacy
5.6 Environmental Education	Port	N/A	Green Restaurant Seminar.	N/A	N/A	3/EO 13423	One-time occurrence	2007	1. INRMP Project Implementation 3. Partnership Effectiveness
5.6 Environmental Education	Port	N/A	Sponsor creation of children's wetlands book.	N/A	N/A	3/EO 11990	One-time occurrence	2007	1. INRMP Project Implementation 3. Partnership Effectiveness
5.6 Environmental Education	Port	N/A	Environmental bay tours on harbor boats.	N/A	N/A	3/EO 11990	Annually	2009	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use
5.6 Environmental Education	Joint–Port and Navy	00242NR015- San Diego Bay Marine Invasive Marine Species Identification	High school students to study biology of San Diego Bay. Partner with various high schools to implement projects in the San Diego Bay that allow student interaction and learning.	ERL 2	N/A	3/EO 11990	As needed	Navy: 2009-2011 (invasive species identification project) Port: 2006-2016 (publication of annual books)	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity
5.6 Environmental Education	Port	N/A	Habitat Heroes-wetlands education.	N/A	N/A	3/EO 11990	One-time occurrence	2007-2008	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
5.6 Environmental Education	Port	N/A	Project SWELL Watershed education.	N/A	N/A	3/CWA	Annually	2006-2013	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.3.9 Upland Transitions	Port	N/A	Landscape designs award system and brochure. Promote an award system for best use of appropriate landscape designs adjacent to the bay. Encourage native and water-conserving landscape designs (bay-scaping) that minimize use of pesticides and fertilizers on properties adjacent to the bay to enhance habitat value, prevent pollution, conserve water, and control exotic introductions. Produce and disseminate a brochure on appropriate landscaping for bayside properties, using existing materials and demonstration gardens as a start.	N/A	N/A	2/NAISA, PPA, EO 13423	As needed	2005 Ongoing annual Integrated Pest Management Seminar	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity

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INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
5.6 Environmental Education	Port	N/A	**Support Ecotourism by expanding interpretive activities.** Take advantage of interpretive opportunities where and how people currently access the bay. Involve municipalities in developing a regional "Walk of Discovery" map that shows bay access and points of interest. Also target bicyclists. Create observation decks and boardwalks, where appropriate and compatible, to improve bird-watching possibilities and appreciation of the bay's environment.	N/A	N/A	3/EO 13186	As needed	2020-2025	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use
5.6 Environmental Education	Joint–Port and Navy	N/A	Environmentally friendly footpath in La Playa.	N/A	N/A	2/NAISA, PPA, EO 13423	One-time occurrence	2006	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
5.6 Environmental Education	Port	N/A	**Bay Art.** Promote appreciation of San Diego Bay's native wildlife and habitats through public art: unique tourist postcards, children's coloring books, posters, art contests, murals on buildings, statues in public areas, and other forms of public art.	N/A	N/A	3/EO 13186	As needed	2014-2020	1. INRMP Project Implementation
5.2.1 Dredge and Fill	Joint–Port and Navy	N/A	Post dredging recolonization study for five years.	N/A	N/A	2/CWA	One-time occurrence	2004-2010	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.4.2 Oil Spill Prevention and Response Planning	Navy	00242NOSC1	**Oil Spill Prediction and Response Research.** Support a cooperative research program based on USGS' Physical Oceanography Real-time System to enhance oil spill prediction and response, understand what drives sediment redistribution, and analyze compatible use of boat traffic/recreational water contact users in the bay. Use the Navy's hydrodynamic model of the bay to create results for multiple oil spill scenarios as readily available "look up tables" that can be used by the regional Navy Operation and Support Centers during spills. This will provide quick views of the likely transport of oil under a variety of conditions for quicker response.	ERL 4	N/A	2/CWA, OPA, DODI 4715.03	Ongoing	2012	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity
6.2.1 Long-term Monitoring	Port	N/A	Geotechnical and fault study throughout San Diego Bay.	N/A	N/A	2/SAIA	As needed	2011-2013	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity

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Federal Executive Orders:
11988 - Floodplain Management; 11990 - Protection of Wetlands; 12962 - Recreational Fisheries; 13112 - Invasive Species; 13186- Protection of Migratory Birds; 13423 - Strengthening the environmental, energy, and transportation management of federal agencies in the United States; 13547 - Stewardship of the Ocean, Our Coasts, and the Great Lakes; 13514 - Federal Leadership in Environmental, Energy, and Economic Performance

Other Instructions and Federal Laws:
ASN Memo 2007 - Assistant Secretary of Navy Memorandum (2007) on use of Low Impact Development Technology for Stormwater Management; CERCLA - Comprehensive Environmental Response, Compensation and Liability Act; CWA - Clean Water Act; CZMA - Coastal Zone Management Act; DODI 4715.03 - Department of Defense Instruction March 2011: Natural resources Conservation Program; DQA - Data Quality Act; ECWA - Estuaries and Clean Water Act of 2000; ESA - Endangered Species Act; EsPA - Estuary Protection Act; FWCA - Fish and Wildlife Coordination Act; MBTA - Migratory Bird Treaty Act; MMPA - Marine Mammal Protection Act; MSA - Magnuson Stevens Fishery Conservation and Management Act, as amended through 2007; NAISA - National Aquatic Invasive Species Act; NAVFACINST 10110.45 - Naval Facility Command Instruction Regional Planning Instruction on Sustainable Development; NAWCA - North American Wetlands Conservation Act; NMBCA - Neotropical Migratory Bird Conservation Act; OPA - Oil Pollution Act of 1990; OPNAVINST 5090.1D - Office of the Chief of Naval Operations Instruction Natural Resources Management; PPA - Plant Protection Act; SAIA - Sikes Act Improvement Act

Table 7-7. Integrated Natural Resources Management Plan Implementation Summary, including the assignment of priorities based on legal driver behind each project (Continued).

INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
4.4.3.2 Artificial Propagation	Port	N/A	**White Sea Bass Restocking Program.** Continue to participate in the Hubbs Research Institute project to restock the population of white sea bass.	N/A	N/A	3/EO 12962	One-time occurrence	2009-2012	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity

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Table 7-8. Projects identified as Navy or Port in-house funds, projects not programmed by Port or Navy (i.e, opportunistic or project-specific tasks), desired research projects for external funding, or outside Port and Navy funding streams. .

INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
5.1 Sustainable Ecosystem	N/A	N/A	**Establish sustainability leadership awards.** Reward excellence in water quality, habitat quality, transportation, and energy management.	N/A	N/A	3/ CWA, EO 13514	Annually	As funding becomes available	1. INRMP Project Implementation 3. Partnership Effectiveness
4.3.6 Salt Marsh	USFWS & San Diego Natural Wildlife Refuge	N/A	**Expand Salt Marsh at Gunpowder Point.**	N/A	N/A	2/ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	USFWS	N/A	**Enhance D Street Fill.** Augment an area of approximately 100 acres (40 ha) of dredge spoil from Sweetwater Channel. Enhancement potential: excavate additional tidal channels, and create additional intertidal (~25 to 30 acres/~10 to 12 ha). Potential credits available. Balance with need to maintain critical habitat for snowy plover.	N/A	N/A	2/ESA, ECWA, NMBCA, SAIA, NAWCA, CZMA, EO 11990, 13186	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
5.3 Watershed Approach 5.3.2 Storm Water Management	San Diego County	N/A	**Implement Otay Watershed Plan.**	N/A	N/A	2/CWA	As needed	As funding becomes available	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity

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Table 7-8. Projects identified as Navy or Port in-house funds, projects not programmed by Port or Navy (i.e, opportunistic or project-specific tasks), desired research projects for external funding, or outside Port and Navy funding streams. (Continued).

INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
4.2 Mitigation and Enhancement	USFWS & San Diego Natural Wildlife Refuge	N/A	**Restore Lower Otay River Wetlands.** Realign and broaden Otay River to a more natural configuration through Pond 20 and other Refuge property. Excavate 8 acres fresh-brackish pond, establish 44 acres of tidal salt marsh and channels, and another 40 acres of willow-riparian woodland and mudflat riparian scrub.	N/A	N/A	2/ESA, CWA, MSA, NAWCA, NMBCA, ECWA, MBTA, EO 11988, 11990, 13112, 13186, DODI 4715.03	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
5.3.2 Storm Water Management	City of San Diego	N/A	**Annual clean out of Switzer Creek catch basin.**	N/A	N/A	1/CWA	Annually	As funding becomes available	1. INRMP Project Implementation 3. Partnership Effectiveness 4. Fish and Wildlife Management and Public Use 5. Team Adequacy 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Joint–Port and Navy (In-House)	N/A	**Multi-user Dredge Spoil Disposal/Enhancement Site Identification.** To aid the effort to reuse dredge material in a beneficial way inside the bay a multi-user beneficial reuse site for habitat restoration or enhancement should be identified so that project sponsors from multiple jurisdictions may contribute jointly as dredge material accumulates. New locations for both upland and nearshore confined disposal sites should be investigated. These sites should combine habitat enhancement with nearshore confined disposal sites. Develop a comprehensive inventory of projects for the beneficial reuse of dredged material around the bay, Including broken concrete and other safe materials.	N/A	N/A	1/CWA, EO 11990	As needed	Project dependent	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity
6.3 Data Integration, Access, and Reporting	Joint–Port and Navy (In-House)	N/A	**Monitoring and Reporting Strategy for INRMP Projects.** Develop a suite of approaches for technical as well as public information distribution. Post report information on public websites.	N/A	N/A	2/CWA, ESA, MSA, DQA, EO 12962, DoDI 4715.03	Annually	Ongoing	1. INRMP Project Implementation 3. Partnership Effectiveness
5.1 Sustainable Ecosystem 5.3.2 Storm Water Management	Joint–Port and Navy	N/A	**Increase the use of recycling funds to prevent and clean up trash build-up.** Prevent waste and encourage recycling to reduce the amount of trash in San Diego Bay and along its shorelines.	N/A	N/A	1/CWA, EO 13514, OPNAVINST 5090.1D	Annually	Ongoing	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.1 Sustainable Ecosystem 5.3.2 Storm Water Management	Joint–Port and Navy	N/A	**Bay BMP Effectiveness Analysis & Handbook for LID/LEED.** Create a user-friendly handbook for both tenants and project managers that offers resources and recommendations for low-impact development with regard to water use, energy use, and pollution control.	N/A	N/A	1/MSA, ECWA, EO 13514, 13423, NAVFACINST 10110.45, ASN Memo 2007	Updated as needed	2015	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
5.1 Sustainable Ecosystem 5.3.2 Storm Water Management	Joint–Port and Navy	N/A	**Train Port and Navy staff in sustainability design review.** Conduct training in sustainable design criteria cooperatively between the Port and the Navy for engineers, construction and design specialists, water quality specialists, and marine biologists. This could be web-based training.	N/A	N/A	2/MSA, ECWA, EO 13514, 13423, NAVFACINST 10110.45, ASN Memo 2007	As needed	Ongoing	1. INRMP Project Implementation 5. Team Adequacy 6. Ecosystem Integrity

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INRMP Management Strategy	Potential Funding Source	EPR Project Code	Project Description	Budget Priority/ Class Level	TAC Rank	Legal Driver	Implementation		Natural Resources Metric Builder, Measure of Success, or Desired Resource Condition
							Frequency	Year	
4.2.2 Mitigation/Enhancement	Joint–Port and Navy	N/A	**Artificial Hard Substrate Management and Minimization Plan.** Determine the ecological functioning of the bay's artificial habitats in relation to other habitats, to develop better conservation and enhancement priorities. Identify and prioritize desired ecological function of artificial structures including 1) trophic support for native fishes and birds, 2) habitat for migratory birds, 3) nursery/refugia for subtidal species, and 4) habitat for endangered and other special status species. Establish general guidelines for shoreline structures for environmental compatibility. Bank stabilization should be located, designed, and constructed primarily to prevent damage to existing development and new development should be located and designed to prevent or minimize the need for shoreline stabilization measures.	N/A	N/A	2/SAIA, ESPA, ECWA, MSA, CERCLA, CWA, CZMA, OPA, EO 13547, ASN Memo 2007	Updated as needed	As funding becomes available	1. INRMP Project Implementation 3. Partnership Effectiveness 5. Team Adequacy 6. Ecosystem Integrity
4.4.3 Fishes	Joint–Port and Navy	N/A	**Expand Fisheries Habitat.** As opportunities (e.g., mitigation) arise within individual projects (e.g. construction/ facilities), fisheries habitat should be created/expand.	N/A	N/A	2/MSA, EO 11990, 12962, 13547	Opportunistically	Opportunistically	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
4.2 Mitigation and Enhancement	Navy	N/A	**Improve NTC boat channel.** Soften the shoreline by excavation, or otherwise provide ecologically beneficial shoreline structures. Improve wetland-upland transition (vegetated swales or water treatment channels for runoff).	N/A	N/A	2/SAIA, PPA, MBTA, MSA, EO 13186, DODI 4715.03, ASN Memo 2007	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 6. Ecosystem Integrity
5.3.2 Storm Water Management 5.2.2 Receiving Water Monitoring & Trend Analysis	Joint–Port and Navy	N/A	**Background Versus Anthropogenic Turbidity Research.** Perform study on turbidity effects from vessel traffic (including tugs, LCACs, etc.), construction, and dredging projects on biological resources.	N/A	N/A	1/CWA, ECWA, ESPA	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 6. Ecosystem Integrity
5.4.1 Remediation of Contaminated Sediments	Joint–Port and Navy	N/A	**Sediment Quality Monitoring.** Perform sediment quality monitoring to evaluate spatial distributions and long-term trends. Include measures of COCs, toxicity, and bioaccumulation in bivalve tissues. Relate the effects of toxics and their severity to health of infaunal assemblages, and associated substrate or water quality conditions.	N/A	N/A	1/CWA	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 6. Ecosystem Integrity
4.3.10 River Mouths and Floodplains	Joint–Port and Navy	N/A	**Restoration of River Mouths Feasibility Study.** Conduct a feasibility study for the restoration of missing river functions, such as increased freshwater and sediment flow. This should be conducted on a project by project basis.	N/A	N/A	2/ECWA, EO 11988, 11990, 13112, 13186, 13547	As needed	Project dependent	1. INRMP Project Implementation 4. Fish and Wildlife Management and Public Use 6. Ecosystem Integrity
6.2.1 Long Term Monitoring Bay Condition and Trend	Navy	N/A	**Install remote video cameras.** On the Silver Strand least tern colony and on osprey platform for webcam to observe predator patterns.	N/A	N/A	1/ESA	Annually	As funding becomes available	1. INRMP Project Implementation 2. Listed Species and Critical Habitat
5.4.2 Oil Spill prevention and cleanup	Navy (In-House)	N/A	**Update NRDA Guide and ACP.** Revise 2008 plan as needed to identify specific locations, methodologies, and responsibilities for data collection in the event of an oil spill.	N/A	N/A	1/OPA, SAIA	As needed	2013	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity

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							Frequency	Year	
5.4.2 Oil Spill Prevention and Planning 6.2.1 Long Term Monitoring Bay Condition and Trend	Navy (In-House)	N/A	**Bay Plan Integration With Existing Planning Documents.** Develop and integrate Ephemeral Data Collection Plan and NRDA Plan into SD Bay INRMP. Develop training to support plan.	N/A	N/A	2/SAIA, OPA, DQA, DODI 4715.03	As needed	2013	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity
4.3.6 Salt Marsh	Joint–Port and Navy	N/A	**Salt Marsh Sustainability Study.** Investigate the hydrologic requirements of salt marsh plants and animals, including minimum water depth, hydroperiod, the role of El Nino and sea level rise.	N/A	N/A	2/SAIA, EO 11990, 13112, 13186	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 6. Ecosystem Integrity
4.4.4 Birds	Joint–Port and Navy	N/A	**Avian Carrying Capacity Study.** Conduct research in support of increasing the bay's carrying capacity for shorebirds and other birds. Develop cost-effective, standardized survey protocol across species groups and habitats. Improve understanding of how each bay habitat functions to support avian species. Investigate shorebird partitioning in microhabitats of intertidal mudflats. Identify and monitor juvenile and larval fish populations and other prey bases within the bay.	N/A	N/A	2/MBTA, NMBCA, NAWCA, ECWA, SAIA, EO 11990, 13186	As needed	As funding becomes available	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 6. Ecosystem Integrity
4.4.4 Birds	Navy	N/A	**Avian Foraging Study.** Conduct direct observation studies of avian foraging. Study the habitat and feeding dependencies of sensitive species dependent on coastal waters. Investigate the direct and indirect effects of shoreline stabilization structures on remaining priority bird habitats.	N/A	N/A	2/MBTA, EO 13186	As needed	California Least Tern Foraging Study 2008-2010	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 6. Ecosystem Integrity
4.2 Mitigation and Enhancement 6.2.2 Project Monitoring	Joint–Port and Navy	N/A	**Improved Permit Monitoring Program.** Improve the effectiveness of monitoring related to permits so that it may provide insight on mitigation priorities and protocols beyond the scope of the project for which it is implemented by encouraging public-private partnerships to research design and implementation.	N/A	N/A	2/SAIA	As needed	As funding becomes available	1. INRMP Project Implementation
4.2 Mitigation and Enhancement	Navy	N/A	**Enhance North Delta/NAB/Least Tern Nesting Shoreline.** Reconstruct mudflat.	N/A	N/A	1/ESA, EO 11990	One-time occurrence	As funding becomes available	1. INRMP Project Implementation 2. Listed Species and Critical Habitat 6. Ecosystem Integrity 7. INRMP Impact on Installation Mission
6.2.1 Long Term Monitoring Bay Condition and Trend	Joint–Port and Navy	N/A	**Coordinated Long Term Ecological Trends Analysis and Monitoring Plan including NRDA sites.** Target management species should be selected that represent particular habitats, processes, and interdependencies or vulnerabilities in the bay. Develop and adopt means to use bay monitoring data in a coordinated manner that will avoid conflict and duplication of effort, such as: establishing a set of permanent monitoring stations throughout the bay for sediment and water column sampling or identifying and sampling for functional ecological groups meaningful to management objectives.	N/A	N/A	2/SAIA, OPA, DQA, DODI 4715.03	Update as needed	As funding becomes available	1. INRMP Project Implementation 3. Partnership Effectiveness 6. Ecosystem Integrity

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7.8 INRMP Annual Review and Metrics

The natural resources managers of local Navy bases and the bay conduct an annual review of INRMP implementation with its agency partners. DoD policy requires installations to review INRMPs annually in cooperation with the two primary partnering parties to the INRMP: USFWS and the state fish and wildlife agency. Annual reviews facilitate "adaptive management" by providing an opportunity to review the goals and objectives of the plan. In addition to tracking the implementation of the INRMP, an annual report is to be provided that briefly summarizes the project and activities that have been implemented during the fiscal year and how these fulfill the objectives identified in the INRMP.

Section 101(b)(2) of the Sikes Act [16 USC 670a(b)(2)] specifically directs that the INRMPs be reviewed "as to operation and effect" by the primary parties "on a regular basis, but not less often than every five years," emphasizing that the review is intended to determine whether existing INRMPs are being implemented to meet the requirements of the Sikes Act and contribute to the conservation and rehabilitation of natural resources on military installations.

The Annual Review process is broadly guided by the Real Estate Manual (DOD 4715.DD-R 1996) and by OPNAVINST 5090.1C, Environmental and Natural Resources Program Manual, 3 October 2007. Policy memoranda in 2002, and supplemented in 2004, clarified procedures for INRMP reviews and revisions:

- Deputy Undersecretary of Defense for Installations and the Environment Policy Memo 10 October 2002, which replaced a 1998 policy memorandum.
- Assistant Deputy Undersecretary of Defense for Environment, Safety and Occupational Health Policy Memo (1 November 2004).

The INRMP Implementation Guidance (10 October 2002 Memo) improved coordination external to DoD (USFWS, state agencies, and the public) and internal to DoD (military operators and trainers, cultural resources managers, pest managers). It also added new tracking procedures, called metrics, to ensure proper INRMP coordination occurred and that projects were implemented.

The 2002 guidance also required that each installation provide a notice of intent to prepare or revise the INRMP. Each military installation now must request that USFWS and the state fish and wildlife agency participate in both the development and review of the INRMPs. To eliminate confusion about where and when coordination with USFWS should occur, current coordination guidelines clarify that the USFWS field office is the appropriate entry point for military installations, and the USFWS Regional Sikes Act Coordinator is the liaison to facilitate INRMP review.

The Supplemental DoD INRMP Guidance (1 November 2004 Memo) further defined the scope of the annual and five-year review, public comment on INRMP reviews, and ESA consultation. A formal review must be performed by "the parties" at least every five years. Informal annual reviews are mandatory to facilitate adaptive management, during which INRMP goals, objectives, and "must fund" projects are reviewed, and a realistic schedule established to undertake proposed actions.

There is no legal obligation to invite the public either to review or to comment upon the parties' mutually agreed upon decision to continue implementation of an existing INRMP without revision. If the parties determine that substantial revisions to an INRMP are necessary, public comment shall be invited in conjunction with any required NEPA analysis.

In most cases INRMPs will incorporate by reference the results of an installation's previous species-by-species ESA consultations, including any reasonable and prudent measures identified in an incidental take statement. Neither a separate biological assessment nor a separate formal consultation should be necessary. Nonetheless, because the INRMP may include management strategies designed to balance the potentially competing needs of multiple species, it may be prudent to engage in informal consultation.

Natural Resources **Metrics Builder**

A Quick-Start Guide to the Natural Resources Metrics Builder:

The Natural Resources Metrics Builder has been developed to provide a standard method for the collection and reporting of business metric information for Natural Resources programs. The metrics are used to determine how well we are doing with respect to Natural Resources management and INRMP implementation across Navy/USMC installations.

The Metrics Builder is comprised of seven focus areas. These focus areas include:

1. INRMP Project Implementation
2. Listed Species and Critical Habitat
3. Partnership Effectiveness
4. Fish and Wildlife Management and Public Use
5. Team Adequacy
6. Ecosystem Integrity
7. INRMP Impact on the Installation Mission

Each focus area has three to seven criteria that have been established by Natural Resources managers and will be used to help determine the status of a given functional area within Natural Resources.

1. To begin using Metrics Builder, first select an installation, and then one of the seven focus areas. This will display a scorecard.

2. Next, for the applicable focus areas, please verify that the list of items or indicators in the left-hand column of the scorecard is valid and corresponds to the installation being reviewed.

NOTE: Check only those indicators that apply within the following focus areas:
Partnership Effectiveness, Team Adequacy, and Ecosystem Integrity. All indicators will not apply to all installations.

3. Provide scores as appropriate for each indicator within the focus area with 4 being the highest possible score. The review team should reach a consensus before a score is determined. The review team should discuss, determine, and select the appropriate score under each question on the scorecard. Click on the headings for definitions and explanations related to each question.

If a question does not match up with an indicator in the left-hand column, please select > NA (Not Applicable) in order to skip a question or indicator that does not apply to your installation.

4. When a scorecard is complete, simply select "Submit Scores" at the bottom of the scorecard.

5. The scores are tallied up for each indicator, and an overall weighted score is calculated for the focus area. A color of red, green, or yellow is assigned to each focus area.

Green scores indicate a satisfactory score.
Yellow scores indicate areas of concern that may require further attention or actions.
Red scores indicate potential problem areas that require added attention or actions.

Please complete the entire score cards for each focus area as it pertains to a given installation.

6. **IMPORTANT**: In the case of a yellow or red score, please provide a description of the issue or concern that may require further attention in the "Findings and Recommendations" section.

Figure 7-4. U.S. Navy "Metrics Builder" for collaborative resource agency/Navy annual review of INRMP implementation.

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Appendix A: Acronyms and Abbreviations

Acronym/Abbreviation	Definition
ACH	America's Cup Harbor
ACP	Area of Contingency Plan
AIS	Aquatic invasive species
at/l	atmosphere per liter
BMP	Best Management Practice
BO	Biological Opinion
BPC	Board of Port Commissioners
CalCOFI	California Cooperative Oceanic Fisheries Investigations
Cal-IPC	California Invasive Plant Council
CCA	California Coastal Act
CCC	California Coastal Commission
CCMP	California Coastal Management Plan
CCP	Comprehensive Conservation Plan
CDBW	California Department of Boating and Waterways
CDFA	California Department of Food and Agriculture
CDFG	California Department of Fish and Game
CDPH	California Department of Public Health
CDPR	California Department of Parks and Recreation
CDWR	California Department of Water Resources
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cm	centimeter
CNDDB	California Natural Diversity Data Base
CNPS	California Native Plant Society
CNRSW	Commander, Navy Region Southwest
CO_2	carbon dioxide
COC	contaminants of concern
CSD	City of San Diego
CVWR	Chula Vista Wildlife Reserve
CWA	Clean Water Act
CZARA	Costal Zone Act Reauthorization Amendments
CZMA	Coastal Zone Management Act
DDT	Dichloro-diphenyl-trichloroethane
DoD	U.S. Department of Defense
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ENSO	El Niño Southern Oscillation
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPR	Environmental Program Requirements
ERL	effect range low
ERL	Environmental Readiness Level
ERM	effect range medium
ESA	Endangered Species Act

Acronym/Abbreviation	Definition
F	Farenheit
F&G	Fish and Game Code
FISC	Fleet and Industrial Supply Center
FMP	Fishery Management Plans
GIS	Geographic Information Systems
ha	hectare
INRMP	Integrated Natural Resources Management Plan
IPCC	Intergovernmental Panel on Climate Change
JURMP	Jurisdictional urban runoff management plans
kg	kilograms
km	kilometer
km2	square kilometers
LCP	Local Coastal Plan
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
m	meters
m3	cubic meters
MBTA	Migratory Bird Treaty Act
MEC	Marine Ecological Consultants
mg/l	miligrams per liter
MHHW	Mean Higher High water
mi	miles
mi2	square miles
MLLW	mean lower low water
MLMA	Marine Life Management Act
mm	millimeter
MMPA	Marine Mammal Protection Act
MOU	Memorandum of Understanding
MPA	Marine Protected Area
mpn	most probable number
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSCP	Multiple Species Conservation Plan
mt	metric tons
NAB	Naval Amphibious Base
NANPCA	Nonindigenous Aquatic Nuisance Prevention and Control Act
NASNI	Naval Air Station North Island
NASSCO	Naval Steel and Shipbuilding Company
NAVFAC	Navy Facilities Engineering Command Southwest
NBC	Naval Base Coronado
NBPL	Naval Base Point Loma
NBSD	Naval Base San Diego
NEMS	Navy Eelgrass Mitigation Sites
NEPA	National Environmental Policy Act
NFMP	Nearshore Fishery Management Plan
NISA	National Invasive Species Act
NMFS	National Marine Fisheries Services
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Services
NRDA	natural resources damage assessment
NRRF	Naval Radio Receiving Facility
NTC	Naval Training Center
NWR	National Wildlife Refuge
OPA	Oil Pollution Act

Acronym/Abbreviation	Definition
OREHP	Ocean Resources Enhancement and Hatchery Program
OSPR	Office of Spill Prevention and Response
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PDO	Pacific Decadal Oscillations
PERL	Pacific Estuarine Research Laboratory
PFMC	Pacific Fishery Management Council
PL	Public Law
Port	Port of San Diego
ppm	parts per million
psu	practical salinity unit
RHMP	Regional Harbor Monitoring Program
RSIP	Regional Shore Infrastructure Plan
RWQCB	Regional Water Quality Control Board
SAIA	Sikes Act Improvement Act
SAIC	Science Applications International Corporation
SAMP	Special Area Management Plan
SANDAG	San Diego Association of Governments
SB	Senate Bill
SCB	Southern California Bight
SCCWRP	Southern California Coastal Water Research Project
SDCVB	San Diego Convention Visitors Bureau
SDG&E	San Diego Gas & Electric Company
SDRWPCB	San Diego Regional Water Pollution Control Board
SDSU	San Diego State University
SL	standard length
SLC	State Lands Commission
SMNWR	Sweetwater Marsh National Wildlife Reserve
SPAWAR	Space and Naval Warfare Command
SQO	sediment quality objective
SSC	Space and Naval Warfare Systems Center
SSTC	Silver Strand Training Complex
SUBASE	Submarine Base
SWAMP	Surface Water Ambient Monitoring Program
SWELL	Stewardship: Watershed Education Learning & Leadership
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TBT	tributyltin
TDI	Tierra Data Inc.
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	Total Organic Carbon
UCCE	University of California Cooperative Extension
ug	micrograms
ug/L	micrograms per liter
URMPs	urban runoff management plans
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Services
USGS	U.S. Geological Survey

Acronym/Abbreviation	Definition
VRG	Vantuna Research Group
WAP	Wildlife Action Plan
WMA	Watershed Management Area
WMI	Watershed Management Initiative
WQS	Water Quality Standards

Appendix B: Glossary

Abiotic
A non-living component of the environment.

Adaptive Management
A dynamic planning process that recognizes that the future cannot be predicted perfectly. In response to these imperfect predictions, planning and management strategies are modified frequently as better information becomes available. It is a continuous process requiring constant monitoring and analysis of past actions, which are then fed back into current decisions.

Algae
Any of several groups of autotrophs (organisms that produce organic material from inorganic chemicals and energy) that lack the structural features (true leaves, roots, and stems) of the higher plants.

Annual Increment
A management section addendum, prepared annually, to facilitate implementation of a Natural Resource Management Plan section. The annual increment concisely provides detail and cost estimates of proposed work or projects to be accomplished during a fiscal year.

Artificial Hard Substrate
An artificial habitat that may consist of rock riprap, seawalls, pier pilings, floating docks, mooring systems, and derelict ships/ship parts.

Assessment
An evaluation that can be based on a single measurement or observation, or can incorporate a series of observations to obtain a better estimate of a particular parameter; often an assessment or inventory serves as the first step towards establishing a monitoring project.

Baseline
Serving as a basis, such as for a survey.

Bathymetry
The science of mapping the contours of ocean floors or lake beds.

Bayscaping
Appropriate native and water-conserving landscaping designs.

Beaches and Dunes
Habitats along the shoreline that are subject to wind and wave turbulence, salt spray, shifting sands, high temperatures, and desiccation.

Benthic
Occurring or related to the bottom of the sea.

Benthos
All bottom habitats from intertidal to deeper dredged channels.

Best Management Practices
Practical, economical and effective management or control practices that will reduce or prevent water pollution. Usually applied as a system of practices based on site-specific conditions rather than a single practice. They are usually prepared by state agencies for land disturbing activities related to agriculture, forestry, and construction.

Bight
A bend or curve in the coastline.

Bioaccumulation
A measure of bioavailability and thereby the potential for chronic or food web effects of sediment contaminants in long-term exposures.

Biodiversity
The diversity of life and its processes; living organisms, the genetic differences among them and the communities and ecosystems in which they occur.

Biological Assessment
A biological evaluation conducted as part of the interagency regulations under the Endangered Species Act. The purpose of the assessment is to allow the regulatory agency to determine whether or not the proposed action is likely to adversely affect the continued existence of a species listed as endangered or threatened, or proposed for listing.

Biological Integrity
A balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region.

Biomass
The total weight of living organisms.

Biotic	A living component of the environment.
Bittern	The bitter liquid left after the crystallization of salt from brine.
Bloom	A sharp increase in the population of phytoplankton, as often occurs in the spring, summer, or fall in different parts of the bay.
Brackish	Somewhat salty, but not as saline as open ocean water.
Candidate Species	Any species being considered by the Secretary of Interior or Commerce for listing under the Endangered Species Act as an endangered or a threatened species, but not yet the subject of a proposed listing.
Cetaceans	Marine mammals with extreme adaptations: the presence of a “blowhole” on the apparent top of the head, flippers as anterior swimming appendages, and horizontal flukes as posterior swimming appendages.
Chlorophyll	A green photosynthetic pigment.
Coastal Created Lands and Disturbed Uplands	Habitats created by deposition of dredged sediments from other locations.
Coastal Zone	An area specifically identified by a coastal state in its approved Coastal Zone Management Plan. It is an area of coastal waters and adjacent shorelines strongly influenced by each other, including islands, transitional and intertidal areas, salt marshes, wetlands, and beaches. Excluded from the coastal zone are lands solely subject to or held in trust by the federal government, its officers or agents.
Coliform	A group of bacteria found in the large intestine of humans and other warm-blooded animals. Coliform counts are used to determine the degree to which water has been polluted by sewage.
Consensus	A decision-making process in which all parties involved explicitly agree on the final decision. Consensus decision making does not mean that all parties are completely satisfied with the final outcome, but that the decision is acceptable to all because no one feels that his or her vital interests or values are violated by it.
Conservation	The prudent care, protection, and management of natural resources that best reflect sound resources stewardship for present and future generations.
Copepod	A type of small, crustacean zooplankton.
Creosote	An oil, found in pier pilings, from which polycyclic aromatic hydrocarbons are released.
Critical Habitat	The geographic area in which are found those physical or biological features essential to the conservation of a species listed and published by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service under the authority of the Endangered Species Act.
Crystallizer	Salt ponds with highest salinity content. Final stage of salt extraction process.
CVN	Part of the Navy’s new, more modern fleet of deep-draft ships powered by nuclear energy.
Deep Subtidal	Bay habitat deeper than the approximate margin of the maintained channels (>20 feet [6 m]), and including the bottom sediments to the water surface.
Demersal Fish	Bottom-dwelling fish.
Deposit Feeders	Animals that ingest detritus and associated bacteria accumulating on and within the sediment.
Detritus	Fresh to partly decomposed plant and animal matter.
Diatoms	Single-celled algae with a two part, perforated, silicious shell. Diatoms are the most common type of phytoplankton in the estuary.
Dinoflagellate	A unicellular organism with two unequal flagella.

Dissolved Oxygen
The concentration of oxygen in water at a specified temperature and atmospheric pressure. It is used as a measure of the water's ability to support aquatic life. Low concentrations do not support fish or similar organisms.

Dredge Spoil
Bottom sediments or materials that have been excavated from a waterway.

Ecosystem
A unit of land or water comprising populations of organisms considered together with their physical environment and the interacting processes between them.

Ecosystem Function
Interacting processes by component parts and their environment. Without the vital processes, the system is dysfunctional or nonfunctional.

Ecosystem Management
Ecosystem management in the Department of Defense draws on a long-term vision of desired future ecological conditions, integrating ecological, economic and social factors. The goal of ecosystem management is to maintain and improve the native biological diversity and sustainability of ecosystems, while supporting human needs, including the military mission.

Eelgrass
Beds of aquatic plants, primarily represented by *Zostera marina*, extending from the low tide zone to primarily 6 to 10 feet (1.8 to 3.0 m), and less commonly to 15 feet (4.6 m).

Endangered or Threatened Species
A species of fauna or flora that has been listed by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service for special protection and management under the Federal Endangered Species Act, or by the California Fish & Game Commission for protection under the California Endangered Species Act.

Endemic
Restricted to a particular location; often refers to a species that is found only in certain locations.

Enhancement
To increase the function and values of a low quality or degraded wetland.

Entrainment
To carry along, drag, or trail, as in a current.

Environs
Surrounding area. Vicinity.

Epifauna
Marine animals that cling to the surface of rocks or other substrate to avoid being swept away by wave action.

Epiphyte
A plant that grows upon another plant, but is not parasitic upon it.

Estuary
A semi-enclosed body of water that has a free connection with the open ocean and within which sea water is measurably diluted with fresh water derived from land drainage. Estuaries are found at the mouths of rivers and streams and are subject to tidal conditions. They include five habitat types: 1) Upland, 2) Freshwater, 3) Intertidal, 4) Subtidal, and 5) Saltwater.

Exotic Species
Species that occur in a given place, area, or region as the result of direct or indirect, deliberate or accidental introduction of the species by human activity, and for which introduction has permitted the species to cross a natural barrier to dispersal. Also called non-native, non-indigenous, or alien.

Filter Feeders
Organisms that feed by filtering out small food items such as detritus and plankton that are suspended in the water column; distinguished from deposit feeders that glean such items from the bottom.

Fines
In aquatic ecology, bed materials less than 2 millimeters in diameter, including silt, clay, and fine organic materials.

Fish and Wildlife Cooperative Plan
A plan for the cooperative management of fish and wildlife on a military installation by the host military activity and the appropriate federal and state fish and wildlife agencies as required by the Sikes Act.

Fish and Wildlife Management
A coordinated program of actions designed to preserve, enhance and regulate indigenous fish and wildlife and their habitats, including conservation of protected species and non-game species, management and harvest of game species, bird aircraft strike hazard reduction, and animal damage control.

Food Web	An assemblage of organisms in an ecosystem, including plants, herbivores and carnivores, showing the relationship of who eats whom.
Footprint	The functional planning zone used in the San Diego Bay Integrated Natural Resource Management Plan; also the site covered or impacted by a project.
Fouling Organism	An invertebrate, such as a barnacle or shipworm, that bores into or encrusts on submerged surfaces such as boats and pilings.
Freshwater Marsh	Nontidal wetland dominated by persistent, emergent, non-woody vegetation.
Freshwater Wetlands and Riparian	Nontidal habitat areas supported at the entry points of freshwater tributaries.
Game Species	Fish and wildlife that may be harvested per applicable federal and state hunting and fishing laws.
Gastropods	Snails and other molluscs that typically possess a coiled dorsal shell and a ventral creeping foot.
Geographical Information System	A computer system used to overlay large volumes of spatial data of different kinds. The data are referenced to a set of geographical coordinates and encoded in digital format so that they can be sorted, selectively retrieved, statistically and spatially analyzed.
Goal	Broad statement of intent, direction and purpose. An enduring, visionary description of where you want to go. A goal is not necessarily completely obtainable.
Grounds	All land areas not occupied by buildings, structures, pavements, and other facilities. Depending on the intensity of management, grounds may be classed as improved, i.e. those near buildings, semi-improved, or unimproved.
Habitat	An area where a plant or animal species lives, grows, and reproduces, and the environment that satisfies their life requirements.
Habitat Conversion	An approach to manipulating habitat conditions in which a habitat is converted from one type to another in order to mimic a desirable natural habitat present at another location; also called “Habitat Replacement”.
Habitat Creation	See “Habitat Conversion”; new habitat is not really created but is converted out of another habitat.
Habitat Enhancement	Habitat enhancement involves the rejuvenation and improvement of the natural system to increase the values it presently has and add new ones. For wetlands, increasing the functions and values of a low-quality or degraded wetland.
Habitat Replacement	See “Habitat Conversion”.
Holoplankton	Zooplankton that spend their entire lives in the open water environment.
Hydrodynamic	The physical features of water motion.
Hypersaline	Saltier than sea water.
Ichthyoplankton	Planktonic larvae of fishes.
Infauna	Marine animals that burrow in substrata (e.g., gravel, sand, mud) to avoid disturbance by wave action and other physical stresses of the environment.
Injury	Any adverse change in a natural resource or impairment of a service provided by a resource relative to baseline, reference, or control conditions. Injury incorporates the concepts of “destruction,” “loss”, and “loss of use.”
Integrated Natural Resources Management Plan	An integrated plan based on ecosystem management that shows the interrelationships of individual components of natural resources management (e.g. fish and wildlife, forestry, land management, public access) to mission requirements and other land use activities affecting an installation’s natural resources.
Interstitial Fauna	Tiny invertebrates that live and move around in spaces between sediment grains or attach to the grains. They pass through standard sampling sieves.

Intertidal Flats Muddy to sandy habitats between -2.2 and+7.8 feet (-0.7 and +2.4 m); normally devoid of flowering aquatic plants, but may include algae.

Inventory A detailed list of items (e.g., organisms, habitats, boats) taken at a specific time and place; it often serves as the first step towards establishing a monitoring project.

Invertebrate Animal lacking a backbone.

Isopods Small, dorsoventrally flattened crustaceans such as the sea louse.

Landscape This term is gaining increasing importance in conservation planning. The landscape contains more than one natural community or habitat and allows attention to be paid to both biodiversity and the need to link natural communities and habitats to support biodiversity.

Larva Immature stage of an animal that looks different from the adult.

Life History The phases that an organism may pass through during its life.

Listed A plant or animal species that has been determined by the state or federal government to be threatened with extinction.

Littoral Ocean habitat between the highest high and the lowest low tide lines.

Macroalgae Seaweed.

Management The application of skill or care in the manipulation, use, treatment or control of things or persons, or in the conduct of an activity, project, program, etc. Includes, but is not limited to, actions or methods such as: assessment, education, enhancement, inventories, laws, mitigation, monitoring, objectives, policies, protection, regulations, research, restoration, and surveys. Also called “stewardship”.

Management Strategy The combination of the objective(s) and policies used to describe the ways and means of managing.

Mariculture The techniques applied to growing marine organisms in captivity.

Marine Protection Area Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features that has been reserved by law or other effective means to protect part or all of the enclosed environment.

Marsh More or less permanently wet area within the intertidal zone, typified by wetland plants within a muddy habitat.

Mean High Tide A line in 1918 showing the area of the bay to be 21 to 22 mi^2 (54 to 57 km^2).

Meiofauna Microscale animals that live on the bottom, often used as a synonym of interstitial fauna.

Meroplankton The larval forms of invertebrates that later settle to the bottom and become benthic juveniles and adults; also called “temporary plankton”.

Mitigation Mitigation is the avoidance, minimization, rectification, and reduction or elimination of negative impacts or compensation by replacement or substitution.

Moderately Deep Subtidal A habitat extending from the approximate lower depth of most eelgrass to the approximate edge of the shipping channel (–12 to –20 feet/–4 to –6 m MLLW). It represents areas that generally have been dredged in the past but are not maintained as navigational channels.

Monitoring A series of observations over time with the intent to assess change. Often an assessment or inventory serves as the first step towards establishing a monitoring project. Based on each one’s purpose, the following types of monitoring are defined:

- **Trend monitoring:** Measurements that are made at regular, well-spaced time intervals in order to determine the long-term trend in a particular parameter.

- **Baseline monitoring:** Measurements used to characterize existing conditions (e.g., water quality, wildlife population, habitat quality) and to establish a data base for planning or future comparisons. While the intent is to capture much of the temporal variability of the constituents of interest, there is no explicit end point at which continued baseline monitoring becomes trend monitoring. Often used synonymously with “inventory monitoring” and “assessment monitoring.”
- **Implementation monitoring:** Administrative determination taken to assess whether activities were carried out as planned (e.g., Best Management Practices, mitigation measures, permit conditions).
- **Effectiveness monitoring:** Measurements taken to evaluate whether specified individual management practices had the desired effect.
- **Project monitoring:** Measurements taken to assess the impact of a particular activity or project, such as on a before or after basis or on a control site versus impact site basis. May be considered by some agencies to be a subset of effectiveness monitoring.
- **Compliance monitoring:** Measurements taken to determine whether specified water-quality or other measurable criteria are being met. Usually the regulations associated with individual criterion specify the location, frequency, and method of measurement.

Mudflat Part of the continuum from open water to dry land, rich in organic matter and microorganisms, generally exposed during all but highest tides.

Multiple Use The sustainable use of natural resources for the best combination of purposes to meet the long-term needs of the Department of Defense and the public.

Natural Community This term generally refers to a vegetation community, such as southern coastal sage scrub, but it is used to encompass all of the habitat, ecosystems, and plant and animal species found within the community.

Natural Resources Landforms, soils, waters, and their associated flora and fauna.

Natural Resources Management Plan A five-year planning document that guides legally and ecologically sound, cost effective management of natural resources to maximize benefits for the installation and neighboring community. It addresses all land, agriculture, forest, fish, and wildlife and outdoor recreation resources of the installation. Superseded by Integrated Natural Resource Management Plan.

Natural Resources Management Procedural Manual Reference that provides comprehensive guidance for implementing requirements of pertinent laws, executive orders, and federal regulations, Department of Defense directives, Secretary of Navy and Naval Operations instructions.

Natural Resources Trustee Federal trustees are those agencies that have statutory responsibilities with regard to protection or management of natural resources or stewardship responsibilities as an manager of federally owned land. State agencies and Indian tribes may also be trustees.

Nematode An invertebrates with a cylindrical body, a conspicuous body cavity, and a complete digestive tract.

NIMITZ A class of carriers that are part of the Navy’s new, more modern fleet of deep-draft ships powered by nuclear energy, referred to as CVNs.

Non-game Species Fish and wildlife species that are not harvested for recreational or subsistence purposes.

Nonpoint Source Pollution Pollution caused by diffuse sources that are not regulated as point sources and are normally associated with runoff from construction activities, urban, agricultural and silvicultural runoff, and other land disturbing activities such as military training and operations that disturb lands, soils, and waters. It can result from land runoff, precipitation, atmospheric deposition, or percolation.

Noxious Weeds Plant species identified by federal or state agencies as requiring control or eradication.

Objective Specific statement that describes a desired condition; can be quantitative.

Pelagic Living in the water column above the bottom of the ocean.

Minute, floating aquatic plants.	**Phytoplankton**
Salt ponds with second highest salinity content.	**Pickling**
Floating or drifting organisms, especially very small ones, found at various depths in the ocean and fresh water; includes protozoa, invertebrates, and larval forms of vertebrates.	**Plankton**
An inventory of sensitive and significant resources (biological, cultural, or geological) that must be identified in order to prevent impairment of the military mission or meet regulatory requirements.	**Planning Level Survey**
Formally-adopted strategy or decision to carry out a course of action.	**Policy**
Segmented worms that have flat lateral extensions on each body segment.	**Polychaetes**
A group of man-made organic chemicals, including about 70 different, but closely related, compounds made up of carbon, hydrogen, and chlorine. If released into the environment, they persist for long periods of time and can concentrate in food chains. They are not water soluble and are suspected to cause cancer in humans. They are an example of an organic toxicant.	**Polychlorinated Biphenyls**
A class of complex organic compounds that are among the heaviest molecular fraction of petroleum hydrocarbons, some of which are persistent and/or cancer-causing. These compounds are released through fossil fuel combustion, spills of oil, gasoline, diesel and other petroleum products, creosote oil, and asphalt production.	**Polycyclic (polynuclear) Aromatic Hydrocarbons**
A standardized measure of salinity used to adjust different salinity measurements to a constant electrical conductivity, temperature, and pressure.	**Practical Salinity Unit**
First stage of salt extraction process and least saline in Salt Ponds.	**Primary**
As used here, prohibition refers to laws in California that restrict activities directly affecting rare plants. This includes the Federal Endangered Species Act, the California Endangered Species Act, and the California Native Plant Protection Act.	**Prohibition**
Includes studies, plans, surveys, inventories, and land/water treatments as well as physical improvements.	**Projects**
Any species of plant or animal that is proposed in the Federal Register to be listed under §4 of the Endangered Species Act.	**Proposed Species**
A rule prescribed for controlling some matter. Generally refers to statutory laws and administrative rules, policies, ordinances, permits and other restrictive conditions placed on an activity by a regulatory agency. While a law is a regulation, a regulation is not a law; a regulation is an interpretation of the law.	**Regulation**
A government agency delegated powers for implementing regulations, either directly as a decision-maker or enforcer of regulations (e.g., Environmental Protection Agency, Regional Water Quality Control Board, U.S. Army Corps of Engineers) or indirectly as an advisor on regulations (e.g., National Marine Fisheries Service and U.S. Fish and Wildlife Service on Clean Water Act, §404).	**Regulatory Agency**
Natural resources such as forests and wildlife that replace themselves in a relatively short time and are capable of providing sustained yields.	**Renewable Natural Resources**
A search or investigation undertaken to discover facts and reach new conclusions by the critical study of a subject or by a course of scientific inquiry.	**Research**
Habitat restoration implies returning certain habitats to their former historical condition. For wetlands, restoration means establishing wetland habitat at an upland site that previously supported wetlands.	**Restoration**
Layer of large, durable fragments of broken rock, specially selected and graded. Its purpose is to prevent erosion by waves or currents and thereby preserve the shape of a surface, slope, or underlying structure.	**Riprap**
Areas closely related to or bordering rivers, streams, lakes, arroyos, playas, ravine bottoms, etc. Dominated by woody vegetation and nontidal water regimes.	**Riparian Areas**

River Mouths	Areas in which water from rivers flows into the bay. They no longer have a natural role, and are controlled by dams or diversion.
Salinities	The total amount of salts in seawater.
Salt Marsh	A marsh area having high salinities in the ambient water and substrate, typical of estuarine areas, or other areas subject to flooding with ocean water, and characterized by thick mats of salt-loving plants.
Salt Works	A habitat consisting of shallow, open-water cells of different salinity levels interspersed with mudflats, dry dikes and salt marsh.
Seagrass	Any of various grass-like plants growing in or by the sea; especially eelgrass.
Seaweed	Any macroscopic marine algae; such plants *en masse* or collectively.
Section 7	Section 7 of the Federal Endangered Species Act specifies that federal agencies must consult with the U.S. Fish and Wildlife Service regarding activities that could affect listed species.
Section 9	Section 9 of the Federal Endangered Species Act prohibits violations of the act, including take of listed fish and wildlife species. It prohibits the destruction of listed plant species on federal land or on private land when done in knowing violation of a state law.
Section 10(a)	Section 10(a) of the Federal Endangered Species Act provides for permits to take listed species under certain conditions.
Sediment	Particles of organic or inorganic origin that accumulate in loose form.
Sensitive	Highly responsive or susceptible to modification by external agents or influences.
Sensitive Habitat	Land, water and vegetation needed to maintain one or more sensitive species.
Sensitive Species	Those species federally listed as endangered or threatened under the Endangered Species Act, proposed for listing, or candidate status.
Sessile	Attached to one place.
Shallow Subtidal	Bay habitat extending from -2.2 to -12 feet (-0.7 to -3.7 m), and including the bottom sediments to the water surface.
Significant	Resources identified as having special importance, or as having or likely to have more influence on a particular aspect of the environment than other components.
Sludge	Semiliquid sewage that has been treated and partially decomposed by bacteria.
Species	A group of individuals that have their major characteristics in common and (usually) can only breed with each other.
Species Abundance	The distribution of the number of species and the number of individuals of each species in a community.
State Listed Species	Any species of fish, wildlife or plant that is protected by an appropriate state agency as issued in a state's endangered species law and other pertinent regulations.
Stewardship	The responsibility to inventory, manage, conserve, protect, and enhance the natural resources entrusted to one's care in a way that respects the intrinsic value of those resources, and the needs for present and future generations.
Stratification	Separation of an aquatic community into distinguishable layers on the basis of temperature, light, vegetative structure and other such factors creating zones for different plant and animal types.
Strategy	Explicit description of ways and means chosen to achieve objectives.
Structural Surrogates	Habitats being added or modified in order to sustain endangered or other sensitive species.

Plants that are rooted in and grow in the sediments at the bottom of a saltwater or freshwater body.	**Submergment Vegetation**
The material forming the bed of a body of water; the material upon which plants grow; or the nutrient medium or physical structure on which an organism feeds and develops.	**Substrate**
Area below the low tide zone in oceans and bays, not exposed to air.	**Subtidal**
A comprehensive look or description; a written statement embodying the result of an inspection.	**Survey**
Animals that capture particles suspended in the overlying water either by filtering or other means.	**Suspension Feeders**
The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time.	**Sustainability**
Managing the use, development, and protection of natural and physical resources in a manner or at a rate that enables people and communities to provide for their social, economic, and cultural well-being, and for their health and safety while (1) sustaining the potential of natural and physical resources to meet reasonably foreseeable needs of future generations; (2) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and (3) avoiding, remedying, or mitigating any adverse effects of activities on the environment.	**Sustainable Management**
Use of an organism, ecosystem, or other renewable resource at a rate that does not exceed its capacity for renewal.	**Sustainable Use**
The Federal Endangered Species Act defines take as “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct,” with regards to threatened or endangered species.	**Take**
Habitats along bay margins including riparian regions, fallowed agricultural lands, sandy beaches, foredunes, backdunes, coastal scrub, and eucalyptus groves.	**Terrestrial Habitat**
A cycle in which differing amounts of bay water leave the bay, mix with ocean water and return with the next tide.	**Tidal cycle**
Land below the historic (1850) mean high tide line, some of which is now filled in and developed.	**Tidelands**
A ciliate protozoan that secretes vase-like cases.	**Tintinnid**
Relating to or caused by a substance that is poisonous substance to a living organism.	**Toxic**
Functional classification of organisms in an ecosystem according to feeding relations from first level autotrophs through herbivores and carnivores.	**Trophic level**
A measure of the amount of material suspended in the water. Increasing the turbidity of the water decreases the amount of light that penetrates the water column. Very high levels of turbidity can be harmful to aquatic life.	**Turbidity**
Habitats in which the soft bottoms of unconsolidated sediment are unstable and shift in response to tides, wind, waves, currents, human activity, or biological activity.	**Unvegetated Shallow Soft-Bottom**
Habitat surrounding the upper edge of the marsh and the zone of highest tide, typified by non-wetland vegetation.	**Upland Transition**
A productive benthic habitat formed by beds of eelgrass.	**Vegetated Shallow Subtidal**
Promotion of the recreational viewing of wildlife as a federal program.	**Watchable Wildlife**
Pelagic open water environment.	**Water Column**
The chemical, physical, and biological qualities of water.	**Water Quality**

Waterbirds

Birds that use moist to flooded conditions of wetlands. Nearly 800 species can be described as waterbirds, of which 260 inhabit North America. Birds lumped as "waterbirds" include cormorants, ibis, pelicans, herons, bitterns, kingfishers, cranes, rails, avocets, sandpipers and others as well as waterfowl.

Waterfowl

One of a group of migratory birds of the bird family Anatidae, which includes ducks, geese, and swans. In North America, this family is represented by 58 species, making it the most diverse family of waterbirds.

Watershed

An area of land draining water, organic matter, dissolved nutrients, and sediments into a lake, stream, or bay.

Wetlands

Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, such as swamps, marshes, and bogs.

Wetlands (designated)

A wetland with one or more of the following attributes: 1) the land periodically supports water plants (hydrophytes), 2) the substrate is dominated by undrained hydric soil, or 3) the soil is periodically saturated or covered by shallow water.

Wildlife Management

The practical application of scientific and technical principles to wildlife populations and habitats so as to manage such populations essentially for ecological, recreational, and/or scientific purposes.

Zooplankton

Floating, often microscopic, animals and immature stages of large animals.

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Appendix C: Comprehensive Species List of San Diego Bay

PHYTOPLANKTON

Diatoms and Other Groups

Achnanthes sp.
Asterionella sp.
Biddulphia sp.
Ceratulina sp.
Chaetoceros sp.
Coenobiodiscus sp.
Coscinodiscus sp.
Ditylum sp.
Dunaliella sp.
Eucampia sp.
Fragilaria sp.
Grammatophora sp.
Gyrosigma sp.
Leptocylindrus sp.
Licomorpha sp.
Navicula sp.
Nitzschia sp.
Phaeodactylum tricornutum
Pleurosigma sp.
Rhizosolenia sp.
Skeletonema sp.
Stephanophysix sp.
Streptotheca sp.
Suriella sp.
Thalassionema sp.
Thalassiothrix sp.
other identified diatoms
unidentified tintinnids

Dinoflagellates

Ceratium sp.
Dinophysis sp.
Lingulodinium sp.
Gymnodinium oplendens
Noctulica sp.
Peridinium sp.
Prorocentrum sp.

ALGAE

Chlorophyta (Green Algae)

Bryopsidaceae
Bryopsis corticulans
Derbesia marina
Cladophoraceae
Chaetomorpha linum
Cladophora sp.
Ulotrichaceae
Ulothrix sp.
woolly hair
Ulotricales sp.
Ulvaceae
Enteromorpha sp.
Ulva expansa
sea lettuce
Ulva tacnista

Phaeophyta (Brown Algae)

Alariaceae
Egregia laevigaia
Eisenia arborea
**Undaria pinnatifida*
Bangiacea
Porphyra perforta
Dictyotaceae
Dictyota flabellata
Ectocarpaceae
Ectocarpus spp.
Fucaceae
Fucaceae sp.
Sargassaceae
Sargassum agarhianum
* *Sargassum muticum*
sargassum
Sargassum palmeri
Scytosiphonaceae
Colpomenia sinuosa
Endarachne binghamiae
Scytosiphon lomentaria

Rhodophyta (Red Algae)

Ceramiaceae
Aglaothamnium cordatum
Antithamnion sp.
Callithamnion sp. A.
Ceramium aerea
Ceramium eatonian
Griffithsia furcellata
Griffithsia pacifica
Tiffaniella snyderae
Dasyaceae
Dasya pacifica
Dasya sinicola var. *abyssicola*
Dasya sinicola var. *californica*

Gelidiacea
Gelidium nudifrons
gelidium
Gelidium sp. A
Gigartinaceae
Gigartina spp.
Turkish towel
Gracilariaceae
Gracilaria lemaneiformis
Gracilaria pacifica
Hypneaceae
Hypnea valentiae
Plocamiaceae
Plocamium sp.
Lomentariaceae
* *Lomentaria hakodatensis*
Rhabdoniaceae
**Caulacanthus ustulatus*
Rhodomelaceae
Polysiphonia bajacali
Polysiphonia pacifica
Pterochondria woodii var. *pymaea*
Rhodomelaceae sp.
Rhodymeniaceae
Rhodymenia californica
Rhodymenia spp.
Sarcodiotheca gaudichaudii

PLANTS

Gymnosperms

Pinaceae
* *Pinus halapensis*
aleppo pine

Dicots

Aizoaceae
* *Carpobrotus chilensis*
sea fig
* *Carpobrotus edulis*
sea fig, hottentot-fig
* *Mesembryanthemum crystallinum*
ice plant, crystalline iceplant
* *Mesembryanthemum nodiflorum*
little ice plant, slender-leaved iceplant
Anacardiaceae
Malosma laurina
laurel leaf sumac
Rhus integrifolia
lemonadeberry
* *Schinus molle*
Peruvian pepper tree
* *Schinus terebinthifolius*
Brazilian pepper tree
Apiaceae
* *Foeniculum vulgare*
sweet fennel
Asteraceae
Amblyopappus pusillus
coast weed
Ambrosia psilostachya
western ragweed
Artemisia californica
California sagebrush
Baccharis salicifolia
mule fat
Baccharis sarothroides
chaparral broom
* *Bassia hyssopifolia*
bassia
* *Centaurea melitensis*
star thistle, tocalote
* *Chrysanthemum carinatum*
tricolor chrysanthemum
* *Chrysanthemum coronarium*
garland chrysanthemum, crown daisy
* *Conyza canadensis*
Canada horseweed
* *Cotula coronopifolia*
brass buttons
Encelia californica
California (coastal) encelia
Gnaphalium bicolor
two-color cudweed
Gnaphalium californicus
ladies' tobacco
Gnaphalium canescens beneolens
everlasting cudweed
Heterotheca grandiflora
telegraph weed
Isocoma menziesii
golden bush
Isocoma menziesii var. *menziesii*
golden bush
Jaumea carnosa
jaumea
Pluchea sericea
arrow weed
* *Senecio bulgaris*
common groundsel
* *Sonchus asper*
prickly sow thistle
* *Sonchus oleraceus*
common sow thistle
Stephanomeria virgata
rod wirelettuce
* *Taraxacum officinale*
common dandelion
Xanthium strumarium
cocklebur
Bataceae
Batis maritima
saltwort
Boraginaceae
Amsinckia menziesii
fiddleneck, ranchers fireweed
Heliotropium curassavicum
Chinese parsley, salt hellotrope
Brassicaceae
* *Brassica nigra*
black mustard
* *Cakile edentula*
sea rocket
Hutchinsia procumbens
* *Lobularia maritima*
sweet allysum
* *Raphanus sativus*
wild radish
Cactaceae
* *Opuntia ficus-indica*
tuna
Opuntia littoralis
coast prickly pear
Opuntia oricola
chaparral prickly pear
Opuntia prolifera
cholla
Capparaceae
Isomeris arborea
bladderpod
Caprifoliaceae
Sambucus mexicana
elderberry
Caryophyllaceae
Cardionema ramossisima
tread lightly
Spergularia marina
salt marsh sand spurry
* *Spergularia rubra*
red sand spurry
Chenopodiaceae
Atriplex canescens
Atriplex canescens canescens
shadscale
Atriplex lentiformis
big saltbush
* *Atriplex lindleyi*
* *Atriplex semibaccata*
Australian saltbush
Atriplex triangularis
spearscale
Atriplex truncata
wedgescale
Atriplex watsonii
Watson salt bush
Chenopodium californicum
California goosefoot

* *Chenopodium murale*
nettle-leaved goosefoot

Salicornia bigelovii annual pickleweed

Salicornia europaea
saltflat annual pickleweed

Salicornia subterminalis
glasswort

Salicornia virginica
pickleweed

* *Salsola kali* Russian thistle

* *Salsola tragus*
tumbleweed

Suaeda californica
California sea blite

Suaeda esteroa
estuary sea blite

Suaeda torreyana
torry sea blite

Suaeda taxifolia
woolly sea blite

Convolvulaceae

Calystegia macrostegia intermedia
south coast morning glory

Cressa truxillensis
alkali weed

Crassulaceae

Crassula connata
pigmy weed

Dudleya edulis
fingertips

Cucurbitaceae

Marah macrocarpus
Cucamonga manroot

Cuscutaceae

Cuscuta salina
salt marsh dodder

Cuscuta salina var. *major*
goldenthread

Euphorbiaceae

Croton californicus
California croton

Euphorbia spathulata
warty spurge

Fabaceae

* *Acacia melanoxylon*
blackwood acacia

* *Astragalus* sp.
milk-vetch

* *Lotus corniculatus*
birdfoot trefoil

Lotus nuttallianus
beach lotus

Lotus scoparius
California broom

Lotus strigosus

* *Medicago polymorpha*
burclover

* *Melilotus alba*
white sweetclover

* *Melilotus officinalis*
yellow sweetclover

* *Trifolium* spp.
clover

Frankeniaceae

Frankenia palmeri
yerba reuma

Frankenia salina
alkali heath

Geraniaceae

* *Erodium botrys*
longbeak stork's bill

* *Erodium cicutarium*
redstem stork's bill

Hydrophyllaceae

Eucrypta chrysanthemifolia
common eucrypta

Phacelia stellaris
Brand's phacelia

Lamiaceae

* *Marrubium vulgare*
horehound

Salvia mellifera
black sage

Malvaceae

* *Malva parviflora*
cheeseweed

Myoporaceae

* *Myoporum laetum*
ngaio tree

Myrtaceae

* *Eucalyptus* spp.
gum

Nyctaginaceae

Mirabilis californica
California four o'clock

Onagraceae

Camissonia cheiranthifolia
beach evening primrose

Camissonia cheiranthifolia suffruticosa
beach evening primrose

* *Olea europaea* olive

Oxalidaceae

* *Oxalis pes-caprae* Bermuda buttercup

Papaveraceae

Eschscholzia californica California poppy

Plumbaginaceae

Limonium californicum sea lavender, western marsh rosemary

Polygonaceae

Eriogonum fasciculatum
California buckwheat

Eriogonum parvifolium

Nemacaulis denudata denudata
coast woolly-head

* *Polygonum arenastrum*

* *Polygonum aviculare*

* *Rumex crispus*
curley dock

Salicaceae

Salix lasiolepis
arroyo willow

Scrophulariaceae

Cordylanthus maritimus maritimus
salt marsh bird's-beak

Solanaceae

Datura wrightii
toluaca

Lycium brevipes var. *brevipes*
desert-thorn

Lycium californicum
California box thorn

* *Lycopersicon esculentum*
tomatoe

* *Nicotiana glauca*
tree tobacco

Solanum douglasii
Douglas' nightshade

Tamaricaceae

* *Tamarix parviflora*

* *Tamarix* sp.

Urticaceae

* *Urtica urens*
dwarf nettle

Verbenaceae

* *Lantana camara*
lantana

Monocots

Araceae

* *Washingtonia filifera*
California fan palm

Cyperaceae

Scirpus californicus
California tule

Juncaceae

Juncus acutus
spiny rush

Juncaginaceae

Triglochin maritima
arrow grass

Liliaceae

Dichelostemma capitatum
bluedicks

Yucca schidigera
Mohave yucca

Poaceae

* *Avena fatua*
wild oat

* *Bromus diandrus*
ripgut brome

* *Bromus madritensis rubens*
red brome

* *Cortaderia jubata*
Pampas grass, Andes grass

* *Cynodon dactylon*
bermuda grass

Distichlis spicata
salt grass

* *Hordeum murinum*
sterile barley, foxtail barley

* *Lolium perenne*
English ryegrass

Monanthochloe littoralis
shoregrass

Nassella pulchra
purple needlegrass
* *Parapholis incurva*
sickle grass
* *Pennisetum setaceum*
crimson fountaingrass
* *Piptatherum miliaceum*
smilo grass
* *Poa annua*
annual bluegrass
* *Polypogon monspeliensis*
rabbit foot grass, annual beard grass
* *Rhynchelytrum repens*
natal grass
* *Schismus barbatus*
common Mediterranean grass
Spartina foliosa
cordgrass

Potamogetonaceae
Ruppia maritima
ditch grass

Typhaceae
Typha domingensis
southern cattail
Typha latifolia
common cattail

Zosteraceae
Zostera marina
eelgrass

ANIMALS

PORIFERA (SPONGES)

Halichondriidae
**Halichondria bowerbankia*
yellow sponge
Halichondria panicea
crumb of bread sponge

Haliclonidae
Haliclona ecbasis
* *Haliclona* sp.
haliclonid sponge

Hymeniacidonidae
Hymenicidon sp.

Leucosoleniidae
Leucosolenia eleanor
white sponge
Leucosolenia sp.

Tetillidae
Tetilla mutabilis
wandering sponge

unknown
Esperiopsis originalis
digitate sponge

CNIDARIA (JELLYFISHES, CORALS)

Hydrozoa (Hydroids)

Campanulariidae
**Gonothyraea clarki*
**Obelia* sp.

Plumulariidae
Aglaophenia sp.
ostrich plume hydroid
Plumularia sp.
plumarid hydroid

Tubulariidae
Tubularia sp.
naked hydroid
* *Tubularia crocea*

unknown
Abietinaria spp.
Bineria sp. A
Corymorpha palma
white hydroid
Hydroid spp.

Scyphozoa (Scypomedusae, large jellyfish)

Phyllorhiza puctata
Rhizostome scyphomedusa

Anthozoa (Sea Anemones, Corals, Sea Pens)

Actiniidae
Epiactis prolifera
proliferating anemone

Diadumenidae
Diadumene franciscana
Diadumene cf. *leucolena*
* *Diadumene lineatu*

unknown
Anthozoan spp.
Bunodeopsis sp.
Cerianthus (nr) *aestuari*
Edwardsiella californica
Harenactis attenuata
Pachycerianthus fimbriatus
mud tube anemone
Renilla kollikeri
sea pansy
Scolanthus sp.

PLATYHELMINTHES (FLATWORMS)

Polyclad spp. flatworm

NEMERTEA (RIBBONWORMS)

Nemertena spp.

NEMATODA (ROUNDWORMS)

Nematode spp.

SIPUNCULA (PEANUTWORMS)

Sipuculid sp.

ANNELIDA (SEGMENTED WORMS)

Oligochaeta (Earthworms)

Oligochaete spp.
oligochaete

Polychaeta (Bristleworms, Fanworms, Clamworms)

Ampharetidae (Ampharetids)
Ampharetidae spp.
Ampharete labrops
Amphicteis scaphorbranchia
Arabellidae (Arabellids)
Arabella semimaculata
Arabella sp.
Drilonereis falcata minor
Drilonereis mexicana
Capitellidae (Capitellids)
Capitella capitata
Capitellidae spp.
Capitata ambiseta
Heteromastus sp.
Mediomastus acutus
Mediomastus ambiseta
Mediomastus californiensis
Mediomastus sp.
Neomediomastus sp.
Notomastus cf. *lineatus*
Notomastus tenuis
Scyphoproctus oculatus
Scyphoproctus spp.
Chaetopteridae
Chaetopterus variopedatus
parchment tube worm
Cirratulidae (Cirratulids)
Caulleriella spp.
Chaetozone cf. *corona*
Chaetozone cf. *setosa*
Chaetozone cf. *spinosa*
Cirratulus cirratus
Cirratulidae, unidentified
Cirratulus spp.
Cirriformia luxuriosa
Cirriformia spriabranchiata
Cirriformia tentaculata
Tharyx parvus
Tharyx sp. A.B
Cossuridae (Cossurids)
Cossura candida
Cossura pygodactylata
Cossura sp.
Ctenodrilidae (Ctenodrilids)
Ctenodrilus serratus
Dorivilleidae (Dorvilleids)
Dorvillea articulata
Dorvillea longicornis
Dorvillea rudolphii
Ophryotrocha puerilis
Schistomeringos longicornis
Eunicidae (Eunicids)
Lysidice sp.
Lysippe labiata
Marphysa dysjuncta
*Marphysa sanguinea
Marphysa stylobranchiata
Marphysa sp.
Flabelligeridae (Flabelligerids)
Brada pleurobranchiata
Flabelligerma essenbergae
Flabelligera infundibularis
Flabelligeridae sp.A
Flabelligeridae sp.B
Pherusa capulata
Pherusa cf. *neopapillata*
Pherusa sp.
Stylaroides sp.
Glyceridae (Glycerids)
Glycera americana
Glycera cf. *americana*
Glycera nana
Glycera rouxii
Glycera tenuis
Glyceridae spp.
Glycinda armigera
Goniadidae (Gonaidids)
Goniada brunnea
Goniada littorea
Goniada spp.
Hesionideae (Hesionids)
Gyptis arenicola glabra
Ophiodromus pugettensis
Lumbrineridae (Lumberinerids)
Lumbrineris acuta
Lumbrineris californiensis
Lumbrineris erecta
Lumbrineris latreilli
Lumbrineris minima
Lumbrineris zonata
Lumbrineris spp.
Maldanidae (Maldanids)
Maldanidae spp.
Malmgreniella macginitiei
Nicomache cf. *lumbricalis*
Praxilella affinis pacifica
Nephtyidae (Nephtyids)
Nephtys caecoides
Nephtys cornuta franciscanus
Nephtys parva
Nephtyidae spp.
Nereidae (Neriids)
* *Neanthes acuminata*
Neanthes caudata
Neanthes virens n
Nematonereis cf. *unicornis*
Nereis brandti
Nereis latescens
Nereis procera n
Nereidae spp.
Onuphidae (Onuphids)
Diopatra splendidissima
Diopatra tridentata
Diopatra spp.
Opheliidae (Opheliids)
Armandia bioculata
Polyopthalmus pictus
Orbiniidae (Orbinids)
Haploscolopos elongatus
Leitoscoloplos elongatus
Leitoscoloplos pugettensis
Naineris uncinata
Orbinidae spp.
Scoloplos acmeceps
Pectinariidae (Pectinarids)
Pectinaria californiensis
Phyllodocidae (Phyllodocids)
Anataides longipes
*Eteone aestuarina
Eteone alba
Eteone californica
Eteone dilata
Eteone spp.
Eteone cf. *lighti*
Eumida bifliata
Phyllodocidae spp.
Pilargiidae
Sigambra tentaculata
Polynoidae (Polynoids)
Halosydna brevistosa
Halosydna johnsoni
Harmothoe cf. *hirsuta*
Harmothoe imbricata
Hesperonoe spp.
Malmgrenia nigralba
Polynoidae spp., sp. A.B.C.
scale worm
Sabellidae (Sabellids)
Chone cf. *gracilis*
Chone cf. *mollis*

Euchone limnicola
Fabicinae sp.
Fabricia limnicola
Fabricinuda limicola
Megalomma circumspectum
Megalomma pigmentum
Sabella crassicornis
Sabellidae spp.
Sabellidae, unidentified

Serpulidae (Serpulids)

Crucigera sp.
* *Demonax sp.*
Eupomatus sp.
Hydroides pacificus
Serpula vermicularis
Serpulidae spp.
Spirorbis eximius
**Vermiliopsis infundibulum*

Sigalionidae

Sthenelais tertiaglabra
Sthenelanella uniformis

Spionidae (Spionids)

Apoprionospio pygmaeus
Boccardia spp.
Boccardia truncata
Boccardiella hamata
Laonice cirrata
Microspio maculata
Nerinides cf. *acuta*
Nerinides pigmentata
Paraprionospio pinnata
Polydora cf. *cardalia*
Polydora cornuta
**Polydora ligni*
Polydora limnicola
Polydora nuchalis
Polydora quadrilobata
Polydora socialis
Polydora websteri
Polydora sp.
Prionospio cf. *heterobranchiata*
Prionospio lighti
Prionospio malmgreni
Prionospio pinnata
Prionospio pygmaeus
Prionospio steenstrupi
Pseudomalacocerus spp.
**Pseudopolydora paucibranchiata*
Rhynchospio glutaea
Rhyncospioarenicola pallidus
Scolelepis acuta
Scolelepis foliosa occidentalis
Scoleopis quinquedentata
Scolelepis tridentata
Spionidae spp.
Spiophanes missionensis
**Streblospio benedicti*

Sternaspidae (Sternaspids)

Sternaspis fossor

Syllidae (Syllids)

Autolytus spp.
**Branchiosyllis exillis*
Brania brevipharyngea
Brania spp.
Eusyllis assimilis
Exogone lourei
Exogone cf. *molesta*
Exogone uniformis
* *Myriandia pachycera*
Odontosyllis parva
Odontosyllis phosphorea
Pionosyllis spp.
Syllidae spp.
Syllis gracilis
Trypanosyllis spp.
Typosyllis cf. *hyalina*
**Typosyllis nipponica*

Terebellidae (Terebellids)

Amaeana occidentalis
* *Nicolea sp.* A Harris
Pista alata
Pista cf. *fasciata*
Pista sp.
Streblosoma crassibranchia
Terebellidae spp.
Terebellides californica

unknown

Aphelochaeta monilaris
Aphelochaeta multifilis
Aphelochaeta spp.
Apistobranchus spp.
Diplocirrus spp.
Eranno lagunae
Euclymeninae spp. indef.
Expolymnia spp.
Leitoscoloplos pugettensis
Levinsenia gracilis
Melinna oculata
Metasychis disparidentata
Montecellina sp. C
Montecellina dorsobranchialis
Montecellina tesselata
Myriochele sp. *M*
Paramage scutata
Parougia caeca
Pholoe glabra
Podarkeopsis glabra
Podarkeopsis perkinsi
Poecilochaetus johnsoni
Tenonia priops

ARTHROPODA (CRUSTACEANS, INSECTS, ARACHNIDS)

Mandibulata

Crustacea

Branchiopoda (Branchiopods)

Branchinecta sandiegonensis
San Diego fairy shrimp

Ostracoda (Ostracods)

**Aspidochoncha limnoriae*
Asteropella slatteryi
Bathyleberis spp.
Conchoecinae sp.
Cylindroleberis sp.
Cylindroleberis mariae
Euphilomedes carcharodonta
Euphilomedes producta
Parasterope barnsei
Philomedes spp.
Podocopidae sp.
**Redekea californica*
Rutiderma cf. *judayi*
Rutiderma lomae
Sarsiella spp.
Soleroconcha spp.

Copepoda (Copepods)

Cyclopoida
Cyclopoid spp.

Harpacticoida
Harpacticoid spp.
harpacticoid

unknown
Parastephos esterlyi

Cirripedia (Barnacles)

Balanidae
**Amphibalanus amphitrite*
**Balanus amphitrite*
little striped barnacle
Balanus glandula
acorn barnacle
Balanus regalio
barnacle
**Balanus tintinnabulum*
red and white barnacle
Megabalanus californianus
red and white barnacle

Chthamalidae
Chthamalus sp.
barnacle

Malacostraca (Crabs and Shrimp)

Cumacea (Cumaceans)
Campylaspis rubromaculata
Cumacea sp. unident.
Cyclaspis sp.
Diastylis sp.
Eudorella pacifica
Oxyurolostylis pacifica

Mysidacea (Mysids, Opossum Shrimps)
Acanthomysis macropsis
Archeomysis maculata
Heteromysis odontops
Holmesimysis sp.
Mysida sp. unident.
Mysidopsis californica
Mysidopsis intii
Neomysis kadiakensis
Neomysis sp.

Nebaliacea (Nebalians)
Epinebalia spp.
Nebalia daytoni
Nebalia pugettensis

Tanaidacea (Tanaids)
Leptochelia cf. *dubia*
Leptochelia sp.
* Sinelobus stanfordi
**Tanaid* sp.
Tanaidacea sp. unident.
Zeuxo narmani

Maxillopoda (Copepods)

Oithonidae
**Oithona davisae*
**Oithona similis*

Pseudodiaptomus
**Pseudodiaptomus marinus*

Isopoda (Isopods)

Bopyridae (Bopyrids)
Schizobopyrina striata

Janiridae (Janirids)
**Ias californica*

Limnoriidae (Limnorids)
**Limnoria quadripunctata*
**Limnoria tripunciata*

Munnidae (Munnids)
Aega sp.
isopod
Munna spp.

Paranthuridae
**Paranthura japonica*

Sphaeromatidae (Sphaeromids)
Cilicaea sculpta
**Sphaeroma quoyanum*
**Sphaeroma walkeri* s
Sphaeromatidae sp.

unknown
Austrosignum tillerae
Cirolana harfordi
cirolanid
Edotea sp.
Paracerceis sculpta
Paranthura elegans
anthurid
Seriolis carinata

Amphipoda (Amphipods)

Gammaridea (Gammarids)

Ampeliscidae (Ampeliscids)
Ampelisca brevisimulata
Ampelisca cristata
Ampelisca hancocki
Ampelisca sp.
Ampeliscidae spp.

Amphilochidae (Amphilodhids)
Amphilochidae spp.

Ampithoidae (Amphithoids)
**Ampithoe valida*
Amphithoe sp.
Ampithoidae spp.

Aoridae (Aorids)
**Aoriodes secunda*
Acuminodeutopus heteruropus
Amphideutopus oculatus
**Grandidierella japonica*
Lembos macromanus
Microdeutopus schmitti
Rudilembroides stenopropodus

Cheluridae
**Chelura terebrans*

Corophiidae (Corophiids)
**Corophium acherusicum*
**Corophium heteroceratum*
**Corophium uenoi*
Corophiidae spp.
* *Erichthonius brasiliensis*
**Monocorophium* spp.

Dexaminidae (Desaminids)
Dexaminidae spp.

Eusiridae
Eusiridae spp.
**Pontogeneia rostrata*

Hyalidae (Hyalid)
Hyale frequens
Hyale spp.
Hyalidae spp.

Isaeidae (Isaeids)
Isaeidae spp.

Ischyroceridae
**Jassa marmorata* (falcata)
Microjassa litotes
Leucothoidae (Leucothoids)
**Leucothoe alata*
Liljeborgiidae (Liljeborgiids)
Listriella goleta
Listrella spp.
Lysianassidae (Lysianassids)
Lysianassidae spp.
Orchomene pacifica
Orchomene pinguis
Orchomene sp.
Oedicerotidea (Oedicarotids)
**Eochelidium* sp. A
Oedicerotidae spp.
Synchelidium rectipalmum
Synchelidium shoemakeri
Photidae
Photis sp.
Phoxocephalidae (Phoxocephalids)
Paraphoxus spp.
Pleustidae (Pleustids)
Parapluestes spp.
Pleustidae sp.
Podoceridae (Phodocerids)
**Podocerus brasiliensis*
Pontogeneia
Pontogeneia minuta
Pontogeneia rostrata
Stenothoidae (Stenothoids)
**Stenothoe valida*
unknown
**Elasmopus rapax*
Gammaridae spp.
Gammaropsis thompsoni
Heterophoxus oculatus
Monoculodes hartmanae
Synchelidium sp.
gammarid
Tiron biocellata
synophiid

Caprellidae (Caprellids, Skeleton Shrimp)

Caprellidae (Caprellids)
**Caprella acanthogaster*
Caprella californica
California skeleton shrimp
Caprella equilbra
Caprella mendax
**Caprella scaura*
Caprella spp.
Caprelliidae spp.
Mayerella banksia
Euphausiacea (Euphau)
Euphilomedes carcharodonta
seed shrimp

Decapoda (Decapods)

Alpheidae (Alpheid shrimp)
Alpheus californiensis
Alpheus sp.A.
Alpheus sp.B.
Betaeus harrimani
Betaeus longidactylus
long fingered shrimp
Betaeus sp.
Atyidae
Atyidae spp.
Callianassidae
Callianassa californiensis
red ghost shrimp
Upogebia pugettensis
callianassid shrimp
Crangonidae (Crangonid shrimp)
Crangon californiensis
Crangon franiscorum
Crangon spp.
Processa canaliculata
Hippolytidae (Hippolytid shrimp)
Heptocarpus cf. *taylori*
Heptocarpus sp. A
Heptocarpus spp.
Hippolyte california
Hipploythe californiensis
grass shrimp
Hippolyte spp.
Spriontocaris sp.
Majidae
Pugettia producta
kelp crab
Pyromaia tuberculata
Palaemonidae
**Palaemon macrodactylus*
Palinaridae
Panulirus interruptus
California spiny lobster
Pinnotheridae (Pinnotherid crab)
Hemigrapsus oregonesis
mudflat crab
Pinnixa barnharti
Scleroplax granulata
Uca crenulata
fiddler crab
Portunidae
Portunus xantusi
swimming crab
Xanthidae
Cancer antennarius
common rock crab
Cancer anthonyi
rock crab
Lophopanopeus bellus diegensis
xanthid mud crab
Lophopanopeus leucomanus
white handed crab
Lophopanopeus sp.
xanthid crab
unknown
Brachyurs sp. unident.
Caridea sp. unident.
Hemisquilla ensigera
Malacoplax californiensis
mudflat crab
Nyeotrypaea californiensis
Pseudosquilla mamorata
Schmittius politus
Speocarcinus californiensis
Squilla polita
Urocaris infraspinis

Insecta

Coleoptera (Beetles)

Alleculidae (Comb-clawed beetles)
Hymenorus sp.
Anthicidae (Ant-like flower beetles)
Anthicus sp.
Ischyropalpus sp.
Mycenotarsus sp.
Notoxus monodon
Buprestidae (Metallic wood-boring beetles)
Acmaeodera labrinthica
Carabidae (Ground beetles)
Acupalpus sp.
Agonum sp.
Amara californica
Amara sp.
Anysodactylus sp.
Bembidion sp.
minute ground beetle
Brachinus tschernkhi
bombardier beetle
Bradycellus sp.
Calathus ruficollis ruficollis
Callida sp.
Calosoma frigidum
Calosoma semilaeve

Carabus nemoralis
Claenius sp.
Dyschurius sp.
Galeritula lecontei
Limnichus sp.
Loricera pilicornis
Microlestes sp.
Omophron ovale and *O. tanneri*
round sand beetles
Pseudaptinus sp.
Pterostichus lustrans
Pterostichus sp.
Scarites subterraneus
Tachys corax
Tetragonoderus sp.

Cerambycidae (Long-horned beetles)
Crossidius testaceous testaceous

Chrysomelidae (Leaf beetles)
Altica sp.
flea beetles
Chalepus sp.
Cryptocephalus sp.
Diabrotica undecimpunctata
western spotted cucumber beetle
Diachus auratus
Donacia sp.
Epitrix sp.
Eurynephalla morosa
Eurynephalla sp.
Exema conspersa
Gastrophysa cyanea
common green dock beetle
Longitarsus sp.
Metachroma californicus
Monoxia sp.
alkali bugs
Pachybrachys sp.
Plataeumaris sp.
Trirhabda sp.

Cicindelidae (Tiger beetles)
Cicindela gabbi
Gabb's tiger beetle
Cicindela haemorrhagica haemorrhagica
Cicindela hirticollis gravida
sandy beach tiger beetle
Cicindela latesignata latesignata
sand dune tiger beetle
Cicindela oregona
Cicindela trifaciata sigmoidea
mudflat tiger beetle

Coccinellidae (Ladybird beetles)
Adalia bipunctata
two-spotted ladybeetle
Auletobius sp.
Coccinella californica
California ladybird
Coleomegilla fuscilabris
Cryptolaemus montrouzieri
mealybug destroyer
Didion nanus
Hippodamia convergens
convergent ladybird
Hyperaspidius comparatus
Hyperaspis fimbriolata
Microweisea sp.
Olla abdominalis
ashy gray ladybird
Psyllobora vigintimaculata
Scymnus sp.

Curculionidae (Weevils, snout beetles)
Bagosus sp.
Endalus sp.
Sphenophorus discolor
Stenopelmus sp.
Trigonoscuta sp.
Tychius sp.

Dermestidae (Carpet beetles)
Anthremus verbasci
Dermestes canisus
Dermestes frischi

Dytiscidae (Predaceous diving beetles)
Agabus disintigratus
Hydroporus sp.
Laccophilus dicipiens
Rhantus hoppingi

Haliplidae (Crawling water beetles)
Haliplus sp.

Helodidae (Marsh beetles)
Cyphon sp.

Heteroceridae (Variegated mud-loving beetles)
Neoheterocerus sp.

Histeridae (Hister beetles)
Hypocaccus lucidulus
Neopachylopus sulcifrons
Saprinus lugens

Hydrophilidae (Scavenger water beetles)
Berosus sp.
Cercyon luniger
Enochrus hamiltoni pacificus
Paracymus elegans
Tropisternus salsamentus

Lathridiidae (Minute brown scavenger beetles)
Melanopthalma sp.

Leiodidae (Round fungus beetles)
unidentified specimen

Limnebiidae (Minute moss beetles)
Ochthebius rectus

Meloidae (Blister beetles)
Nemognatha sp.

Melyridae (Soft-winged flower beetles)
Amecocerus sp.
Endeodes basalis
Trichrochrous nigrinus

Mordellidae (Tumbling flower beetles)
Mordellistena sp.

Oedemeridae (False blister beetles)
Copidita quadrimaculata

Rhyzophagidae (Root-eating beetles)
Phyconomus maritima

Scarabaeidae (Scarab beetles)
Aegialia sp.
Aphodius sp.
Cotina texana
Cotinus mutabilis
green fruit beetle
Parathyce palpalis
Phyllophaga sp.

Silphidae (Carrion beetles)
Nicrophorus marginatus
red and black burying beetle
Nicrophorus nigritus
black burying beetle
Silpha lapponica
satin silphid

Staphylinidae (Rove beetles)
Aleochera sulcicollis
Bledius flavipennis
Bledius nr. *monstratus*
spiny-legged rove beetle
Cafius canaescens
Cafius seminitens
Carpelimus sp.
Psamathobledius punctissimus
salt marsh rove beetle
Staphylinus maxillosus
Stenus sp.
Tachinus sp.
Thinopinus pictus
pictured rove beetle

Tenebrionidae (Darkling beetles)
Amphidora littoralis
Amphidora nigrapilosa
black-haired darkling beetle
Blaptinus sp.
Coelus ciliatus
ciliated dune beetle
Coelus globusus
globose dune beetle
Conibius sp.
Coniontis sp.
Cratidus osculens
woolly darkling beetle
Cryptadius inflatum
Eleodes armata
armored stink beetle
Eleodes gracilis
Phaleria rotundata
Phloedes diabolicus
Stibia sp.

Diptera (Flies)

Agromyzidae (Leaf-miner flies)
Phytomyza albiceps

Anthomyiidae (Anthomyiid flies)
Fucella assimilis
Fucella rejecta
Fucella rufitibia

Asilidae (Robber flies)
Efferia sp.

Bombylidae (Bee flies)
Bombylius sp.
Exoprosopa sp.
progressive bee fly

Calliphoridae (Blow flies)
Phaenicia sericata
green bottle fly
Eucalliphora lilea
common blow fly
Ceratopogonidae
(Punkies, Biting Midges)
Culicoides variipennis occidentalis
Chloropidae(Fruit flies)
Hippelates sp.
Incertella sp.
Meromyza saltatrix
Siphonella sp.
Coelopidae (Seaweed flies)
Coelopa vanduzeei
Conopidae (Thick-headed flies)
Physocephala texana
Thecophora occidentalis
Culicidae (Mosquitos)
Aedes squamiger
salt marsh mosquito
Culex pipiens
Dolichopodidae (Long-legged flies)
Asyndetus sp.
Hydrophorus praecox
Pelastoneurus cyaneus
Raphium sp.
Drosophilidae
(Small fruit flies, pomace flies)
Drosophila sp.
Ephydridae (Shore flies)
Atissa littoralis
Brachydeutera argentata
Ceropsilopa coquilletti
Ceropsilopa dispar
Clanoneurum americanum
Ephydra milbrae
salt marsh brine fly
Ephydra riparia
Lamproscatella dicheata
Mosillus tibialis
Notiphila erythocera
Notiphila pulchrifrons
Scatella obsoleta
Scatella paludum
Empididae (Dance flies)
Platypalpus sp.
Muscidae (Muscid flies)
Musca domestica
house fly
Neriidae (Cactus flies)
Volucella mexicana
cactus fly
Otitidae (Picture-winged flies)
Acrosticta rufiventris
Califortalis hirsutifrons
Ceroxys latiusculus
Phoridae (Hump-backed flies)
Dohrniphora cornuta
Pipunculidae (Big-headed flies)
Pipunculus ater
Psychodidae (Sand flies)
Pericoma sp.
Sarcophagidae (Flesh flies)
Sarcophaga sp.
Scatopsidae
(Minute black scavenger flies)
Rhegmoclemnia melandria
Spaecoridae (Small dung flies)
Leptocera sp.
Stratiomyidae (Soldier flies)
Nemotelus tristis
Syrphidae (Syrphid flies)
Mesograpta marginata
Paragus tibialis
Tabanidae (Horse Flies, Deer Flies)
Tabanus punctifer
big black horse fly
Tendipedidae (Water midges)
Chironimus sp.
Cricotopus spartinus
Tethinidae
Pelomyia coronuta
Pelomyiella melanderi

Hemiptera (True bugs)

Berytidae (Stilt bugs)
Jalysus wickhami
Coreidae (Leaf-footed bugs)
Leptoglossus clypealis
western leaf-footed bug
Corixidae (Water boatmen)
Corisella inscripta
Trichocorixia reticulata
saline water boatman
Trichocorixia verticalis californica salt
marsh water boatman
Gerridae (Water striders)
Gerris remigis
common water strider
Trepobates becki
Hebridae (Velvet water bugs)
Morrogota hebroides
Miridae (Leaf bugs, Plant bugs)
Creontiades sp.
Lygus hesperus
Lygus lineolaris
tarnished plant bug
Melanopleurus sp.
Taylorilygus pallidus
Nabidae (Damsel bugs)
Nabis ferus linnaeus
Damsel bug
Notonectidae (Backswimmers)
Buenoa sp.
small backswimmer
Notonecta unifasciata
single-banded backswimmer
Pentatomidae (Stink bugs)
Chlorochroa sp.
green stink bug
Margantia histrionica
Harlequin Cabbage Bug
Podisus sp.
spined soldier bug
Rhytidolomia faeta
Poiariidae (Thread-legged bugs)
Emesinae sp.
Pyrrhocoridae (Red bugs, Stainers)
Largus cinctus
ordered plant bug
Reduviidae (Assassin bugs)
Nabis sp.
Sinea sp.
Saldidae (Shore bugs)
Pentacora signoreti
Pentacora sphacelata
Saldula fernaldi
Fernald's shore bug
Saldula luctosa
salt marsh shore bug
Saldula opiparia
Saldula pallipes
black shore bug
Tingidae (Lace bugs)
Corythuca sp.
Veliidae (Riffle bugs)
Microvelia sp.

Homoptera (Cicadas, Hoppers amd Aphids)

Aleyrodidae (Whiteflies)
Trialeuodes vaporariorum
Aphididae (Aphids)
Aphise gossypii
cottony aphid
Brachycaudis cardui
thistle aphid
Brevicoryne brassicae
cabbage aphid
Cercopidae (Froghoppers, Spittlebugs)
Aphrophora annulata annulate
Clastoptera lineatocollis
Cicadellidae (Leafhoppers)
Balchutha neglecta
Ballana vema
Ballana vesca
Carneocephalus sp.
Collandonus montanus
Draeculaecephala minerva
Empoasca alboneura
Empoasca decora
Eupteryx melissae
Hordnia circellata
blue sharpshooter
Idiodonus sp.
Macrosteles fascifrons
Mormoria sp.

Penestragania robusta
Stragania sp.
green leafhopper
Cicadidae (Cicadas)
Okanagana vanduzeei
Cixiidae (Cixiid planthoppers)
Oliarus sp.
Delphacidae (Delphacids, planthoppers)
Delphacodes propinqua
Deltocephalus minutus
Prokelisia salina
Stobaeria muiri
Diaspididae (Armored scales)
Haliaspis spartina
cordgrass scale
Dictyopharidae (Dictyopharids, planthoppers)
Orgerius propius
Flatidae (Flatids, planthoppers)
Mistharnophantia sonorana
Issidae (Issids, planthoppers)
Danepteryx manca
Margarodidae (Giant coccids)
Icerya purchasi
cottony-cushion scale
Membracidae (Treehoppers)
Spissistilus festinus
three-cornered alfalfa hopper
Stictocephala sp.
buffalo treehoppers
Pseudococcidae (Meally bugs)
Distichlicoccus salinus
Puto echinatus
fluffy mealy bug
Psyllidae (Psyllids)
Craspedolepta martini
Craspedolepta pulchella

Hymenoptera (Ants, Wasps and Bees)

Apidae (Bees)
* *Apis mellifera*
honey bee
Bombus sonorus
Sonoran bumble bee
Bombus vosnesenskii
yellow-faced bumble bee
Chalcididae (Chalcids, wasps)
Chalcidoidea chalcid
Formicidae (Ants)
* *Iridomyrmex humilis*
Argentine ants
Pogonomyrmex californicus
harvester ants
Ichneumonidae (Ichneumonids, wasps)
Ichneumonid sp.
Mutillidae (Velvet ants)
Dasymutilla sp.
Pompilidae (Spider wasps)
Hemipepsis sp.
tarantula hawk
Sphecidae (Sphecids, wasps)
Ammophila sp.
thread-waisted wasp
Bembix sp.
sand wasp
Sphex ichneumonia
golden digger wasp
Tiphiidae (Tipiids, wasps)
Methoca sp.
Vespidae (Vespids, wasps)
Polistes sp.
paper wasp

Lepidoptera (Moths and Butterflies)

Danaidae (Milkweed butterflies)
Danaus plexippus
monarch
Geometridae (Geometer moths, Inchworms)
Caenurgia togataria
Perizoma custodiata
Hesperiidae (Common skippers)
Erynnis funeralis f
unereal duskywing
Hylephila phyleus
fiery skipper
Panoquina errans
wandering salt marsh skipper
Pyrgus communis
checkered skipper
Lycaenidae (Gossamer-winged butterflies)
Brephidium exilis
western pygmy blue
Strymon melinus
common hairstreak
Noctuidae (Millers, Cutworms)
Tarachidia candefacta
Zale lunata
Moon umber
Nymphalidae (Brush-footed butterflies)
Nymphalis antiopa
mourning cloak
Vanessa annabella
west coast lady
Vanessa atalanta red
admiral
Vanessa cardui
painted lady
Papilionidae (Swallowtails)
Papilio rutulus
western tiger swallowtail
Papilio zelicaon
anise swallowtail
Pieridae (Whites, Sulphurs, and Orange-tips)
Colias eurytheme
* *Pieris rapae*
cabbage butterfly
Psychidae (Bagworm moths)
Pterophoridae (Plume moths)
Agdistis americana
Pyralidae (Snout moths)
Lipographa fenestrella
salt marsh snout mouth
Lipographa truncatella
Synclita sp.
Sphingidae (Sphinx or Hawk moths)
Hyles lineata
white-lined sphinx

Collembola (Springtails)

Poduridae (Collembola, Springtails)
Anurida maritima
marine springtail
Archistoma interstitialis

Dermaptera (Earwigs)

Forficulidae (Earwigs)
* *Forficula auricularia* earwig

Ephemeroptera (Mayflies)

Baetidae (Mayflies)
Callibaetis pacificus pacific
spotted may fly

Neuroptera (Lacewings and Antlions

Chrysopidae (Green lacewings)
Chrysoperla carnea

Hemerobiidae (Brown lacewings)
Hemerobius pacificus
Sympherobius sp.

Myrmeleontidae (Antlions)
Myrmeleon immaculatus

Odonata (Damselflies and Dragonflies)

Aeshnidae (Darners)
Aeshna multicolor
blue darner
Anax junius
common gree darner

Coenagrionidae (Narrow-winged damselflies)
Enallagama ceville
Ishnura barberi
forktail damselfly
Ishnura denticollis
forktail damselfly

Libellulidae (Common skimmers)
Libelluta saturata
big red skimmer
Pachydiplax longipennis
swift long-winged skimmer
Sympetrum sp.
Tarnetrum corruptum
Tramea lacerata
jagged-edged saddlebag

Orthoptera (Crickets and Grasshoppers)

Acridiidae (Grasshoppers)
Chloealtis gracilis
slant-faced grasshopper
Conozoa sulcifrons sulcifrons
Melanoplus cirereus
Melanoplus obespsolus
Orphulella pelidona
Psoloessa thamnogaea
Trimerotropis pallidipennis
pallid-winged grasshopper

Gryllacrididae (Ground and Camel crickets)
Ceuthophilus californianus
California camel cricket
Pristoceuthophilus sp.
mushroom camel cricket
Stenopelmatus fuscus
Jerusalem cricket

Gryllidae (Crickets)
Cycloptilum distinctum
Gryllus sp.
field cricket
Oecanthus argentimus
tree cricket

Mantidae (Mantids)
Litaneutria minor minor
ground mantid

Mantodea (Mantids)

Mantidae (Mantids)
Stagmomantis californica
California mantis

Strepsiptera (Twisted-winged parasites)

Stylopidae
Elenchus sp.

Thysanoptera (Thrips)

Tubulifera
Leptothrips mali

Thysanura (Bristletails)

Lepismatidae
Allacrotelsa spinulata
common/Becker's wife
Lepisma saccharina
Neomachilis sp.

Chelicerata

Arachnida (Spiders, Mites, Pseudoscorpions)

Agelenidae (Funnel web weavers)
Agelenopsis sp.
grass spiders
Calilena sp.

Anyphaenidae
Teudis mordax

Araneidae (Orb weavers)
Araneus sp.
Argiope argentata
silver argiope
Eustala conchlea
Mastophora sp.
bola spider
Clubionidae (Sac spiders)
Ctenizidae (Trapdoor spiders)
Bothriocyrtum californicum
California trapdoor spider
Aptostichus sp.
Dictynidae (Dictynids, spiders)
Dictyna agressa
Dictyna varyna
Tricholathys saltona
Dysderidae
** Dysdera crocata*
Eremobatidae (Wind scorpions)
Eremobates sp.
Eriogonidae
Erigone dentosa
Walckeraeria sp.

Garypidae (Pseudoscorpions)
Garypus californicus
Linyphiidae
Bathyphantes sp.
Lycosidae (Wolf spiders)
Allopecosa kochi
Arctosa littoralis
Clubiona pomoa
Geolycosa sp.
burrowing wolf spider
Lycosa sp.
wolf spider
Pardosa ramulosa
thin-legged wolf spider
Schizocosa mccooki
Oxyopidae (Lynx spiders)
Peucetia viridans
green lynx spider
Philodromidae (Philodromid spiders)
Ebo pepinensis
Tibellus chamberlini

Pholcidae
Psilochorus sp.
Salticidae (Jumping spiders)
Metaphidippus sp.
metaphid jumping spider
Pellenes elegans
Pseudicius sp.
Tetragnathidae (Large-jawed orb weavers)
Tetragnatha laboriosa
long-jawed orb weaver
Theridiidae (Comb-footed spiders)
Crustulina sticta
Latrodectus mactans
black widow
Steatoda fulva
Thomisidae (Crab spiders)
Misumenops lepidus
Xysticus gulosus
Zodariidae Araneida
Lutica abalonea
sand spider
unknown
Clysosa sp.

MOLLUSCA (CLAMS, SNAILS AND CEPHALAPODS)

Gastropoda (Snails, Limpets, Sea Hares, Nudibranchs)

Acmeidae
Acmaea limatula
file limpet
Acteocinidae
Acteocina culcitella
Acteocina inculta
Acteocina magdalenenis
glassy bubble
Cylichna alba
acteocinid
Cylichnella harpa
Cylichnella inculta
Aelidae
Aelidae spp.
Anaspidea
Aplysia californica
California sea hare
Assimineidae
Assiminea californica
assimineid snail
Caecidae
Caecum californicum
California caecum
Fartulum occidentale
caecid
Calyptraeidae
Crepidula fornicata
Crepidula onyx
onyx slipper shell
Crepipatela lingulata
half-slipper shell
Cephalaspidae
Aglaja diomedia
tectibranch
Bulla gouldiana
Gould's bubble

Chelidonura inermis
large sea slug
Haminaea vesicula
blister paper bubble
Cerithiopsidae
Cerithidea californica
California horn shell
Cerithidea fuscata
horn shell snail
Columbellidae
Columbellidae spp.
Mitrella carinata
dove shell
Mitrella tuberosa
Fissurellaceae
Collisela depicta fissurellid
Lacunidae
Lacuna marmorata
chink shell
Nassariidae
Nassarius medicus
Nassarius perpinguis
Nassarius tegula
mud-dog whelk
Naticidae
Neverita reclusiana
Nudibranchia
**Catriona rickettsi*
Discodoris sandiegensis
San Diego sea slug
Nudibranch spp.
Olividae (Olive Shells)
Olivella baetica
olive shell
Olivella sp.
olive shell

Phasianellidae
Tricolia compta
banded pheasant
Pyramidellidae
Odostomia sp.
odostome
Turbonilla sp.
pyramidellid
Rissoidae (Rissoid snail)
Alvinia spp.
Barleeia californica
Barleeia subtenuis
Rissoella sp.
Vitrinellidae
Vitrinorbis diegensis
vitronorbis
Vitrinellidae spp. *vitrinella*
unknown
Aclis tectibranch
Acmira catherinae
Acmira horikoshii
Alabina spp.
Crucibulum spinosum
cup and saucer limpet
Ophiodermella ophioderma
penciled turret shell
Ophiodermella spp.
turret shell
Philine sp.
Sulcoretusa xystrum
Tachyhynchus sp.
turret shell

Bivalvia (Clams, Cockles, Mussels, Oysters, Shipworms)

Arcidae
**Arca transversa*
Mactridae
Mactra californica
California dish clam
Spisula catilliformis
narrow dish clam
Spisula spp.
Myidae
Platyodon cancellatus
checked borer
Mytilidae
Adula diegensis
San Diego pea pod
**Geukensia (Ischadium) demissa*
ribbed mussel
**Musculista senhousia*
Japanese mussel
Mytilus edulis
bay mussel
**Mytilus galloprovincialis*
Volsella flabellata (Modiolus modiolus)
giant horsemussel

Ostreidae
**Ostrea edulis*
Psammobiidae
Gari californica
sunset clam
Tagelus californianus
Tagelus subteres
Semelidae
**Theora fragilis*
clam
**Theora lubrica*
Solenidae
Siliqua lucida
solenid clam
Solen rosaceus
rosy razor clam
Solen sicarius
razor clam
Tellinidae
Macoma nasuta
bent-nosed clam
Macoma secta
sand-flat clam

Macoma yoldiformis
tellinid clam
Teredinidae
**Lyrodus pedicellatus*
southern shipworm
**Teredo navalis*
shipworm
Veneridae
**Tapes japonica (semidecussata)*
venerid clam
Tivela sp.
venus clam
Veneridae spp.
unknown
Asthenothaerus villiosior
clam
Calyptogenia sp. *A*
clam
Chione undatella wavy
cockle
Dhione fluctifraga
smooth cockle
Laevicardium substriatum
eggshell clam

Cephalopoda (Octopi, Squids)

Octopus bimaculatus
two-spotted octopus

Octopus bimaculoides

ECHINODERMATA (STARFISH, URCHINS AND CUCUMBERS)

Echinoidea (Sea Urchins, Sand Dollars, Heart Urchins)

Dendraster excentricus
eccentric sand dollar

Holothuroidea (Sea Cucumbers)

Holothuroidea sp.
sea cucumber

Leptosynapata albicans
southern California sea cucumber

Ophiuroidea (Brittle Stars, Serpent Stars)

Amphiodia (nr) *occidentalis*
brittle star
Amphipholis pugetana
brittle star

Axiognathus squamatus
brittle star
Ophiactis simplex
brittle star

Ophiuroidea sp.

PHORONIDA (PHORONIDS)

Phoronid spp.

ECTOPROCTA (BRYOZOA)

**Amathia convoluta*
**Bowerbankia imbricata*
Bowerbankia spp.
Bryzoan spp.
Bugula californica
**Bugula neritina*
**Bugula stolonifera*

Celleporaria brunnea
whitish brown bryzoan
Cheilostomata sp.
Crisia sp.
**Cryptosula pallasiana*
Cyclostome sp.
**Rhynchozoon bispinosum*

**Schizoporela unicornis*
Thalamoporella californica
**Tricellaria gracilis*
**Watersipora arcuata*
**Watersipora subtorquata*
**Watersipora* sp. A
**Zoobotryon verticillatum*

CHORDATA

Urochordata (Sea Squirts, Compound Ascidians, Tunicates)

Ascidia zara
tunicate
**Ascidia* sp.
tunicate
**Botrylloides diegensis*
tunicate
**Botrylloides perspicuum*
**Botrylloides violaceus*
**Botryllus schlosseri*
tunicate
**Botryllus sp.*
**Ciona intestinalis*
tunicate
**Ciona savignyi*
tunicate
**Diplosoma listerianum*
**Lucania parva*
**Microcosmus squamiger*
tunicate
**Molgula ficus*
**Polyandrocarpa zorritensis*
tunicate
**Styela canopus*
tunicate
**Styela clava* (formerly *barnharti*)
tunicate
Styela montereyensis
California styela
**Styela plicata*
tunicate
**Symplegma brakenhielmi*
tunicate
**Symplegma reptans*

Cephalochordata (Lancelets)

Branchiostoma californiense
lancelet

Vertebrata

Chondrichthyes (Sharks and Rays)

Carcharhinidae
Carcharhinus remotus
narrowtooth shark
Galeorhinus zyopterus
soupfin shark
Mustelus californicus
gray smoothhound
Mustelus henlei
brown smoothhound
Mustelus lunulatus
sicklefin smoothhound
Prionace glauca blue shark
Triakis semifasciata
leopard shark
Gymnuridae
Gymnura marmorata
California butterfly ray
Heterodontidae
Heterodontus francisci
California horn shark
Myliobatididae
Myliobatis californica
bat ray
Platyrhinidae
Platyrhinoidis triseriata
thornback
Rhinobatidae
Rhinobatus productus
shovelnose guitarfish
Urolophus halleri
round stingray
Zapteryx exasperatus
banded guitarfish
Sphyrnidae
Sphyrna zygaena
smooth hammerhead shark
Squalidae
Squalus acanthias
spiny dogfish
Squatinidae
Squatina californica
pacific angel shark

Osteichthyes (Bony Fishes)

Albulidae
Albula vulpes
bonefish
Antherinidae
Atherinops affinis
topsmelt
Atherinopsis californiensis
jacksmelt
Atherinidae
Leuresthes tenuis
California grunion
Batrachoididae
Porichthys myriaster
specklefin midshipman
Porichthys notatus
plainfin midshipman
Belonidae
Strongylura exilis
California needlefish
Blennidae
Hypsoblennius gentilis
bay blenny
Hypsoblennius jenkensi
mussel blenny
Bothidae
Citharichthys stigmaeus
speckled sand dab
Hippoglossina stomata
bigmouth sole
Xysteurys liolepis
fantail sole
Carangidae
Caranx caballus
green jack
Caranx hippos
crevalle jack
Trachurus symmetricus
jack mackerel
Chanidae
Chanos chanos
milkfish
Clinidae
Gibbonsia elegans
spotted kelpfish
Gibbonsia montereyensis
crevice kelpfish
Gibbonsia metzi
striped kelpfish
Heterostichus rostratus
giant kelpfish
Parachinus integripinnis
reef finspot
Clupeidae
Clupea harengus pallasii
Pacific herring
* *Dorosoma petenense*
threadfin shad

Sardinops sagax caeruleus
Pacific sardine

Cottidae

Leptocottus armatus
staghorn sculpin

Scorpaena guttata
spotted scorpionfish or sculpin

Scorpaenichthys marmoratus
cabezon

Cynoglossidae

Symphurus atricauda
California tonguefish

Cyprinodentidae

Fundulus parvipinnis
California killifish

Embiotocidae

Amphistichus argenteus
barred surfperch

Cymatogaster aggregata
shiner surfperch

Damalichthys vacca
pile surfperch

Embiotoca jacksoni
black surfperch

Hyperprosopon argenteum
walleye surfperch

Micrometrus minimus
dwarf surfperch

Phanerodon furcatus
white surfperch

Rhacochilus toxotes
rubberlip surfperch

Engraulidae

Anchoa compressa
deepbody anchovy

Anchoa delicatissima
slough anchovy

Cetengraulis mysticetus
anchoveta

Engraulis mordax
northern anchovy

Girellidae

Girella nigricans
opaleye

Gobiesocidae

Rimicola muscarum
kelp clingfish

Gobiidae

* *Acanthogobius flavimanus*
yellowfin goby

Clevelandia ios
arrow goby

Gillichthys mirabilis
longjaw mudsucker

Gobionellus longicaudus
longtail goby

Ilypnus gilberti
cheekspot goby

Lepidogobius lepidus
bay goby

Quietula y-cauda
shadow goby

* *Tridentiger trigonocephalus*
chameleon goby

Hacnulidae

Haemulon flaviguttatum
Cortez grunt

* *Poecilia latipinna*
sailfin molly

Hemiramphidae

Hyporhamphus rosae
California halfbeak

Kyphosidae

Hermosilla azurea
zebra perch

Labridae

Halichoeres semicinctus
rock wrasse

Oxyjulis californica
senorita

Mugilidae

Mugil cephalus
striped mullet

Pleuronectidae

Hypsopsetta guttulata
diamond turbot

Paralichthys californicus
California halibut

Platichthys stellatus
starry flounder

Pleuronectes vetulus
English sole

Pleuronichthys coenosus
C-O turbot

Pleuronichthys ritteri
spotted turbot

Pleuronichthys verticalis
hornyhead turbot

Pristipomatidae

Anisotremus davidsonii
sargo

Xenistius californiensis
salema

Sciaenidae

Atractoscion nobilis
white seabass

Cheilotrema saturnum
black croaker

Cynoscion parvipinnis
shortfin corvina

Genyonemus lineatus
white croaker

Menticurrhus undulatus
California corbina

Roncador stearnsii
spotfin croaker

Seriphus politus
queenfish

Umbrina roncador
yellowfin croaker

Scombridae

Sarda chiliensis
Pacific bonito

Scomber japonicus
Pacific mackerel

Scomberomorus sierra
sierra

Scorpididae

Medialuna californiensis
halfmoon

Serranidae

* *Morone (Roccus) saxatilis*
striped bass

Paralabrax clathratus
kelp bass

Paralabrax maculatofasciatus
spotted sand bass

Paralabrax nebulifer
barred sand bass

Sphyraenidae

Sphyraena argentea
California barracuda

Stromateidae

Peprilus simillimus
Pacific butterfish

Syngnathidae

Bryx arctos
snubnose pipefish

Hippocampus ingens
Pacific seahorse

Syngnathus auliscus
barred pipefish

Syngnathus californiensis
kelp pipefish

Syngnathus exilis
barcheek pipefish

Syngnathus griseolineatus
bay pipefish

Synodontidae

Synodus lucioceps
California lizardfish

Reptilia (Reptiles)

Anguidae

Gerrhonotus multicarinatus webii
San Diego alligator lizard

Anniellidae

Anniella pulchra pulchra
silvery legless lizard

Cheloniidae

Chelonia mydas
green sea turtle

Colubridae

Pituophis melanoleucus annectens
San Diego gopher snake

Thamnophis hammondii hammondii
Hammond's two-striped garter snake

Hylidae

Hyla regilla
Pacific tree frog

Phrynosomatidae

Sceloporous occidentalis
western fence lizard

Uta stansburiana
side-blotched lizard

Sceloporus

Phrynosoma coronatum blainvillei
San Diego horned lizard

Scincidae
Eumeces skiltonianus interparietalis
Coronado skink

Aves (Birds)

Anseriformes

Anatidae (Swans, geese, and ducks)
!*Aix sponsa*
wood duck
Anas acuta
northern pintail
Anas americana
American wigeon
Anas crecca carolinensis
green-winged teal
Anas clypeata
northern shoveler
Anas cyanoptera septentrionalium
cinnamon teal
Anas discors
blue-winged teal
Anas penelope
Eurasian wigeon
Anas platyrhynchos platyrhynchos
mallard
Anas strepera strepera
gadwall
Anas sp.
domestic duck
Aythya affinis
lesser scaup
Aythya americana
redhead
Aythya collaris
ring-necked duck
!*Aythya fuligula*
tufted duck
Aythya marila nearctica
greater scaup
Aythya valisineria
canvasback
Branta bernicla hrota
light-bellied brant
Branta bernicla nigricans
black brant
Branta canadensis
Canada goose
Bucephala albeola
bufflehead
Bucephala clangula
common goldeneye
!*Bucephala islandica*
Barrow's goldeneye
!*Chen caerulescens*
snow goose
!*Chen rossii*
Ross' goose
Clangula hyemalis
long-tailed duck
!*Cygnus columbianus*
tundra swan
!*Dendrocygna bicolor*
fulvous whistling-duck
!*Histrionicus histrionicus*
harlequin duck
Lophodytes cucullatus
hooded merganser
Melanitta fusca deglandi
white-winged scoter
Melanitta americana
black scoter
Melanitta perspicillata
surf scoter
Mergus merganser
common merganser
Mergus serrator
red-breasted merganser
Oxyura jamaicensis rubida
ruddy duck
!*Somateria spectabilis*
king eider

Galliformes

Odontophoridae (Quails)
Callipepla californica californica
California quail

Phasianidae (Pheasants)
Phasianus colchicus
ring-necked pheasant

Gaviiformes

Gaviidae (Loons)
Gavia immer
common loon
Gavia pacifica
Pacific loon
Gavia stellata
red-throated loon

Podicipediiformes

Podicipedidae (Grebes)
Aechmophorus clarkii transitionalis
Clark's grebe
Aechmophorus occidentalis occidentalis
western grebe
Podiceps auritus cornutus
horned grebe
!*Podiceps grisegena holboellii*
red-necked grebe
Podiceps nigricollis californicus
eared grebe
Podilymbus podiceps podiceps
pied-billed grebe

Procellariiformes

Hydrobatidae
(Storm-Petrels and shearwaters)
!*Oceanodroma homochroa*
ashy storm-petrel
!O*ceanodroma leucorhoa*
Leach's storm-petrel
!*Oceanodroma melania*
black storm-petrel
!*Oceanodroma microsoma*
least storm-petrel
!*Puffinus bulleri*
Buller's shearwater

Pelecaniformes

Fregatidae (Frigatebirds)
!*Fregata magnificens*
magnificent frigatebird
Pelecanidae (Pelicans)
Pelecanus erythrorhynchos
American white pelican
Pelecanus occidentalis californicus
brown pelican
Phalacrocoracidae (Cormorants)
Phalacrocorax auritus
double-crested cormorant
Phalacrocorax pelagicus
pelagic cormorant
Phalacrocorax penicillatus
Brandt's cormorant
Sulidae (Boobies)
!*Sula leucogaster brewsteri*
brown booby

Ciconiiformes

Ardeidae (Herons)
Ardea alba egretta
great egret
Ardea herodias wardi
great blue heron
Botaurus lentiginosus
American bittern
Bubulcus ibis ibis
cattle egret
Butorides virescens anthonyi
green heron
Egretta caerulea
little blue heron
Egretta rufescens dickeyi
reddish egret
Egretta thula thula
snowy egret
Egretta tricolor ruficollis
tricolored heron
!*Ixobrychus exilis hesperis*
least bittern
!*Nyctansassa violacea bancrofti*
yellow-crowned night heron
Nycticorax nycticorax hoactli
black-crowned night heron
Nyctansassa violaceus bancrofti X Nycticorax nycticorax hoactli (per. com. Tim Burr)
Cathartidae (Vultures)
Cathartes aura meridionalis
turkey vulture
!*Gymnogyps californianus*
California condor
Ciconiidae (Storks)
!*Mycteria americana*
wood stork
Threskiornithidae (Ibises)
Plegadis chihi
white-faced ibis

Falconiformes

Accipitridae (Hawks, kites, and eagles)
Accipiter cooperii
Cooper's hawk
Accipiter striatus velox
sharp-shinned hawk
!*Aquila chrysaetos canadensis*
golden eagle
Buteo jamaicensis calurus
western red-tailed hawk
!*Buteo lagopus sanctijohannis*
rough-legged hawk
Buteo lineatus elegans
red-shouldered hawk
!*Buteo platypterus platypterus*
broad-winged hawk
!*Buteo regalis*
ferruginous hawk
!*Buteo swainsoni*
Swainson's hawk
Circus cyaneus hudsonius
northern harrier
Elanus leucurus
white-tailed kite
!*Haliaeetus leucocephalus*
bald eagle
Falconidae (Falcons)
!*Caracara cheriway auduboni*
crested caracara
Falco columbarius columbarius
American merlin
Falco mexicanus
prairie falcon
Falco peregrinus anatum
peregrine falcon
Falco sparverius sparverius
American kestrel
Pandionidae (Osprey)
Pandion haliaetus carolinensis
osprey

Gruiformes

Rallidae (Coot, gallinules, and rails)
Fulica americana americana
American coot
Gallinula chloropus cachinnans
common moorhen
†! *Laterallus jamaicensis coturniculus*
black rail
Porzana carolina sora
Rallus limicola limicola
Virginia rail
Rallus longirostris levipes
light-footed clapper rail
Gruidae (Cranes)
!*Grus canadensis*
sandhill crane

Charadriiformes

Alcidae (Murrelets)
!*Synthliboramphus antiquus*
ancient murrelet
!*Synthliboramphus craveri*
Craveri's murrelet
Charadriidae (Plovers)
Charadrius alexandrinus nivosus
western snowy plover
Charadrius montanus
mountain plover
Charadrius semipalmatus
semipalmated plover
Charadrius vociferus vociferus
killdeer
!*Charadrius wilsonia beldingi*
Wilson's plover
!*Pluvialis fulva*
pacific golden-plover
Pluvialis squatarola
black-bellied plover
Haematopodidae (Oystercatchers)
Haematopus bachmani
black oystercatcher
!*Haematopus palliatus*
American oystercatcher

Laridae (Gull,terns, and skimmers)
Chlidonias niger surinamensis
black tern
Larus argentatus smithsonianus
herring gull
Leucophaeus atricilla
laughing gull
Larus californicus californicus
California gull
Larus canus brachyrhynchus
mew gull
!*Larus crassirostris*
black-tailed gull
Larus delawarensis
ring-billed gull
Larus glaucescens
glaucous-winged gull
Larus glaucescens X Larus occidentalis
olympic gull
Larus heermanni
Heerman's gull
Larus hyperboreus barrovianus
glaucous gull
Larus occidentalis wymani
western gull
Chroicocephalus philadelphia
Bonaparte's gull
Larus pipixcan
Franklin's gull
Larus thayeri
Thayer's gull
Rissa tridactyla pollicaris
black-legged kittiwake
Rynchops niger niger
black skimmer
Sternula antillarum browni
California least tern
Hydroprogne caspia
Caspian tern
Thalasseus elegans
elegant tern
Sterna forsteri
Forster's tern
!*Onychoprion fuscatus oahuensis/crissalis*
sooty tern
Sterna hirundo hirundo
common tern
Thalasseus maximus
royal tern
Geochelidon nilotica vanrossemi
gull-billed tern
Sterna paradisaea
artic tern
!*Sterna sandvicensis acuflavida*
sandwich tern
!*Xema sabini*
Sabine's gull

Stercorariidae (Jaegers)
!*Stercorarius longicaudus pallescens*
long-tailed jaeger
Stercorarius parasiticus
parasitic jaeger
Stercorarius pomarinus
pomarine jaeger

Recurvirostridae (Stilts and avocets)
Himantopus mexicanus mexicanus
black-necked stilt
Recurvirostra americana
American avocet

Scolopacidae (Sand pipers and phalaropes)
Actitis macularius
spotted sandpiper
Aphriza virgata
surfbird
Arenaria interpres
ruddy turnstone
Arenaria melanocephala
black turnstone
Calidris alba
sanderling
Calidris alpina pacifica
dunlin
Calidris bairdii
Baird's sandpiper
Calidris canutus roselaari
red knot
Calidris himantopus
stilt sandpiper
Calidris mauri
western sandpiper
Calidris melanotos
pectoral sandpiper
Calidris minutilla
least sandpiper
Calidris pusilla
semipalmated sandpiper
Gallinago delicata
Wilson's snipe
Tringa semipalmata inornatus
willet
Limnodromus griseus caurinus
short-billed dowitcher
Limnodromus scolopaceus
long-billed dowitcher
Limosa fedoa fedoa
marbled godwit
!*Limosa lapponica baueri*
bar-tailed godwit
Numenius americanus
long-billed curlew
Numenius phaeopus hudsonicus
whimbrel
!*Phalaropus fuclicarius*
red phalarope
Phalaropus lobatus
red-necked phalarope (northern)
Phalaropus tricolor
Wilson's phalarope
Philomachus pugnax
ruff
Tringa flavipes
lesser yellowlegs
Tringa incana
wandering tattler
Tringa melanoleuca
greater yellowlegs
Tringa solitaria cinnamomea
solitary sandpiper

Columbiformes

Columbidae (Pigeons and doves)
* *Columba livia*
rock pigeon
!*Streptopelia chinensis*
spotted dove
!*Streptopelia decaocto*
Eurasian collared-dove
Zenaida asiatica mearnsi
white-winged dove
Zenaida macroura marginella
mourning dove

Psittaciformes

Psittacidae (Parrots)
Amazona viridigenalis
red-crowned parrot

Cuculiformes

Cuculidae (Cuckoos)
!*Coccyzus americanus occidentalis*
yellow-billed cuckoo
Geococcyx californianus
greater roadrunner

Strigiformes

Strigidae (Typical owls)
Asio flammeus flammeus
short-eared owl

Athene cunicularia hypugaea
burrowing owl
Bubo virginianus
great horned owl

Tytonidae (Barn owl)
Tyto alba pratincola
barn owl

Caprimulgiformes

Caprimulgidae (Nightjars)
Chordeiles acutipennis texinsis
lesser night hawk
!*Chordeiles minor hesperis*
common night hawk

Apodiformes

Apodidae (Swifts)
Aeroautes saxatalis saxatalis
white-throated swift
Chaetura vauxi vauxi
Vaux's swift

Trochilidae (Hummingbirds)
Archilochus alexandri
black-chinned hummingbird
Calypte anna
Anna's hummingbird
Calypte costae
Costa's hummingbird
Selasphorus rufus
rufous hummingbird
Selasphorus sasin
Allen's hummingbird
Stellula calliope
Calliope hummingbird

Coraciiformes

Alcedinidae (Kingfisher)
Megaceryle alcyon
belted kingfisher

Piciformes

Picidae (Woodpeckers)
Colaptes auratus
northern flicker

Passeriformes

Aegithalidae (Long-tailed tits)
Psaltriparus minimus melanurus
bushtit

Alaudidae (Larks)
Eremophila alpestris
horned lark

Bombycillidae (Waxwings)
Bombycilla cedrorum
cedar waxwing

Cardinalidae (Grosbeaks)
Passerina amoena
lazuli bunting
Passerina caerulea
blue grosbeak
Pheucticus melanocephalus maculatus
black-headed grosbeak

Corvidae (Jays and crows)
Aphelocoma californica obscura
scrub jay
Corvus brachyrhynchos hesperis
American crow
Corvus corax clarionensis
common raven

Emberizidae (Sparrows and allies)
Aimophila ruficeps canescens
rufous-crowned sparrow
!Ammodramus caudacutus nelsoni
saltmarsh sparrow
Passerculus sandwichensis
Savannah sparrow
Passerculus sandwichensis beldingi
Belding's Savannah sparrow
Passerculus sandwichensis rostratus
large-billed Savannah sparrow
!*Calamospiza melanocorys*
lark bunting
Junco hyemalis
dark-eyed junco
Melospiza lincolnii
Lincoln's sparrow
Passerella iliaca
fox sparrow
Melospiza georgiana ericrypta
swamp sparrow
Melospiza melodia cooperi
San Diego song sparrow
Melozonecrissalis
California towhee
Pipilo maculatus megalonyx
rufous-sided towhee
Pipilo chlorurus
green-tailed towee
Pooecetes gramineus
vesper sparrow
Spizella passerina arizonae
chipping sparrow
Zonotrichia atricapilla
golden-crowned sparrow
Zonotrichia leucophrys
white-crowned sparrow

Fringillidae (Finches)
Spinus lawrencei
Lawrence's goldfinch
Spinus pinus pinus
pine siskin
Spinus psaltria hesperophilus
lesser goldfinch
Spinus tristis salicamans
American goldfinch
Carpodacus mexicanus frontalis
house finch

Hirundinidae (Swallows)
Petrochelidon pyrrhonota tachina
cliff swallow
Hirundo rustica erythrogaster
barn swallow
!*Progne subis subis*
purple martin
Riparia riparia riparia
bank swallow
Stelgidopteryx serripennis
northern rough-winged swallow
Tachycineta bicolor
tree swallow

Tachycineta thalassina thalassina
violet-green swallow

Icteridae (Blackbirds and allies)

Agelaius phoeniceus neutralis
red-winged blackbird

Agelaius tricolor
tricolored blackbird

Euphagus cyanocephalus
Brewer's blackbird

Icterus cucullatus nelsoni
hooded oriole

Icterus galbula
Baltimore oriole (northern)

Molothrus ater
brown-headed cowbird

Sturnella neglecta
western meadowlark

Quiscalus mexicanus
great-tailed grackle

Xanthocephalus xanthocephalus
yellow-headed blackbird

Laniidae (Shrikes)

Lanius ludovicianus
loggerhead shrike

Mimidae (Mimic thrushes)

Mimus polyglottos polyglottos
northern mockingbird

Oreoscoptes montanus
sage thrasher

Toxostoma redivivum redivivum
California thrasher

Motacillidae (Wagtails, pipits)

!*Anthus cervinus*
red-throated pipit

Anthus rubescens pacificus
American pipit

Muscicapidae (Gnatcatchers)

Polioptila caerulea
blue-gray gnatcatcher

Polioptila californica
California gnatcatcher

Parulidae (warblers)

Dendroica coronata auduboni
Audubon's warber (yellow-rumped)

Dendroica coronata hooveri
myrtle warbler (yellow-rumped)

Dendroica nigrescens
black-throated gray warbler

Dendroica occidentalis
hermit warbler

Dendroica palmarum palmarum
palm warbler

Dendroica petechia
yellow warbler

Dendroica townsendi
Townsend's warbler

Geothlypis trichas
common yellowthroat

Icteria virens auricollis
yellow-breasted chat

Oporornis tolmiei tolmiei
MacGillivray's warbler

Setophaga ruticilla
American redstart

Oreothlypis celata
orange-crowned warbler

Oreothlypis luciae
Lucy's warbler

Oreothlypis ruficapilla ridgwayi
Nashville warbler

Oreothlypis virginiae
Virginia warbler

Wilsonia pusilla
Wilson's warbler

Passeridae (Old world sparrow)

* *Passer domesticus domesticus*
house sparrow

Ptilogonatidae (Phainopepla)

Phainopepla nitens lepida
phainopepla

Regulidae (Kinglets)

Regulus calendula calendula
ruby-crowned kinglet

!*Regulus satrapa apache*
golden-crowned kinglet

Sturnidae (Starlings)

* *Sturnus vulgaris vulgaris*
European starling

Thraupidae (Tanagers)

Piranga ludoviciana
western tanager

Sylviidae (Babblers)

Chamaea fasciata henshawi
wrentit

Troglodytidae (Wrens)

!*Campylorhynchus brunneicapillus sandiegoense*
cactus wren

Cistothorus palustris
marsh wren

Thryomanes bewickii Bewick's wren

Troglodytes aedon parkmanii
house wren

Turdidae (Thrushes)

Catharus guttatus
hermit thrush

Catharus ustulatus
Swainson's thrush

!*Sialia currucoides*
mountain bluebird

Turdus migratorius propinquus
American robin

Tyrannidae (Flycatchers)

Contopus cooperi
olive-sided flycatcher

Contopus sordidulus sordidulus
western wood-pewee

Empidonax difficilis difficilis Pacific-slope flycatcher

Empidonax hammondii
Hammond's flycatcher

!*Empidonax oberholseri*
dusky flycatcher

!*Empidonax traillii*
willow flycatcher

Empidonax wrightii
gray flycatcher

Myiarchus cinerascens cinerascens
ash-throated flycatcher

Sayornis nigricans semiatra
black phoebe

Sayornis saya saya
Say's phoebe

!*Tyrannus melancholicus satrapa*
tropical kingbird

Tyrannus verticalis
western kingbird

Tyrannus vociferans vociferans
Cassin's kingbird

Vireonidae (Vireos)

Vireo bellii pusillus
least Bell's vireo

Vireo gilvus swainsoni
warbling vireo

Vireo solitarius
blue-headed vireo

Mammalia (Marine Mammals)

Cetacea

Delphinus delphis
common dolphin

† *Eschrichtius robustus*
gray whale

† *Grampus griseus*
Risso's dolphin

Lagenorhynchus obliquidens
Pacific white-sided dolphin

Tursiops truncatus
common bottlenose dolphin

Carnivora

Phoca vitulina
Pacific harbor seal

Zalophus californianus
California sea lion

* - Non-native to San Diego Bay

† - Extirpated from San Diego Bay

! - Accidental, not regularly occuring at San Diego Bay

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Appendix D: Species and Their Habitats

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Table D-1. San Diego Bay plant species and their habitats.

SPECIES			HABITAT: Subtidal				Intertidal						Upland					Notes
Exotic	Scientific Name	Common Name	Deep Subtidal	(Hard / Soft Substrate)	Shallow Subtidal	(Hard / Soft Substrate)	Intertidal Rocky	Intertidal Sandy	Intertidal Mudflat	Salt Marsh	Artificial Structures	Upland Transitional	Dune	Freshwater Marsh	Riparian	Disturbed		Notes
ALGAE																		
	Chlorophyta	green algae																
	Bryopsis corticulans						X											
	Derbesia marina						X											
	Chaetomorpha linum				X	X	X											mat forming; opportunistic
	Cladophora sp.				X	X	X											mat forming; opportunistic; attached to artificial substrate
	Enteromorpha sp.				X	X	X			X								mud sediment surface; attached to artificial substrate
	Ulva expansa	sea lettuce			X	X	X											mat forming; opportunistic
	Phaeophyta	brown algae																
	Porphyra perforta										X							attached to piling surfaces or on hard, man made substrates at base of pilings
	Dictyota flabellata				X	X	X	X	X									rocky bottom
	Ectocarpus spp.				X	X	X											rocky bottom
	Fucaceae sp.																	drift algae on bottom
	Sargassum agarhianum				X													rocky bottom
	Sargassum palmeri																	mud sediment surface
	Colpomenia sinuosa				X		X											rocky bottom
	Rhodophyta	red algae																
	Aglaothamnium cordatum				X	X	X	X	X									rocky bottom
	Antithamnion sp.		X	X	X	X					X							attached to fixed object or plant; mud sediment surface
	Callithamnion sp. A										X							attached to piling surfaces or on hard, man-made substrates at base of pilings
	Ceramium eatonian				X	X	X											mat forming; opportunistic
	Griffithsia furcellata		X	X			X											only in clear quiet water
	Griffithsia pacifica		X	X			X											micro algae; rocky bottom
	Tiffaniella snyderae			X	X	X		X	X									psammophytic; mat forming; opportunistic
	Daysa sinicola var. *abyssicola*		X	X	X	X	X											microalgae; rocky bottom
	Daysa sinicola var. *californica*		X	X	X	X	X											microalgae; rocky bottom; succession mat
	Gelidium sp. A																	mud sediment surface
	Gelidium nudifrons				X	X												mat forming; opportunistic
	Gigartina sp.	Turkish towel			X	X	X											mat forming; opportunistic
	Gracilaria lemaneiformis				X	X												mat forming
	Gracilaria pacifica																	mud sediment surface
	Hypnea valentiae		X	X		X	X	X	X									
	Plocamium sp.										X							attached to piling surfaces or on hard, man-made substrates at base of pilings; drift algae on bottom
	Polysiphonia bajacali		X	X	X	X					X							attached to fixed object in shallow subtidal
	Polysiphonia pacifica				X	X	X											attached to fixed objects or plants; rocky bottom
	Pterochondria woodii var. *pymaea*						X											opportunistic
	Rhodymenia sp.				X	X	X											rocky bottom
	Sarcodiotheca gaudichaudii																	mud sediment surface

Table D-1. San Diego Bay plant species and their habitats. (Continued)

SPECIES			HABITAT: Subtidal				Intertidal					Upland						
Exotic	Scientific Name	Common Name	Deep Subtidal	(Hard / Soft Substrate)	Shallow Subtidal	(Hard / Soft Substrate)	Intertidal Rocky	Intertidal Sandy	Intertidal Mudflat	Salt Marsh	Artificial Structures	Upland Transitional	Dune	Freshwater Marsh	Riparian	Disturbed	Notes
PLANTS—DICOTS																	Jepson description
*	*Mesembryanthemum crystallinum*	ice plant								■		■	■			■	coastal bluffs, disturbed ground common
*	*Mesembryanthemum nodiflorum*	little ice plant								■							coastal bluffs, margins of saline wetlands; uncommon
*	*Schinus molle*	California pepper tree										■		■	■	■	washes, slopes, abandoned fields Jepson lists exotic
*	*Foeniculum vulgare*	sweet fennel										■	■			■	roadside waste places; invasive and abundant
	Amblyopappus pusillus	coast weed										■					coastal dunes, beaches, headlands
	Artemisia californica	California sagebrush										■					coastal sage near coast
	Baccharis sarothroides	chaparral broom										■	■			■	gravely sandy washes, roadsides
*	*Centaurea melitensis*	star thistle										■				■	disturbed fields, open woods; uncommon
*	*Chrysanthemum carinatum*	tricolor chrysanthemum										■				■	waste ground
*	*Cotula coronopifolia*	brass buttons										■					saline and freshwater marshes; common
	Heterotheca grandiflora	telegraph weed										■	■				disturbed area, dune, dry river bed
	Isocoma menziesii	golden bush										■	■				landward side of dunes, hillsides, arroyos
	Jaumea carnosa	jaumea								■							coastal salt marsh
	Pluchea sericea	arrow weed										■					stream beds, washes, some saline; stabilizer; invasive
	Batis maritima	saltwort								■							salt marsh
	Heliotropium curassavicum	Chinese parsley										■					moist to dry saline soils; stabilizer; invasive
	Hutchinsia procumbens											■					alkaline flats, saline seeps
*	*Lobularia maritima*	sweet alyssum										■				■	waste places
	Cardionema ramosissimum	tread lightly										■	■				sandy beaches, dunes, bluffs
	Spergularia marina	salt marsh sand-spurrey								■		■	■				sandy coasts, salt marshes
	Atriplex canescens	salt bush										■					clay to gravelly flats
*	*Atriplex lindleyi*	salt bush										■				■	open disturbed
*	*Atriplex semibaccata*	Australian salt bush										■				■	waste places
	Atriplex truncata	salt bush										■					alkaline soils, flats
	Atriplex watsonii	Watson salt bush								■		■	■				sand dunes, salt marshes
	Salicornia bigelovii	animal pickleweed								■							salt marshes
	Salicornia europaea	salt flat annual pickleweed								■		■					salt marsh, alkaline flat; stabilizer
	Salicornia subterminalis	glasswart								■		■					salt marsh, alkaline flat; stabilizer
	Salicornia virginica	pickleweed								■		■					salt marsh, alkaline flat; stabilizer
*	*Salsola kali*	Russian thistle								■		■				■	not listed in Jepson
	Suaeda californica	California sea-blite								■		■					margins of coastal salt marsh
	Cressa truxillensis	alkali weed								■		■					saline and alkaline soil; invasive
	Crassula connata	pygmy weed															open areas; locally abundant
	Cuscuta salina	salt marsh dodder								■		■		■			marshes, flats, ponds; common
	Lotus nuttallianus	beach lotus										■	■			■	beaches, coastal scrub, urban weedy; rare
	Lotus strigosus											■				■	coastal scrub, disturbed areas

Table D-1. San Diego Bay plant species and their habitats. (Continued)

Exotic	Scientific Name	Common Name	Subtidal: Deep Subtidal	Subtidal: (Hard / Soft Substrate)	Subtidal: Shallow Subtidal	Subtidal: (Hard / Soft Substrate)	Intertidal: Intertidal Rocky	Intertidal: Intertidal Sandy	Intertidal: Intertidal Mudflat	Intertidal: Salt Marsh	Intertidal: Artificial Structures	Upland: Upland Transitional	Upland: Dune	Upland: Freshwater Marsh	Upland: Riparian	Upland: Disturbed	Notes
	Frankenia palmeri	yerba reuma								■		■	■				alkali flats, dunes, coastal marsh; rare in CA
	Frankenia salina	alkali heath								■		■					salt marsh, alkali flats
	Salvia mellifera	black sage										■					coastal sage scrub, chaparral; stabilizer
	Camissonia cheiranthifolia	beach evening primrose										■	■				sandy slopes, flats, dunes
	Camissonia cheiranthifolia suffruticosa											■	■				sandy slopes, flats, dunes
	Limonium californicum	sea lavender								■		■	■				coastal strand, salt marsh, beaches, bays; stabilizer
	Eriogonum fasciculatum	California buckwheat										■					dry slopes, washes, scrub canyons
	Eriogonum parvifolium											■					dunes, sea bluffs
	Nemacaulis denudata	thread stem										■	■				coastal strand, desert scrub, sandy
*	*Rumex crispus*	curly dock								■		■					disturbed places; abundant
	Salix lasiolepis	arroyo willow										■			■		shores, marshes, meadows, bluffs; stabilizer; invasive
	Cordylanthus maritimus maritimus	salt marsh bird's-beak								■							federally endangered; coastal salt marsh
*	*Nicotiana glauca*	tree tobacco										■			■	■	open disturbed flats
*	*Tamarix* sp.	tamarisk										■			■	■	often in saline habitats
PLANTS—MONOCOTS																	
	Juncus acutus	spiny rush								■							salt marshes, saline seeps; stabilizer
	Triglochin maritima	arrow grass								■		■					marshes, saline-alkaline margins and mud;stabilizer
	Yucca schidigera	Mohave yucca										■					chaparral, creosote scrub, dry
*	*Bromus madritensis rubens*	red brome										■				■	open disturbed
*	*Cortaderia jubata*	Pampas grass										■		■	■	■	disturbed sites, coastal habitat; invasive
	Distichlis spicata	salt grass								■		■		■	■		salt marsh, moist alkaline stabilizing; invasive
*	*Hordeum murinum*	sterile barley										■				■	moist disturbed
	Parapholis incurva	sickle grass								■							salt marsh above highest tide; Jepson lists exotic
*	*Polypogon monspeliensis*	rabbit foot grass										■		■	■		moist places, along streams, ditches
	Spartina foliosa	cordgrass							■	■							salt marsh, mud flats
	Ruppia maritima	ditch grass							■	■				■			marshes, ponds, sloughs; stabilizer
*	*Typha domingensis*	southern cattail												■	■		marshes; Jepson lists not exotic
	Typha latifolia	common cattail												■	■		marshes, ponds, lakes
	Zostera marina	eelgrass				■			■								shallow water, bays, estuaries

Table D-2. San Diego Bay invertebrate species and their habitats.

Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
PHYLUM PORIFERA							
	Halichondria panicea					■	epifauna on pilings and floats
*	*Haliclona* sp.	haliclonid sponge			■	■	protected places on rocks, floating docks and tide pools; from midtidal zone to 20 feet (6 m) deep
	Hymenicidon sp.					■	epifauna on pilings and floats
	Tetilla mutabilis	wandering sponge		■			on surface
	Leucosolenia sp.					■	epifauna on pilings and floats
	Esperiopsis originalis	digitate sponge		■			
PHYLUM CNIDARIA							
*	*Obelia* sp.					■	epifauna on pilings and floats
	Aglaophenia sp.	ostrich plume hydroid				■	epifauna on pilings and floats
	Plumularia sp.	plumarid hydroid				■	epifauna on pilings and floats
	Tubularia sp.	naked hydroid			■	■	attached to almost any solid object continuously submerged in shallow water; commonly found on boat hulls
*	*Tubularia crocea*			■			
	Corymorpha palma	white hydroid		■			
	Epiactis prolifera	proliferating anemone	■		■		attached to rocks, large algae, and eelgrass; from between high and low tide line to 30 feet (9 m) deep
	Diadumene franciscana	anemone		■	■		
	Diadumene cf. *leucolena*	anemone		■	■		
	Cerianthus (nr) aestuari	burrowing anemone		■			
	Edwardsiella californica	burrowing anemone		■			
	Harenactis attenuata	burrowing anemone		■			
	Pachycerianthus fimbriatus	mud tube anemone		■			
	Renilla kollikeri	sea pansy		■			
	Scolanthus sp.	anemone		■			
PHYLUM PLATYHELMINTHES							
	Polyclad spp.	flatworms	■	■			both subtidal and intertidal
PHYLUM NEMERTEA							
	Nemertena spp.			■			both subtidal and intertidal
PHYLUM ASCHELMINTHES							
	Nematode spp.			■			both subtidal and intertidal
PHYLUM SIPUNCULA							
	Sipunculid sp.			■			
PHYLUM ANNELIDA							
	Oligochaete spp.	oligochaete		■			both subtidal and intertidal
	Ampharete labrops	ampharetid		■			
	Ampharetidae spp.	ampharetid		■			
	Amphicteis scaphorbranchia	ampharetid		■			
	Arabella semimaculata	arabellid	■	■			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Arabella sp.	arabellid	X				
	Drilonereis falcata minor	arabellid		X			
	Drilonereis mexicana	arabellid		X			
	Capitata ambiseta	capitellid		X			
*	*Capitella capitata*	capitellid	X	X			
	Capitellidae spp.	capitellid		X			
	Heteromastus sp.	capitellid		X			
	Mediomastus acutus	capitellid		X			
	Mediomastus ambiseta	capitellid		X			
	Mediomastus californiensis	capitellid		X			
	Mediomastus sp.	capitellid	X				
	Neomediomastus sp.	capitellid		X			
	Notomastus cf. *lineatus*	capitellid		X			
	Notomastus tenuis	capitellid		X			
	Scyphoproctus oculatus	capitellid		X			
	Scyphoproctus spp.	capitellid		X			
	Chaetopterus variopedatus	parchment tube worm		X	X		
	Caulleriella sp(p.)	cirratulid		X			
	Chaetozone cf. *corona*	cirratulid		X			
	Chaetozone cf. *setosa*	cirratulid		X			
	Chaetozone cf. *spinosa*	cirratulid		X			
	Cirratulidae, unidentified	cirratulid		X			
	Cirratulus sp(p.)	cirratulid					
	Cirriformia luxuriosa	cirratulid		X			
	Cirriformia spriabranchiata	cirratulid		X			
	Cirriformia tentaculata	cirratulid		X			
	Tharyx parvus	cirratulid		X			
	Tharyx sp. A.B.	cirratulid	X				
	Cossura candida	cossurid	X	X			
	Cossura pygodactylata	cossurid	X				
	Cossura sp.	cossurid	X				
	Ctenodrilus serratus	ctenodrilid		X			
	Dorvillea articulata	dorvilleid		X			
	Dorvillea longicornis	dorvilleid		X			
	Dorvillea rudolphii	dorvilleid	X	X			
	Ophryotrocha puerilis	dorvilleid		X			
	Schistomeringos longicornis	dorvilleid		X			
	Lysidice sp.	eunicid	X				
	Lysippe labiata	eunicid		X			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Marphysa dysjuncta	eunicid		■			
*	*Marphysa sanguinea*	eunicid		■			
	Marphysa sp.	eunicid	■				
	Marphysa stylobranchiata	eunicid	■	■			
	Brada pleurobranchiata	flabelligerid		■			
	Flabelligera infundibularis	flabelligerid	■				
	Flabelligeridae sp.A	flabelligerid	■				
	Flabelligeridae sp.B	flabelligerid	■				
	Flabelligerma essenbergae	flabelligerid		■			
	Pherusa capulata	flabelligerid		■			
	Pherusa cf. neopapillata	flabelligerid	■				
	Pherusa sp.	flabelligerid		■			
	Stylaroides sp.	flabelligerid		■			
	Glycera americana	glycerid	■	■			
	Glycera cf. *americana*	glycerid		■			
	Glycera nana	glycerid					
	Glycera rouxii	glycerid		■			
	Glycera tenuis	glycerid	■				
	Glyceridae spp.	glycerid		■			
	Glycinda armigera	glycerid		■			
	Goniada brunnea	gonaidid					
	Goniada littorea	gonaidid		■			
	Goniada sp.(p.)	gonaidid					
	Lumbrineris acuta	lumbrinerid		■			
	Lumbrineris californiensis	lumbrinerid		■			
	Lumbrineris erecta	lumbrinerid		■			
	Lumbrineris latreilli	lumbrinerid		■			
	Lumbrineris minima	lumbrinerid		■			
	Lumbrineris spp.	lumbrinerid					taxonomic status of species of the genus *Lumbrineris* is very uncertain; many species names may be incorrect.
	Lumbrineris zonata	lumbrinerid	■	■			
	Maldanidae spp.	maldanid	■	■			
	Malmgreniella macginitiei	maldanid		■			
	Nicomache cf. lumbricalis	maldanid		■			
	Praxilella affinis pacifica	maldanid		■			
	Nephtyidae spp.	nephtyid		■			
	Nephtys caecoides	nephtyid		■			
	Nephtys cornuta franciscanus	nephtyid		■			
*	*Neanthes acuminata*	neriid		■			
*	*Neanthes caudata*	neriid		■			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Neanthes virens	neriid		■			
	Nematonereis cf. *unicornis*	neriid		■			
	Nereidae spp.	neriid	■	■			
	Nereis brandti	neriid	■				
	Nereis latescens	neriid		■			
	Nereis procera	neriid		■			
	Diopatra sp(p.)	onuphid		■			
	Diopatra tridentata	onuphid		■			
	Armandia bioculata	opheliid		■			
	Polyopthalmus pictus	opheliid		■			
	Haploscolopos elongatus	orbinid		■			
	Leitoscoloplos elongatus	orbinid		■			
	Leitoscoloplos pugettensis	orbinid		■			
	Naineris uncinata	orbinid		■			
	Orbinidae spp.	orbinid	■	■			
	Scoloplos acmeceps	orbinid	■	■			
	Pectinaria californiensis	pectinariid		■			
	Eteone alba	phyllodocid		■			
	Eteone californica	phyllodocid		■			
	Eteone cf. *lighti*	phyllodocid		■			
	Eteone dilata	phyllodocid	■				
	Eteone sp.(p.)	phyllodocid		■			
	Phyllodocidae spp.	phyllodocid		■			
	Sigambra tentaculata	Pilargiidae		■			
	Halosydna brevistosa	polynoid		■			
	Halosydna johnsoni	polynoid		■			
	Harmothoe cf. *hirsuta*	polynoid		■			
	Harmothoe imbricata	polynoid		■			
	Hesperonoe sp (p.)	polynoid		■			
	Polynoidae spp., sp. A.B.C.	scale worm	■	■			
	Chone cf. *gracilis*	sabellid	■	■			
	Chone cf. *mollis*	sabellid		■			
	Euchone limnicola	sabellid	■				
	Fabicinae sp.	sabellid		■			
	Fabricia limnicola	sabellid	■	■			
	Fabricinuda limicola	sabellid		■			
	Megalomma circumspectum	sabellid		■			
	Megalomma pigmentum	sabellid		■			
	Sabella crassicornis	sabellid		■			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Sabellidae spp.	sabellid		X			
	Sabellidae, unidentified	sabellid	X				
	Crucigera sp.	serpulid		X			
	Hydroides pacificus	serpulid		X			
	Serpulidae spp.	serpulid		X			
	Sthenelais tertiaglabra	sigalionid		X			
	Sthenelanella uniformis	sigalionid		X			
	Apoprionospio pygmaeus	spionid		X			
	Boccardia spp.	spionid	X	X			
	Boccardia truncata	spionid		X			
	Boccardiella hamata	spionid		X			
	Laonice cirrata	spionid		X			
	Microspio maculata	spionid		X			
	Nerinides cf. *acuta*	spionid		X			
	Nerinides pigmentata	spionid		X			
	Paraprionospio pinnata	spionid		X			
	Polydora cf. *cardalia*	spionid		X			
	Polydora cf. *nuchalis*	spionid	X	X			
	Polydora cf. *socialis*	spionid		X			
	Polydora cornuta	spionid		X			
*	*Polydora ligni*	spionid	X	X			in soft fragile tubes covered with mud and attached to hard objects in protected places on mud and clay bottoms, near low tide line and shallow water
	Polydora limnicola	spionid	X				
	Polydora nuchalis	spionid	X				
	Polydora quadrilobata	spionid		X			
	Polydora socialis	spionid		X			
	Polydora sp.	spionid	X				
	Polydora websteri	spionid		X			
	Prionospio cf. *heterobranchiata*	spionid	X	X			
	Prionospio lighti	spionid		X			
	Prionospio malmgreni	spionid		X			
	Prionospio pinnata	spionid		X			
	Prionospio pygmaeus	spionid	X	X			
	Prionospio steenstrupi	spionid		X			
	Pseudomalacocerus spp.	spionid		X			
*	*Pseudopolydora paucibranchiata*	spionid		X			
	Rhynchospio glutaea	spionid		X			
	Scolelepis acuta	spionid		X			
	Scolelepis foliosa occidentalis	spionid		X			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Scolelepis tridentata	spionid		X			
	Scoleopis quinquedentata	spionid		X			
	Spionidae spp.	spionid	X	X			
	Spiophanes missionensis	spionid	X	X			
*	*Streblospio benedicti*	spionid		X			
	Sternaspis fossor	sternaspid		X			
	Autolytus spp.	syllid		X			
	Brania brevipharyngea	syllid		X			
	Brania spp.	syllid		X			
	Eusyllis assimilis	syllid		X			
	Exogone cf. *molesta*	syllid		X			
	Exogone lourei	syllid	X	X			
	Exogone uniformis	syllid		X			
	Odontosyllis parva	syllid		X			
	Odontosyllis phosphorea	syllid		X			
	Pionosyllis spp.	syllid		X			
	Syllidae spp.	syllid		X			
	Syllis gracilis	syllid		X			
	Trypanosyllis spp.	syllid		X			
	Typosyllis cf. *hyalina*	syllid		X			
	Amaeana occidentalis	terebellid		X			
	Pista alata	terebellid		X			
	Pista cf. *fasciata*	terebellid		X			
	Pista sp.	terebellid	X				
	Streblosoma crassibranchia	terebellid		X			
	Terebellidae spp.	terebellid		X			
	Terebellides californica	terebellid		X			
	Aphelochaeta monilaris			X			
	Aphelochaeta multifilis			X			
	Aphelochaeta sp(p.)			X			
	Apistobranchus sp(p.)			X			
	Diplocirrus sp(p.)			X			
	Eranno lagunae			X			
	Euclymeninae spp. indef.			X			
	Expolymnia sp(p.)			X			
	Leitoscoloplos pugettensis			X			
	Levinsenia gracilis			X			
	Melinna oculata			X			
	Metasychis disparidentata			X			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Montecellina dorsobranchialis			■			
	Montecellina sp. C			■			
	Montecellina tesselata			■			
	Myriochele sp. M			■			
	Paramage scutata			■			
	Parougia caeca			■			
	Pholoe glabra			■			
	Podarkeopsis glabra			■			
	Podarkeopsis perkinsi			■			
	Poecilochaetus johnsoni			■			
	Tenonia priops			■			
PHYLUM ARTHROPODA							
*	*Aspidochoncha limnoriae*	ostracod		■			
	Asteropella slatteryi	ostracod		■			
	Bathyleberis spp.	ostracod		■			
	Conchoecinae sp.	ostracod		■			
	Cylindroleberis mariae	ostracod		■			
	Cylindroleberis sp.	ostracod		■			
	Euphilomedes producta	ostracod		■			
	Euphilomedes carcharodonta	ostracod	■				
	Parasterope barnsei	ostracod	■	■			
	Philomedes spp.	ostracod		■			
	Podocopidae sp.	ostracod		■			
*	*Redekea californica*	ostracod		■			
	Rutiderma cf. *judayi*	ostracod		■			
	Rutiderma lomae	ostracod		■			
	Sarsiella spp.	ostracod		■			
	Soleroconcha spp.	ostracod		■			
	Cyclopoid spp.	cyclopoid		■			
	Harpacticoid spp.	harpacticoid		■			
	Parastephos esterlyi	copepod		■			
*	*Balanus amphitrite*	little striped barnacle			■	■	on rocks, pilings, and shells in bays and estuaries, from low tide line to 197 feet (60 m) deep
*	*Balanus tintinnabulum*	red and white barnacle			■		
	Megabalanus californianus	red and white barnacle			■	■	on rocks, pilings, kelps, and other hard-shelled animals, from low tide line to 30 feet (9 m) deep
	Chthamalus sp.	barnacle			■		
	Campylaspis rubromaculata	cumacean		■			
	Cumacea, unidentified	cumacean	■				
	Cyclaspis sp.	cumacean		■			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	SPECIES		HABITAT				
	Diastylis sp.	cumacean		■			
	Eudorella pacifica	cumacean		■			
	Oxyurolostylis pacifica	cumacean		■			
	Acanthomysis macropsis	mysid		■			in water just above unconsolidated sediment
	Archeomysis maculata	mysid		■			in water just above unconsolidated sediment
	Heteromysis odontops	mysid		■			in water just above unconsolidated sediment
	Holmesimysis sp.	mysid	■				
	Mysida, unidentified	mysid	■				
	Mysidopsis californica	mysid		■			in water just above unconsolidated sediment
	Mysidopsis intii	mysid		■			in water just above unconsolidated sediment
	Neomysis kadiakensis	mysid		■			in water just above unconsolidated sediment
	Neomysis sp.	mysid	■				
	Epinebalia spp.	nebalian		■			
	Nebalia daytoni	nebalian		■			
	Nebalia pugettensis	nebalian		■			
	Leptochelia cf. *dubia*	tanaid		■			
	Leptochelia sp.	tanaid		■			
*	Tanaid sp.	tanaid		■			
	Tanaidacea, unidentified	tanaid	■				
	Zeuxo narmani	tanaid		■			
	Schizobopyrina striata	bopyrid		■			
	Munna spp.	munnid		■			
	Cilicaea sculpta	sphaeromid		■			
*	*Sphaeroma quoyanum*	sphaeromid		■			
	Sphaeromatidae sp.	seriolid		■			
	Austrosignum tillerae	isopod		■			
	Cirolana harfordi	cirolanid		■			
	Paracerceis sculpta	isopod	■				
	Paranthura elegans	anthurid	■	■			
	Seriolis carinata	isopod		■			
	Ampelisca brevisimulata	ampeliscid		■			
	Ampelisca cristata	ampeliscid		■			
	Ampelisca hancocki	ampeliscid		■			
	Ampelisca sp.	ampeliscid		■			
	Ampeliscidae spp.	ampeliscid		■			
	Amphilochidae spp.	amphilochid		■			
	Amphithoe sp.	amphithoid		■			
	Ampithoidae spp.	amphithoid		■			
	Acuminodeutopus heteruropus	aorid		■			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Amphideutopus oculatus	aorid		■			
	Lembos macromanus	aorid		■			
	Microdeutopus schmitti	aorid		■			
	Rudilembroides stenopropodus	aorid		■			
	Corophiidae spp.	corophiid		■			tube forming species
*	*Corophium acherusicum*	corophiid	■	■			
*	*Corophium uenoi*	corophiid		■			tube forming species
	Erichthonius brasiliensis	corophiid		■			
*	*Grandidierella cf. japonica*	corophiid	■	■			
	Dexaminidae spp.	desaminid		■			
	Eusiridae spp.	eusirid		■			
	Hyale frequens	hyalid		■			
	Hyale spp.	hyalid		■			
	Hyalidae spp.	hyalid		■			
	Isaeidae spp.	isaeid		■			
	Leucothoe alata	leucothoid		■			
	Listriella goleta	liljeborgiid					
	Listrella spp.	liljeborgiid		■			
	Lysianassidae spp.	lysianassid		■			
	Orchomene pacifica	lysianassid		■			
	Orchomene pinguis	lysianassid	■				
	Orchomene sp.	lysianassid		■			
	Oedicerotidae spp.	oedicerotid		■			
	Synchelidium rectipalmum	oedicerotid		■			
	Synchelidium shoemakeri	oedicerotid	■				
	Photis sp.	gammarid		■			
	Paraphoxus spp.	phoxocephalid		■			
	Parapluestes spp.	pleustid		■			
	Pleustidae sp.	pleustid		■			
*	*Podocerus brasiliensis*	podocerid		■			
	Pontogeneia minuta	gammarid		■			
	Pontogeneia rostrata	gammarid		■			
*	*Stenothoe valida*	stenothoid	■	■			
	Elasmopus rapax	gammarid		■			
	Gammaridae spp.	gammarid	■				
	Gammaropsis thompsoni	gammarid		■			
	Heterophoxus oculatus	gammarid		■			
	Monoculodes hartmanae	gammarid		■			
	Synchelidium sp.	gammarid		■			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Tiron biocellata	synophiid		X			
	Caprella californica	California skeleton shrimp	X	X			on vegetation/zoobotryon, usually above unconsolidated sediment
	Caprella equilbra	skeleton shrimp	X	X			on vegetation/zoobotryon, usually above unconsolidated sediment
	Caprella mendax	skeleton shrimp	X	X			on vegetation/zoobotryon, usually above unconsolidated sediment
	Caprella spp.	skeleton shrimp	X	X			on vegetation/zoobotryon, usually above unconsolidated sediment, eelgrass
	Caprelliidae spp.	skeleton shrimp	X	X			on vegetation/zoobotryon, usually above unconsolidated sediment
	Mayerella banksia	caprellid		X			
	Euphilomedes carcharodonta	seed shrimp		X			
	Alpheus californiensis	alpheid shrimp		X			
	Alpheus sp.A., sp. B	alpheid shrimp	X				
	Betaeus harrimani	alpheid shrimp	X				
	Betaeus longidactylus	alpheid shrimp	X				
	Betaeus sp.	alpheid shrimp	X				
	Atyidae spp.	decapod		X			
	Callianassa californiensis	red ghost shrimp	X	X			
	Upogebia pugettensis	callianassid shrimp	X				
	Crangon franiscorum	crangonid shrimp	X				
	Crangon spp.	crangonid shrimp		X			
	Processa canaliculata	crangonid shrimp		X			
	Heptocarpus cf. *taylori*	hippolytid shrimp					
	Heptocarpus sp. A	hippolytid shrimp	X				
	Heptocarpus spp.	hippolytid shrimp		X			
	Hipploypte californiensis	grass shrimp		X			
	Hippolyte california	hippolytid shrimp	X				
	Hippolyte spp.	hippolytid shrimp		X			
	Spriontocaris sp.	hippolytid shrimp		X			
	Pugettia producta	kelp crab			X	X	rocks and pilings from low tide line to 1,427 feet (435 m) deep
	Pyromaia tuberculata	decapod	X	X			
*	*Palaemon macrodactylus*	decapod	X				
	Panulirus interruptus	California spiny lobster			X	X	associated with rock riprap, buoy anchors and other man made objects, at low tide line to moderately deep water
	Hemigrapsus oregonensis	mudflat crab		X			intertidal and subtidal unconsolidated sediment, on mud flats and eelgrass beds between the high and low tide lines
	Pinnixa barnharti	pinnotherid crab		X			
	Scleroplax granulata	pinnotherid crab		X			intertidal mudflats
	Uca crenulata	fiddler crab		X			intertidal mud flats, in burrows in sandy mud bays near and estuaries near high tide line
	Portunus xantusi	swimming crab		X			swims just above mud, rests on bottom
	Cancer antennarius	common rock crab		X	X		gravel bottoms from between the low and high tide line to 131 feet (40 m) deep
	Cancer anthonyi	rock crab		X			
	Lophopanopeus bellus diegensis	xanthid mud crab	X	X			under rocks on mud or sand bottoms, from low tide line to 240 feet (73 m) deep
	Lophopanopeus sp.	xanthid crab		X			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Brachyurs, unidentified	decapod	X				
	Caridea, unidentified	carideau shrimp	X				
	Hemisquilla ensigera	mantis shrimp		X			
	Malacoplax californiensis	mudflat crab		X			
	Nyeotrypaea californiensis	decapod		X			
	Pseudosquilla mamorata	mantis shrimp		X			
	Schmittius politus	mantis shrimp		X			
	Urocaris infraspinis	decapod		X			
PHYLUM MOLLUSCA							
	Acteocina culcitella	bubble shell	X				
	Acteocina inculta	bubble shell		X			
	Acteocina magdalenenis	glassy bubble		X			
	Cylichna alba	acteocinid	X				
	Cylichnella harpa	acteocinid tectibranch		X			
	Cylichnella inculta	acteocinid tectibranch		X			
	Aelidae spp.	aelid		X			
	Aplysia californica	California sea hare	X	X			unconsolidated sediment; sheltered locations, from low tide line to 59 feet (18 m) deep, feed on red, brown, and green algae, and eelgrass
	Assiminea californica	assimineid snail		X			
	Caecum californicum	California caecum		X			
	Fartulum occidentale	caecid		X			
	Crepidula fornicata	gastropod		X	X		
	Crepidula onyx	onyx slipper shell		X	X		
	Crepipatela lingulata	half-slipper shell		X	X		
	Aglaja diomedia	tectibranch		X			
	Bulla gouldiana	Gould's bubble	X	X			
	Chelidonura inermis	large sea slug	X	X			
	Haminaea vesicula	blister paper bubble		X			
	Cerithidea californica	California horn shell		X			intertidal mudflat/saltmarsh habitat
	Cerithidea fuscata	horn shell snail		X			unconsolidated sediment on mudflats and in saltmarsh
	Columbellidae spp.	columbellid		X			
	Mitrella carinata	dove shell		X			
	Mitrella tuberosa	columbellid	X				
	Collisela depicta	fissurellid		X			
	Lacuna marmorata	chink shell		X			
	Nassarius perpinguis	gastropod					
	Nassarius tegula	mud-dog whelk	X	X			
	Neverita reclusiana	gastropod		X			
	Nudibranch spp.	nudibranch		X			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
	Olivella baetica	olive shell		■			
	Olivella sp.	olive shell		■			
	Tricolia compta	banded pheasant		■			
	Odostomia sp.	odostome		■			
	Turbonilla sp.	pyramidellid					
	Alvinia spp.	rissoid snail		■			
	Barleeia californica	rissoid snail	■	■			
	Barleeia subtenuis	rissoid snail		■			
	Rissoella sp.	rissoid snail		■			
	Vitrinorbis diegensis	vitronorbis		■			
	Vitrinellidae spp.	vitrinella		■			
	Aclis tectibranch	gastropod	■	■			
	Acmira catherinae	gastropod		■			
	Acmira horikoshii	gastropod		■			
	Alabina spp.	gastropod		■			
	Crucibulum spinosum	cup and saucer limpet	■	■			
	Ophiodermella ophioderma	penciled turret shell		■			
	Ophiodermella spp.	turret shell		■			
	Philine sp.	gastropod		■			
	Sulcoretusa xystrum	gastropod		■			
	Tachyhynchus sp.	turret shell		■			
	Mactra californica	California dish clam		■			
	Spisula catilliformis	narrow dish clam		■			
	Spisula spp.	dish clam		■			
	Platyodon cancellatus	checked borer		■			
*	*Geukensia (Ischadium) demissa*	ribbed mussel		■			
*	*Musculista senhousia*	Japanese muscle	■	■			
	Mytilus edulis	bay mussel			■		
*	*Mytilus galloprovincialis*	mytilid					
	Volsella flabellata (Modiolus modiolus)	giant horsemussel		■			
	Gari californica	sunset clam		■			
	Tagelus californianus	jackknife clam	■	■			
	Tagelus subteres	jackknife clam		■			
	Siliqua lucida	solenid clam		■			
	Solen rosaceus	rosy razor clam		■			
	Solen sicarius	razor clam		■			
	Macoma nasuta	bent-nosed clam	■	■			
	Macoma secta	sand-flat clam	■	■			
	Macoma yoldiformis	tellinid clam		■			

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
*	*Lyrodus pedicellatus*	southern shipworm		X		X	
*	*Teredo navalis*	shipworm		X		X	
*	*Tapes japonica (semidecussata)*	venerid clam		X			
	Tivela sp.	Venus clam		X			
	Veneridae spp.	venerid clam		X			
	Asthenothaerus villiosior	clam		X			
	Laevicardium substriatum	eggshell clam		X			
*	*Theora fragilis*	clam		X			
	Octopus bimaculatus	two-spotted octopus		X			intertidal, subtidal, unconsolidated sediment, man-made
	Octopus bimaculoides			X		X	intertidal, subtidal, unconsolidated sediment, man-made
PHYLUM ECHINODERMATA							
	Dendraster excentricus	eccentric sand dollar		X			sand, silt, sediment; on sand bottoms of sheltered bays and open coasts,from low tide line to 131 feet (40 m) deep
	Holothuroidea sp.	sea cucumber	X				
	Leptosynapta albicans	Southern California sea cucumber	X	X			
	Amphiodia (nr) occidentalis	brittle star	X	X			in sand under rocks, algae, mudflats, and eelgrass roots, from low tide line to 1,214 feet (370 m) deep
	Amphipholis pugetana	brittle star		X			
	Axiognathus squamatus	brittle star	X	X	X		unconsolidated sediment; among gravel in tide pools, in crevices and algal holdfasts, on rocky shores, from between the high tide and low tide line to 2,625 feet (800 m) deep
	Ophiactis simplex	brittle star		X			
	Ophiuroidea sp.		X				
PHYLUM PHORONIDA							
	Phoronid spp.	phoronid		X			
PHYLUM ECTOPROCTA							
	Amathia spp.	bryzoan		X	X		
	Bowerbankia spp.	bryzoan		X	X		
	Bryzoan spp.	bryzoan		X	X		
	Bugula neritina	bryzoan		X	X		
	Cheilostomata sp.	bryzoan		X	X		
	Cryptosula pallasiana	bryzoan		X	X		
	Thalamoporella californica	bryzoan		X	X		
	Zoobotryon verticillatum	bryzoan		X			on surface of unconsolidated sediment, becomes very abundant during summer
PHYLUM CHORDATA							
*	*Botrylloides diegensis*	tunicate		X	X		
*	*Botryllus schlosseri*	tunicate		X	X		
*	*Ciona intestinalis*	tunicate		X		X	unconsolidated sediment and piling/float surface
*	*Ciona savignyi*	tunicate		X		X	unconsolidated sediment and piling/float surface
*	*Microcosmus squamiger*	tunicate		X		X	unconsolidated sediment and piling/float surface

Table D-2. San Diego Bay invertebrate species and their habitats. (Continued)

SPECIES			HABITAT				
Exotic	Scientific Name	Common Name	Eelgrass	Unconsolidated Sediment	Hard Substrate	Artificial Hard Substrate	Notes
*	*Polyandrocarpa zorritensis*	tunicate		X		X	unconsolidated sediment and piling/float surface
*	*Styela canopus*	tunicate		X		X	unconsolidated sediment and piling/float surface
*	*Styela clava* (formerly *barnharti*)	tunicate		X			
*	*Styela plicata*	tunicate	X	X			
	Branchiostoma californiense	lancelet		X			

Table D-3. San Diego Bay fishes: their habitats and feeding strategies.

SPECIES			HABITAT							DIET			
				Relative Abundance[b]									
				Intertidal		Nearshore		Channel					
Exotic	Scientific Name	Common Name	Functional Group/Bay Region[a]	No Veg	Veg	No Veg	Veg		Notes on Habitat Use and Feeding	Fish	Aquatic Invertebrate	Aquatic Vegetation	Plankton
SHARKS AND RAYS													
	Carcharhinus remotus	narrowtooth shark							open water				
	Galeorhinus zyopterus	soupfin shark							open water; feed on fish and some squid				
	Mustelus californicus	gray smoothhound							open water; feed on crabs, fishes and shrimp				
	Mustelus henlei	brown smoothhound							open water; feed on crabs, shrimp and some fish				
	Mustelus lunulatus	sicklefin smoothhound							open water				
	Prionace glauca	blue shark							open water; shallow coastal waters over sand and mud; generally feed on small schooling fishes				
	Triakis semifasciata	leopard shark							demersal; over sand and mud in shallow bays and inshore waters to depths of 300 feet (91 m)				
	Gymnura marmorata	California butterfly ray							demersal on unconsolidated sediment				
	Heterodontus francisci	California hornshark							demersal on unconsolidated sediment				
	Myliobatis californica	bat ray							demersal on unconsolidated sediment; shallow, sandy areas in bays and on coasts to 150 feet (46 m); kelp beds				
	Platyrhinoidis triseriata	thornback							demersal on unconsolidated sediment; over sand and mud to depths of 150 feet(46 m); feed on sand-dwelling worms, snails, clams, crabs, and shrimps; ovoviviparous				
	Urolophus halleri	round stingray	TOP10EI N, NC, SC, S						demersal on unconsolidated sediment; over sand or mud in shallow bays and off coast to 69 feet (21 m); feed on shrimps, crabs, snails, and clams				
	Zapteryx exasperatus	banded guitarfish							demersal on unconsolidated sediment				
	Sphyrna zygaena	smooth hammerhead shark							open water				
	Squalus acanthias	spiny dogfish							open water; soft bottoms; migratory				
	Squatina californica	Pacific angel shark							demersal, sandy and muddy bottoms from shallow water to 600 feet (183 m); usually feed on prey such as California halibut				
BONY FISH													
	Albula vulpes	bonefish	NC, S						openwater, shallow waters over soft bottoms; feed on clams, snails, shrimps, and small fishes				
	Atherinops affinis	topsmelt	TOP10EI N, NC, SC, S						open water; surface waters near shore, in basy, and around kelp beds; topsmelt mature in two to three years and spawn during the late winter and spring, often over estuaries and mudflats, attaching eggs to kelp and other algae, feed on plankton and algae				
	Atherinopsis californiensis	jacksmelt	N, NC, SC, S						open water				
	Leuresthes tenuis	California grunion	N, NC, SC						open water; off sandy beaches to depths of 59 feet (18 m); spawns on beaches at night during spring high tide, eggs are buried in sand and hatch when the next spring tide occurs				
	Porichthys myriaster	specklefin midshipman							demersal on unconsolidated sediment				
	Porichthys notatus	plainfin midshipman							demersal on unconsolidated sediment; over sand and mud to depths of 1,200 feet (366 m); occurs in shallow water during the late spring to spawn, male becomes emaciated while guarding the eggs and young; feeds at night on other fishes and crustaceans				
	Strongylura exilis	California needlefish	NC, SC, S						open water				
	Hypsoblennius gentilis	bay blenny	VEGSPP N, NC						on bottom				
	Hypsoblennius jenkensi	mussel blenny							on hard structure in association with mussels/barnacles				
	Citharichthys stigmaeus	speckled sand dab							demersal on unconsolidated sediment; over soft bottoms to 1,800 feet (549 m); spawns during the winter, some females spawn twice each season				
	Hippoglossina stomata	bigmouth sole							demersal on unconsolidated sediment				
	Xysteurys liolepis	fantail sole	N, NC						demersal on unconsolidated sediment				
	Caranx caballus	green jack							open water				
	Caranx hippos	crevalle jack							open water				

Table D-3. San Diego Bay fishes: their habitats and feeding strategies. (Continued)

SPECIES			HABITAT							DIET			
				Relative Abundance[b]									
				Intertidal		Nearshore		Channel					
Exotic	Scientific Name	Common Name	Functional Group/Bay Region[a]	No Veg	Veg	No Veg	Veg		Notes on Habitat Use and Feeding	Fish	Aquatic Invertebrate	Aquatic Vegetation	Plankton
	Trachurus symmetricus	jack mackerel							open water; offshore on surface and at midwater; around reefs and kelp; feeds on krill, squids, anchovies, and lanternfishes; major food source for seals, sea lions, porpoises, swordfishes, sea basses, and pelicans				
	Chanos chanos	milkfish							open water				
	Gibbonsia elegans	spotted kelpfish	VEGSPP N, NC						demersal on unconsolidated sediment				
	Gibbonsia montereyensis	crevice kelpfish							demersal on unconsolidated sediment				
	Heterostichus rostratus	giant kelpfish	TOP10EI, VEGSPP N, NC, SC, S						demersal on unconsolidated sediment; rocky areas with eelgrass, leafy red algae, jointed coralline algae, or kelp beds to depths of 132 feet (40 m); feed on small crustaceans, mollusks, and fishes				
	Parachinus integripinnis	reef finspot	VEGSPP										
	Scorpaenichthys marmoratus	cabezon							demersel on unconsolidated sediment and hard substrate, rocks and reefs in intertidal zone and below low tide level to 252 feet (77m)				
	Scorpaena guttata	spotted scorpionfish	N, NC										
	Symphurus atricauda	California tonguefish	N, NC						demersal on unconsolidated sediment				
	Fundulus parvipinnis	California killfish	BESPP NC, SC, S						open water near bottom				
	Amphistichus argenteus	barred surfperch							demersal				
	Cymatogaster aggregata	shiner surfperch	TOP10EI, VEGSPP N, NC, SC, S						demersal; in bays around piers				
	Damalichthys vacca	pile surfperch							demersal				
	Embiotoca jacksoni	black surfperch	VEGSPP NC						demersal				
	Hyperprosopon argenteum	walleye surfperch							demersal; surf, over snad, around piers, reefs, and kelp beds, bays up to depths of 59 feet (18 m); breeds October through December, giving birth to between five and twelve young in the spring; feeds on small crustaceans				
	Micrometrus minimus	dwarf surfperch	VEGSPP N						demersal				
	Phanerodon furcatus	white surfperch							demersal				
	Rhacochilus toxotes	rubberlip surfperch							demersal; reefs, piers, and kelp beds, from shallow bays to 150 feet (46 m); feeds on shrimp, amphipods, small crabs, and other crustaceans				
	Anchoa compressa	deepbody anchovy	BESPP NC, SC, S						open water				
	Anchoa delicatissima	slough anchovy	TOP10EI, BESPP N, NC, SC, S						open water				
	Cetengraulis mysticetus	anchoveta							open water				
	Engraulis mordax	northern anchovy	TOP10EI, RCSPP N, NC, SC, S						open water; spawns during winter and early spring, and the pelagic eggs take only 2–4 days to hatch; schools move large distances up and down the coast; important food source for other fishes, birds, and mammals				
	Sardinops sagax	Pacific sardine	TOP10EI, RCSPP N, NC, SC						open water				
	Girella nigricans	opaleye							demersal; unconsolidated sediment and hard substrate; shallow reefs and kelp beds to depths of 96 feet (29 m); spawn from April–May and area mature at two to three years; feed on algae and eelgrass, get nourishment from small animals living on the plants				

Table D-3. San Diego Bay fishes: their habitats and feeding strategies. (Continued)

SPECIES				HABITAT						DIET			
				Relative Abundance[b]									
				Intertidal		Nearshore		Channel					
Exotic	Scientific Name	Common Name	Functional Group/Bay Region[a]	No Veg	Veg	No Veg	Veg		Notes on Habitat Use and Feeding	Fish	Aquatic Invertebrate	Aquatic Vegetation	Plankton
*	*Acanthogobius flavimanus*	yellowfin goby	SC, S						on/in unconsolidated sediment				
	Clevelandia ios	arrow goby	BESPP N, NC, SC, S						on/in unconsolidated sediment				
	Gillichthys mirabilis	longjaw mudsucker	BESPP						on/in unconsolidated sediment				
	Gobionellus longicaudus	longtail goby							on/in unconsolidated sediment				
	Ilypnus gilberti	cheekspot goby	BESPP N, NC, SC, S						on/in unconsolidated sediment				
	Lepidogobius lepidus	bay goby							on/in unconsolidated sediment				
	Quietula y-cauda	shadow goby	BESPP N, NC, SC, S						on/in unconsolidated sediment				
*	*Tridentiger trigonocephalus*	chameleon goby							on/in unconsolidated sediment				
	Haemulon flaviguttatum	Cortez grunt							demersal				
	Hyporhamphus rosae	California halfbeak	BESPP N, NC, SC, S						open water				
	Hermosilla azurea	zebra perch							open water				
	Halichoeres semicinctus	rock wrasse	N										
	Oxyjulis californica	senorita	N						Reefs and kelp beds to depths of 150 feet (46 m); feed on small snails, crustaceans, worms, and larval fishes				
	Mugil cephalus	striped mullet	BESPP S						demersal on unconsolidated sediment; this species supports the only commercial fishery in the Bay; coasts, estuaries, and fresh water; important food fish that travel up rivers, but spawn in the sea				
	Leptocottus armatus	staghorn sculpin	N, NC, SC, S										
	Hypsopsetta guttulata	diamond turbot	BESPP N, NC, SC, S						demersal on unconsolidated sediment; over soft bottoms from6–150 feet (2–46 m)				
	Paralichthys californicus	California halibut	TOP10EI, RCSPP N, NC, SC, S						demersal on unconsolidated sediment; over soft bottoms to 600 feet (183 m); important commercial fish				
	Platichthys stellatus	starry flounder							demersal on unconsolidated sediment; in bays and estuaries over soft bottoms and often open coast to 900 feet (274 m); feeds on crabs, shrimps, worms, clams, and small fishes, can tolerate low salininity				
	Pleuronectes vetulus	English sole							demersal on unconsolidated sediment; over soft bottoms to 1,800 feet (549 m), migratory fish that can travel up to 700 miles (1,127 km), among top three flat fish in terms of pounds caught by commercial trawlers				
	Pleuronichthys coenosus	CO turbot							demersal on unconsolidated sediment; over soft bottoms and rocks to depths of 1,140 feet (347 m); probably spawn during late winter and early spring, eggs float near surface				
	Pleuronichthys ritteri	spotted turbot	BESPP N, NC						demersal on unconsolidated sediment				
	Pleuronichthys verticalis	hornyhead turbot							demersal on unconsolidated sediment				
	Anisotremus davidsonii	sargo							open water				
	Xenistius californiensis	salema	N, NC, SC						open water				
	Atractoscion nobilis	white seabass							demersal on unconsolidated sediment and hard substrate				
	Cheilotrema saturnum	black croaker	N, NC, SC, S						demersal on unconsolidated sediment				
	Genyonemus lineatus	white croaker							demersal on unconsolidated sediment				
	Menticurrhus undulatus	California corbina							demersal on unconsolidated sediment				
	Roncador stearnsii	spotfin croaker							demersal on unconsolidated sediment				
	Seriphus politus	queenfish	N						demersal on unconsolidated sediment				

Table D-3. San Diego Bay fishes: their habitats and feeding strategies. (Continued)

SPECIES			HABITAT							DIET			
				Relative Abundance[b]									
				Intertidal		Nearshore		Channel					
Exotic	Scientific Name	Common Name	Functional Group/Bay Region[a]	No Veg	Veg	No Veg	Veg		Notes on Habitat Use and Feeding	Fish	Aquatic Invertebrate	Aquatic Vegetation	Plankton
	Umbrina roncador	yellowfin croaker	N, NC, SC, S						demersal on unconsolidated sediment; over sand in surf zone, near rocks or kelp and to 26 feet (8 m) in bays, spawn during summer				
	Sarda chiliensis	Pacific bonito							open water				
	Scomber japonicus	Pacific mackerel	N, NC, SC						open water; warm coastal waters over continental shelf; schooling fish that feed on other schooling fish like anchovies and herrings, also feed on invertebrates				
	Scomberomorus sierra	sierra							open water				
	Medialuna californiensis	halfmoon							demersal; reefs and kelp beds from near surface to depths of 132 feet (40 m); probably spawn during summer and fall; mature at about two years; feed on small invertebrates, especially those living among algae"				
*	*Morone (Roccus) saxatilis*	striped bass							open water; inshore over various bottoms and freshwater inlets; spawns in freshwater.				
	Paralabrax clathratus	kelp bass	VEGSPP, RCSPP N, NC						demersal on unconsolidated sediment and hard substrate; reefs, wrecks and kelp beds to 150 feet (46 m); feeds on crustaceans, squids, octopuses, polychaete worms and fishes				
	Paralabrax maculatofasciatus	spotted sand bass	TOP10EI, BESPP, RCSPP N, NC, SC, S						demersal on unconsolidated sediment				
	Paralabrax nebulifer	barred sand bass	TOP10EI, RCSPP N, NC, SC, S						demersal on unconsolidated sediment				
	Sphyraena argentea	California barracuda	N, NC						open water				
	Peprilus simillimus	Pacific butterfish											
	Bryx arctos	snubnose pipefish							demersal mostly associated with vegetation or zoobotryon				
	Hippocampus ingens	Pacific seahorse	VEGSPP						demersal mostly associated with vegetation or zoobotryon				
	Syngnathus auliscus	barred pipefish	VEGSPP N, NC, SC, S						demersal mostly associated with vegetation or zoobotryon				
	Syngnathus californiensis	kelp pipefish	N, NC, SC, S						demersal mostly associated with vegetation or zoobotryon				
	Syngnathus exilis	barcheek pipefish	N, NC, SC, S						demersal mostly associated with vegetation or zoobotryon				
	Syngnathus griseolineatus	bay pipefish	VEGSPP N, NC, SC, S						demersal mostly associated with vegetation or zoobotryon; mate in early summer and female deposits eggs in brood pouch of male; feed on small crustaceans				
	Synodus lucioceps	California lizardfish	N						demersal on unconsolidated sediment				

a. Functional Groups: TOP10EI—Top 10 Species in Ecological Index; BESPP—Indigenous Bay Estuarine Species; VEGSPP—Species Closely Associated with Eelgrass; RCSPP—Recreational and Commercial Species.
Bay Regions: N—North; NC—North-central; SC—South-central; S—South.

b. Shading of relative abundance in three categories (1-33%, 34-66%, and 67-100%, lightest to darkest respectively) is based on sampling by Allen (1998). Unfilled spaces indicate none or few of that species were captured in Allen's study

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Table D-4. San Diego Bay birds: their diet, status, and habitat.

	SPECIES		DIET					STATUS[a]	HABITAT													
	Scientific Name	Common Name	Aquatic vegetation	Fish	Aquatic Inverts	Small Vertebrates	Scavenge		Open Water	Deep Subtidal	Medium Subtidal	Shallow Subtidal	Shallow Subtidal Vegetation	Intertidal Rocky	Intertidal Sandy	Intertidal Mudflat	Salt Marsh	Salt Works	Artificial Structures	Freshwater Marsh	Riparian	Upland Transition
WATERFOWL																						
Dabbling Ducks	*Anas acuta*	northern pintail	■		■			WO				■	■				■					■
Dabbling Ducks	*Anas americana*	American wigeon	■		■			W				■	■			■	■					■
Dabbling Ducks	*Anas crecca*	green-winged teal	■		■			WO				■	■			■	■					■
Dabbling Ducks	*Anas clypeata*	northern shoveler	■		■			WO				■	■			■	■					■
Dabbling Ducks	*Anas cyanoptera*	cinnamon teal	■					BR				■	■			■	■					■
Dabbling Ducks	*Anas platyrhynchos*	mallard	■		■			BR				■	■			■	■					■
Dabbling Ducks	*Anas strepera*	gadwall	■		■			BR				■	■				■					
Diving Ducks	*Aythya americana*	redhead	■		■			BR				■	■									
Diving Ducks	*Aythya collaris*	ring-necked duck	■		■			W	■	■	■		■			■	■					■
Diving Ducks	*Melanitta perspicillata*	surf scoter			■			W	■	■	■	■		■	■							
Diving Ducks	*Bucephala albeola*	bufflehead			■			W	■	■	■	■				■	■	■				
Diving Ducks	*Aythya affinis*	lesser scaup	■		■			W	■	■	■		■			■	■					
Diving Ducks	*Bucephala clangula*	common golden-eye			■			W	■	■	■							■				
Diving Ducks	*Clangula hyemalis*	oldsquaw			■			V	■	■	■							■				
Diving Ducks	*Melanitta fusca*	white-winged scoter			■			WV	■	■	■						■					
Diving Ducks	*Mergus serrator*	red-breasted merganser		■	■			W	■	■	■						■					
Diving Ducks	*Oxyura jamaicensis*	ruddy duck	■		■			BR	■	■	■		■			■	■					
Geese	*Branta canadensis parvipes*	lesser Canada goose	■		■			W		■	■		■									
Geese	*Branta bernicla*	black brant	■		■			W	■	■	■		■				■					
Grebes	*Aechmophorus clarkii*	Clark's grebe		■	■		■	BR	■	■	■	■					■					
Grebes	*Aechmophorus occidentalis*	western grebe		■	■		■	BRW	■	■	■	■					■					
Grebes	*Podiceps auritus*	horned grebe		■	■			W	■	■	■	■					■					
Grebes	*Podiceps grisegena*	red-necked grebe	■	■	■			WV	■	■	■	■	■				■					
Grebes	*Podiceps nigricollis*	eared grebe		■	■			WO	■	■	■	■					■					
Grebes	*Podilymbus podiceps*	pied-billed grebe		■	■		■	BR	■	■	■	■					■					
SHOREBIRDS																						
Plovers	*Charadrius alexandrinus nivosus*	western snowy plover			■			EBR							■	■	■	■				■
Plovers	*Charadrius semipalmatus*	semipalmated plover			■			W							■	■	■	■				
Plovers	*Charadrius vociferus*	killdeer			■			BR						■	■	■	■	■				■
Plovers	*Pluvialis squatarola*	black-bellied plover			■			W							■	■	■	■				■

Table D-4. San Diego Bay birds: their diet, status, and habitat. (Continued)

SPECIES			DIET					STATUS[a]	HABITAT													
	Scientific Name	Common Name	Aquatic vegetation	Fish	Aquatic Inverts	Small Vertebrates	Scavenge		Open Water	Deep Subtidal	Medium Subtidal	Shallow Subtidal	Shallow Subtidal Vegetation	Intertidal Rocky	Intertidal Sandy	Intertidal Mudflat	Salt Marsh	Salt Works	Artificial Structures	Freshwater Marsh	Riparian	Upland Transition
Sandpipers	*Actitis macularia*	spotted sandpiper	■		■			WB										■				
Sandpipers	*Aphriza virgata*	surfbird	■		■			W						■	■			■				
Sandpipers	*Arenaria interpres*	ruddy turnstone	■		■			W								■	■	■				
Sandpipers	*Arenaria melanocephala*	black turnstone			■			W						■		■	■					
Sandpipers	*Calidris canutus*	red knot	■		■			W								■	■	■				
Sandpipers	*Calidris pusilla*	semipalmated sandpiper			■			M									■	■				
Sandpipers	*Capella gallinayo*	common snipe			■			W									■	■				
Sandpipers	*Catoptrophorus semipalmatus*	willet		■	■			W						■	■	■	■	■				
Sandpipers	*Calidris alba*	sanderling			■			W							■	■	■	■				
Sandpipers	*Calidris mauri*	western sandpiper			■			W							■	■	■	■				
Sandpipers	*Calidris alpinia*	dunlin			■			W							■	■	■	■				
Sandpipers	*Calidris minutilla*	least sandpiper	■		■			W							■	■	■	■				
Sandpipers	*Heteroscelus incanus*	wandering tattler			■			W						■								
Sandpipers	*Limnodromus griseus*	short-billed dowitcher			■			W								■	■	■				
Sandpipers	*Limnodromus scolopaceus*	long-billed dowitcher			■			W								■	■	■				
Sandpipers	*Limosa fedoa*	marbled godwit			■			W								■	■	■				
Sandpipers	*Numenius americana*	long-billed curlew			■			W								■	■	■				
Sandpipers	*Numenius phaeopus*	whimbrel			■			W								■	■	■				
Sandpipers	*Phalaropus lobatus*	red-necked phalarope	■		■			M				■				■	■	■				
Sandpipers	*Phalaropus tricolor*	Wilson's phalarope	■		■			M				■				■	■	■				
Sandpipers	*Tringa flavipes*	lesser yellowlegs		■	■			M								■	■	■				
Sandpipers	*Tringa melanoleuca*	greater yellowlegs		■	■			W								■	■	■				
Others	*Haematopus bachmani*	black oystercatcher			■			V							■							
Others	*Himantopus mexicanus*	black-necked stilt			■			BR								■	■	■				
Others	*Recurvirostra americana*	American avocet	■	■	■	■	■	BR								■	■	■				

Table D-4. San Diego Bay birds: their diet, status, and habitat. (Continued)

	SPECIES		DIET					STATUS[a]	HABITAT													
	Scientific Name	Common Name	Aquatic vegetation	Fish	Aquatic Inverts	Small Vertebrates	Scavenge		Open Water	Deep Subtidal	Medium Subtidal	Shallow Subtidal	Shallow Subtidal Vegetation	Intertidal Rocky	Intertidal Sandy	Intertidal Mudflat	Salt Marsh	Salt Works	Artificial Structures	Freshwater Marsh	Riparian	Upland Transition
SEABIRDS																						
Gulls	*Larus argentatus*	herring gull		■	■		■	W	■	■	■	■	■	■	■	■	■	■	■			■
Gulls	*Larus thayeri*	Thayer's gull	■	■	■	■	■	W	■	■	■	■	■	■	■	■	■	■	■			
Gulls	*Larus californicus*	California gull			■	■		W	■	■	■	■	■	■	■	■	■	■	■			■
Gulls	*Larus canus*	mew gull	■	■	■	■	■	W	■	■	■	■	■	■	■	■	■	■	■			■
Gulls	*Larus delawarensis*	ring-billed gull	■	■	■	■	■	W	■	■	■	■	■	■	■	■	■	■	■			■
Gulls	*Larus glaucescens*	glaucous-winged gull		■	■		■	W	■	■	■	■	■	■	■	■	■	■	■			■
Gulls	*Larus heermanni*	Heerman's gull		■	■		■	R	■	■	■	■	■	■	■	■	■	■	■			■
Gulls	*Larus occidentalis*	western gull		■	■		■	BR			■	■	■	■	■	■	■	■	■			■
Gulls	*Larus philadelphia*	Bonaparte's gull		■	■			W		■	■	■	■	■	■	■	■	■	■			■
Terns and Skimmers	*Rynchops niger*	black skimmer		■	■			BR		■	■	■			■	■		■				
Terns and Skimmers	*Sterna antillarum browni*	California least tern		■	■			SB		■	■	■			■	■	■	■	■			
Terns and Skimmers	*Sterna caspia*	Caspian tern		■	■			BR		■	■	■			■	■	■	■				
Terns and Skimmers	*Sterna forsteri*	Forster's tern		■	■			BR		■	■	■			■	■	■	■				
Terns and Skimmers	*Sterna hirundo*	common tern		■	■			M		■	■	■			■	■	■	■				
Terns and Skimmers	*Sterna nilotica*	gull-billed tern			■			SB		■	■	■			■	■	■	■				
Terns and Skimmers	*Sterna elegans*	elegant tern		■	■			BR		■	■	■				■	■	■				
Terns and Skimmers	*Sterna maximus*	royal tern		■	■			RO		■	■	■			■	■	■	■				
Others	*Pelecanus erythrorhynchos*	American white pelican		■				W		■	■	■					■		■			
Others	*Pelecanus occidentalis*	California brown pelican		■				ER		■	■	■					■		■			
Others	*Phalacrocorax auritus*	double-crested cormorant		■				BR		■	■							■	■			
Others	*Phalacrocorax pelagicus*	pelagic cormorant	■	■	■			W		■	■											
Others	*Phalacrocorax penicillatus*	Brandt's cormorant		■	■			BR		■	■								■			
Others	*Gavia immer*	common loon		■	■			W		■	■	■					■					
Others	*Gavia pacifica*	pacific loon	■	■	■			W		■	■	■	■				■					
Others	*Gavia stellata*	red-throated loon		■	■			W		■	■	■					■					
MARSH BIRDS																						
Rails	*Fulica americana*	American coot	■	■	■	■		BR		■	■	■	■	■	■	■	■	■	■	■	■	■
Rails	*Gallinula chloropus*	common moorhen	■		■	■	■	BR									■			■		
Rails	*Porzana carolina*	sora	■		■			WO				■					■					
Rails	*Rallus limicola*	Virginia rail		■	■			BR				■					■					
Rails	*Rallus longirostris levipes*	light-footed clapper rail	■		■			EBR				■					■					

Table D-4. San Diego Bay birds: their diet, status, and habitat. (Continued)

	SPECIES		DIET					STATUS[a]	HABITAT														
	Scientific Name	Common Name	Aquatic vegetation	Fish	Aquatic Inverts	Small Vertebrates	Scavenge		Open Water	Deep Subtidal	Medium Subtidal	Shallow Subtidal	Shallow Subtidal Vegetation	Intertidal Rocky	Intertidal Sandy	Intertidal Mudflat	Salt Marsh	Salt Works	Artificial Structures	Freshwater Marsh	Riparian	Upland Transition
Herons and Egrets	*Ardea albus*	common egret						BR														
	Ardea herodias	great blue heron						BR														
	Butorides virescens	green-backed heron						BR														
	Egretta caerulea	little blue heron						BR														
	Egretta thula	snowy egret						BR														
	Egretta reufenscens	reddish egret						W														
	Egretta tricolor	tricolored heron						W														
	Nyctansassa violaceus	yellow-crowned night heron						V														
	Nycticorax nycticorax	black-crowned night heron						BR														
UPLAND TRANSITIONAL BIRDS																						
Hawks, Kites, and Owls	*Circus cyaneus*	northern harrier						BR														
	Accipter cooperii	Cooper's hawk						BR														
	Accipter striatus	sharp-shinned hawk						W														
	Elanus leucurus	white-tailed kite						BR														
	Falco columbarius	merlin																				
	Falco peregrinus	peregrine falcon																				
	Pandion haliaetus	osprey						RO														
	Falco sparverius	American kestrel						BR														
	Asio flammeus	short-eared owl						W														
	Athene cunicularia hypugaea	burrowing owl						BR														
Passerines	*Ammodramus sandwichensis beldingi*	Belding's savannah sparrow						EBR														
	Ammodramus sandwichensis rostratus	Large-billed savannah sparrow						W														
	Cistothorus palustris	marsh wren																				
	Lanius ludovicianus	loggerhead shrike																				
	Eremophila alpestris	coast horned lark																				
	Ceryls alcyon	belted kingfisher						BR														

a. Status Code: B=breeds in county regularly; E=designated as endangered or threatened; M=occurs in county mainly in migration; O=breeds in county occasionally; R=year-round resident; S=mainly a summer visitor; V=vagrant; W= mainly a winter visitor

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Appendix E: Profiles of Sensitive Species Not Listed Under Federal or State Endangered Species Acts

Nuttall's Lotus—*Lotus nuttalianus*

Nuttall's lotus, a CNPS List 1B species, is an annual herb in the family Fabaceae (Legumes). It occurs in coastal strand and coastal scrub habitats in San Diego County and Baja California, Mexico, below 98 feet (30 m) elevation (Hickman 1993; CNPS 1994). It produces small yellow flowers from March through June. It occurs in association with another rare plant, coast woolly heads (see below) (Reiser 1994).

In recent years Nuttall's lotus has been declining rapidly due to development and other human activities and the invasion of its habitat by non-native weedy species (CNPS 1994). It is now know to occur in less than ten locales in the state, including the following sites in the San Diego Bay area: Silver Strand beach, southwest of Emory Cove west of the freeway, north of Crown Cove, and the NRRF (CNPS 1994; Reiser 1994). A historic site on North Island has been extirpated. Other known current locales are Border Field and Torrey Pines State Parks, and the mouths of both the San Luis Rey and Santa Margarita Rivers.

Coast Woolly Heads—*Nemacaulis denudata* var. *denudata*

Coast woolly heads, a CNPS List 2 species, is an annual herb in the family Polygonaceae (the Buckwheat family) that occurs on coastal strand habitats in southern California and Baja California, Mexico. Its flowers are small and clustered within heads of woolly fibers (Hickman 1993; CNPS 1994). Its distribution has been greatly reduced due to development, recreational activities, and invasive weeds. Extant populations in California include Silver Strand west of Emory Cove (Reiser 1994). It also occurs at the mouth of the Santa Margarita river, Penasquitos Lagoon, and Border Field State Park. Historical occurrences in the San Diego Bay area include a fill site in National City, Coronado, and Imperial Beach (Reiser 1994).

Palmer's Frankenia—*Frankenia palmeri*

Palmer's frankenia, a CNPS List 2 species, is a perennial shrub of the family Frankenaceae (the genus *Frankenia* is the only genus in the family) that can be found on coastal dunes and salt marshes in southwestern San Diego County and northern Baja California, Mexico, below 1,476 feet (450 m) (Hickman 1993; CNPS 1994). Its flowers are white to pink, appearing from May to July. It grows on raised mounds in association with glasswort and *Suaeda* spp. (Reiser 1994).

Its status is seriously threatened by development (CNPS 1994). There is only one known native population in San Diego County, at Gunpowder Point. Two other transplanted populations may be found at the D Street Fill site and at Tijuana River National Wildlife Refuge (Reiser 1994). Historically it also occurred on the bay portion of the Silver Strand (Reiser 1994).

Globose Dune Beetle—*Coelus globosus*

The globose dune beetle is a federal Species of Concern that inhabits coastal sand dunes and sand hummocks in scattered localities from Bodega Head, Sonoma County to Ensenada, Baja California, as well as the channel islands (except San Clemente) (Nagano 1979; Snover 1992). Throughout much of its range it co-occurs with the closely related *Coelus ciliatus*. Its population status has declined in recent years due to development of coastal areas and recreational use of remaining coastal dune habitats. Many of southern California's coastal dunes have also seen significant invasions by non-native plant species, which tend to be detrimental to native fauna, especially arthropods. *Coelus* spends the days burrowed into the sand beneath dune vegetation, and comes to the surface at night, leaving distinctive furrows in the sand around the perimeter of the vegetation. It feeds upon the leaves, twigs, seeds, and detritus of dune vegetation, both on the sand surface and below. It will also climb up into the plant canopies to feed. Overall it shows a marked preference for native plant species over invasive non-natives. One exception is sea rocket (*Cakile maritima*) which is actually preferred by adults over the native dune ragweed (*Ambrosia chamissonis*). However, in coastal areas sea rocket is an annual plant that dies off at the time of year when *Coelus* larvae are approaching the end of their development period. Particularly detrimental is the hottentot fig or sea fig (*Carpobrotus* spp.), which provides little or no food for dune beetles and most other dune arthropods. There are generally very few beetles and other dune arthropods found in the sands beneath *Carpobrotus* stands (Nagano 1979; Snover 1992 and unpublished data).

The globose dune beetle was proposed for listing as threatened in 1979, and was also a Category 2 species. In the San Diego Bay area, it has been found on the dunes at Silver Strand, as well as the coastal dune habitats near the NRRF. *Carpobrotus* does occur in both areas and poses a direct threat to the continued persistence of the species.

Tiger Beetles—*Cicindela* spp.

All tiger beetles are highly active, fast-moving predators, preying upon any small arthropods they can overpower, especially flies, moths, ants, and isopods. The adults can be seen on warm sunny days in the spring, summer, or fall on open mud or sand. The larvae inhabit burrows in the soils of the same regions, where they capture prey as its passes near the burrow entrance. Tiger beetles are generally considered beneficial insects, as they prey upon significant numbers of small flies, such as kelp flies, that can become quite numerous and bothersome to humans in the area.

Tiger beetles in general are severely threatened by urban expansion, insecticide use, and recreational use of the beaches and coastal habitats of southern California and elsewhere. Seven species of the genus *Cicindela* are known to inhabit the southern California coast, six of which have been recorded in the San Diego Bay area, though two of these have not been relocated in recent surveys (*C. oregona* and *C. hirticollis gravida*). Four of the six species are considered rare (see below for accounts on individual species). The species *C. haemorrhagica haemorrhagica*, which has been recorded at Sweetwater Marsh National Wildlife Refuge (Merkel & Associates, Inc. 2000), is not considered rare. The sand dune tiger beetle was described earlier, since it has a federal threatened status. The three species described below have experienced declines in recent years and can now only be found at a handful of their former locales due to habitat loss.

Sandy Beach Tiger Beetle—*Cicindela hirticollis gravida*

This beetle is a federal Species of Concern usually found on sandy areas subject to tidal flow. Historically it has been found in several locations adjacent to San Diego Bay, including Silver Strand and Coronado. It may still occur on the Silver Strand near the NAB, but this area was not surveyed by Nagano in 1979.

Mudflat Tiger Beetle—*C. trifasciata sigmoidea*

This beetle is a California Species of Concern that inhabits mudflats and other areas with dark-colored, moist-to-wet sands. Adults can sometimes be seen running through sparse stands of *Salicornia*. The mudflat tiger beetle currently persists at various localities in Ventura, Los Angeles, Orange, and San Diego Counties, including the Sweetwater Marsh National Wildlife Refuge.

Gabb's Tiger Beetle—*C. gabbi*

Gabb's tiger beetle is a California Species of Concern that frequents the mudflats and salt flats of coastal marshes. Current populations are known from Sweetwater Marsh National Wildlife Refuge and Silver Strand, as well as Border Field and one location in Orange County. The population at Sweetwater Marsh National Wildlife Refuge was the largest of the populations surveyed in 1979. Investigations conducted by Merkel & Associates, Inc. (2000) reconfirmed Gabb's tiger beetle at Sweetwater.

Arrow Goby—*Clevelandia ios*

Status: No official status, population managed by the CDFG.

Abundance, Distribution, and Trend: The arrow goby occurs from British Colombia, Canada to Northern Baja California, Mexico and inhabits sand or mud bottom in estuaries, lagoons and tidal sloughs. Previous bay-wide fish assessments have concluded that the fish populations were similar in composition and abundance from 1988 through 1999, thus it is likely that the current population of the arrow goby is stable. Impacts to bay habitat have been greatly reduced in the last 10 years and specifically to the south bay, were this species is at its greatest density. VRG (2006) recorded similar biomass and number of individuals utilizing identical survey techniques in 2005 as Allen (1999) used in his 1994 through 1999 surveys.

Habitat Use: Typically associated with shallow subtidal and intertidal sand to mud bottoms, this species utilizes primarily eelgrass habitat and mudflats. Arrow gobies are documented to retreat into shrimp burrows when threatened, and at low tide. Distributed throughout San Diego Bay, this species is most abundant in the south bay were suitable habitat and protection from predators is most available. Unlike other gobies, it does not build a nest or care for its young (Eschmeyer *et. al.* 1983).

Food Habits and Predation: Adults feeds on diatoms, green algae, tintinnids, and the eggs and young of their shrimp hosts (Hart 1973). In some instances the species positions large food particles near crabs to be torn into smaller pieces. Rockfish species, staghorn sculpin, whitespot greenling, and terns prey upon arrow gobies.

Abundance in the Bay: Allen (1999) and VRG (2006) listed its capture in all four regions of the bay, with the south bay displaying the greatest number of individuals. Considering this species accounted for over three percent of the total catch in the south bay during Allen's study and the fact that it is difficult to effectively sample over large areas using standard trawl methods, it is reasonable to assume that the population estimates reported by Allen (1999) and VRG (2006) are on the low side. The San Diego Bay current population estimate is 434,000 individuals (VRG 2006).

Factors Influencing Population Numbers: Changes in abundance likely occur seasonally as changes in prey availability and increased predation during tern nesting season take place. Arrow gobies are known to be highly resilient to local perturbations and are well adapted to temperature and salinity changes, making significant changes to its population unlikely. Various species of birds including terns, herons, and diving birds have been documented to take arrow gobies frequently.

Indicator Justification: The species is a year around resident that relies on the bay to complete its whole life cycle, and utilizes specialized habitat and species interactions for foraging. The population is also of sufficient size to reasonably detect change through monitoring. In fact this species is commonly used in toxicological studies to evaluate heavy metals and other toxic chemicals.

California Halibut—*Paralichthys californicus*

Status: No official status, population managed by the CDFG.

Abundance, Distribution, and Trend: The California halibut is a member of the flounder family occurring from Magdalena Bay, Baja California, Mexico to the Quillayute River, British Columbia, Canada. A separate population occurs in the upper Gulf of California. Associated primarily with near coastal ocean waters, the California halibut ranges in depth from 5-600 feet. The species is well documented to undergo seasonal migrations between offshore feeding areas and shallow water spawning grounds, commonly utilizing bays, harbors and estuaries. California halibut are an important commercial and recreational fishery species with greater than two million pounds taken in California annually. CDFG sport fishing regulations allow for the take of up to five fish greater than 22 inches in length south of Point Sur, Monterey (limit of three north of Point Sur). Commercial and recreational landings of California halibut have remained steady at nearly one million pounds per fishery for the last 20 years.

Habitat Use: California halibut utilize near coastal ocean waters and associated bays and estuaries during all stages of their life history. Adult California halibut inhabit soft-bottom habitats in coastal waters generally less than 300 feet deep, with greatest abundance at depths of less than 100 feet (CDFG 2003). Newly settled and larger juvenile halibut are frequently taken in un-vegetated shallow-water embayments and infrequently on the open coast, suggesting that embayments are important nursery habitats. Protecting the juvenile halibut (0.4-6 inches [10-150 mm] SL) at this stage, which lasts one to two years, is critical to the size and health of the entire population. Various trawl surveys have captured predominately juveniles throughout all the bay regions, with adults typically collected in deep channels nearest to the bay entrance (VRG 2006).

Food Habits and Predation: California halibut feed almost exclusively upon anchovies, similar small fishes, and squid. Larger individuals primarily forage in near shore coastal waters, but regularly take advantage of concentrated prey species within bays and estuaries, such as the northern anchovy, top smelt, and slough anchovy. Juvenile halibut prey on small fishes within shallow coastal waters, estuaries, and bays and are food items themselves for larger fishes, birds, and marine mammals.

Abundance in the Bay: California halibut represent a significant biomass within all regions of San Diego Bay and are considered one of the primary upper level predators (Allen 1999). Annual and seasonal abundance vary minimally, as illustrated by results presented in surveys performed from 1994-1999 (Allen 1999). Abundance of halibut in San Diego Bay is affected by the seasonal reproductive success of adults in coastal waters and is additionally influenced by current fluctuations and predator/prey species interactions during larval dispersion. Commercial and recreational fishing take has been consistent for the last two decades, thus the San Diego Bay population likely follows similar trends. The current population estimate for San Diego Bay is 589,000 individuals (VRG 2006).

Factors Influencing Population Numbers: Breeding stock and larval success are the primary factors influencing halibut populations within San Diego Bay. Adequate management of the California halibut population appears to be in place due to the fact that fisheries landings have remained relatively consistent for nearly 20 years. Juvenile halibut likely represent the greatest portion of individuals of this species within the bay and are most influenced by factors affecting settlement, larval success, and food supply. Suitable soft bottom habitats remain an important factor in sustaining juvenile settlement and grow out. Fishing size limitations and bag limits have been effective management tools in sustaining a viable population.

Indicator Justification: California halibut depend on suitable bay and estuarine habitat to complete their life cycle. Newly settled and larger juvenile halibut are frequently taken in un-vegetated shallow-water embayments and infrequently on the open coast, suggesting that embayments are important nursery habitats (2003). The advantages of bays as nursery areas probably include a decrease in the risk of mortality of newly-settled juveniles and an increase in the growth rate of larger juveniles that feed upon the abundant small fishes in the bays. The species is a year around resident of all regions of San Diego Bay; adults play an important role as an upper level predator while juveniles are a food source for other fish, birds, and marine mammals. Additionally, California halibut populations are of sufficient size to be monitored, and provide a significant contribution to commercial and recreational fisheries.

Northern Anchovy—*Engraulis mordax*

Status: No Official Status

Abundance, Distribution, and Trend: The northern anchovy is abundant in California and has a range from the Queen Charlotte Islands, British Columbia to southern Baja, Mexico (Eschmeyer 1983). Considered pelagic, this species forms large, tightly-knit, polarized schools that regularly move into nearshore waters and adjacent bays and estuaries. Northern anchovies are divided into northern (British Columbia-Oregon), central (California to Descanso, Mexico), and southern (Mexico) subpopulations. The central subpopulation used to be the focus of a large commercial fishery in the U.S. and Mexico with the majority of the remaining subpopulation concentrated in the SCB, between Point Conception, California and Point Descanso, Mexico (PFMC 2007). Great variation in population size is characteristic of the major stocks of small pelagic fishes (Csirke 1988). The largest and best known stock of northern anchovy is the central subpopulation. The biomass of this stock was low in the 1950s and 1960s (200,000-500,000 metric tons [mt]) and grew rapidly in the early 70's, reaching a maximum historic biomass of 1.2 million tons in 1973 (Jacobson and Lo 1993), declining thereafter. Over the last 5 years the biomass has stabilized in the 300,000-400,000 mt range. San Diego Bay standing stock and biomass of forage fish are greatest in the north and north central regions of the bay (VRG 2006).

Habitat Use: Northern anchovy populations located in San Diego Bay vary seasonally, utilizing the bay's concentrated plankton and warm water during the winter and early spring when open ocean waters are less productive and colder. This species typically forages at the surface near deep channels during daylight hours, though they likely migrate throughout most regions of the bay at various times and conditions. Typically, northern anchovies are captured in midwaters of the nearshore and channel subhabitats that are associated with the north bay. The slough anchovy is an important relative of the northern anchovy that dominates the shallower southern portion of the bay, but fills the same niche. The northern anchovy is a filter feeder that utilizes changing tides and current boundaries that concentrate plankton to feed.

Food Habits and Predation: Northern anchovy are planktivorous, filtering small invertebrates, fish eggs, and phytoplankton from the water column. This species' feeding behavior leads to its primary use of deep channels and areas were sufficient nutrients and conditions occur that allow for rapid plankton growth. Schooling behavior by this species provides an easily available food supply for top-level predators including resident and migratory birds, marine mammals, and larger fish species.

Abundance in the Bay: Fluctuations of the northern anchovy population have been most closely related to oscillations in the California Current, which has significant effects on both recruitment and food supply (Lo *et. al* 1995). During twenty seasonal sampling surveys in the bay (July 1994-April 1999), Allen (1999) reported taking 78 species of fishes from throughout San Diego Bay. Of these, the northern anchovy was the most abundant species bay-wide, forming 43% of the total catch by number. The current population estimate within San Diego Bay is 2,067,000; the most numerous age class being juveniles (VRG 2006).

Indicator Justification: The northern anchovy is a broadcast spawner that produces millions of eggs which develop as larvae in the water column and act as a vital food source for predators through all of their life stages. The population is of sufficient size and density to be regularly monitored and could provide statistically meaningful numbers for year-to-year comparisons. The northern anchovies' food requirements make them sufficiently sensitive to bay disturbances impacting water quality and available prey items. Their life history and growth rates are also well understood, making it easy to assess their population structure, and make comparisons to regional stocks.

Management: Currently managed by the PFMC and regulated by the NMFS and CDFG.

Shiner Perch—*Cymatogaster aggregata*

Status: No official status, population managed by CDFG.

Abundance, Distribution, and Trend: The shiner perch is a common surfperch (*Embiotocidae*) found in estuaries, lagoons, and coastal streams along the Pacific coast from Alaska to Baja California, Mexico (Miller and Lea 1972). It is the sole member of its genus and is one of the most common fish in the bays and estuaries of its range, favoring beds of eelgrass, and often aggregating around piers and other structures. Limited literature is available on the general population trends of shiner perch throughout their range, but regional studies in individual bays and estuaries provide information on localized population status. Biomass and number of individuals of shiner perch varied insignificantly in trawl surveys performed by Allen (1999) from 1994-1999. Identical surveys performed by the VRG in 2005 (VRG 2006) collected comparable numbers of individuals. The sport fishing take of this species is thought to be increasing and remains a concern for its potential to effect specific southern California populations.

Habitat Use: This species is well represented in all regions of San Diego Bay, utilizing a multitude of habitats and bathymetric ranges. Typically associated with piers, wharves, and other structures, this species forms small aggregations and is an opportunistic feeder. Different year classes exhibit some degree of seasonal onshore-offshore movement. Apparently, shiner perch use estuaries as nursery grounds more extensively than other types of surfperch. Bane and Robinson (1970) observed that most juveniles and one-year-old adults remain in the bay during their first year, emigrating to coastal waters when they are two years old. Various trawl surveys illustrate that all life stages of this species occur within each region of San Diego Bay.

Food Habits and Predation: Young shiner perch feed primarily on copepods, while adults eat various small crustaceans, mollusks, and algae. Areas with underwater structure play an important role for this species as both potential feeding areas and as shelter from predation. Shiner perch are a valuable prey item for other bony fish, sea lions, and sharks. Sport fishing also plays a role in predation though most anglers release their catch of this species. CDFG regulations allow for a take of 20 shiner perch in addition to the surfperch bag limit; they are provided no seasonal or geographic closers within California.

Abundance in the Bay: Shiner perch are common throughout San Diego Bay and are easily observed or captured from coastal access points. Based on Allen (1999) and VRG (2006) the Shiner perch is among the top ten most abundant fish in San Diego Bay, calculated by both biomass and occurrence. The current population is estimated at 3,891,000 individuals (VRG 2006).

Factors Influencing Population Numbers: Shiner perch have little or no commercial fishery but are actively targeted by sport fishermen. Not a broadcast spawner, shiner perch reproduce efficiently (success per unit produced) but relatively slowly. This species relies on its current population size and fast breeding cycle in order to compete with conspecific broadcast spawners. Male shiner perch reach sexual maturity soon after birth. Females can also be inseminated soon after birth and carry the sperm in their ovaries until December, when fertilization occurs (Shaw 1971). Anderson and Bryan (1970) reported that the male shiner has a life span of three years and the female five years. Considering the reproductive strategy and congregational nature of this species, isolated populations could be susceptible to localized impacts.

Indicator Justification: Shiner perch are live breeders with relatively low productivity, making the presence of juveniles an important indictor of current habitat conditions. The importance of shiner perch as an indicator species within San Diego Bay is based on its abundance, feeding habits, accumulation of contaminants, and affiliation with eelgrass habitat. Additionally, shiner perch have high site fidelity, frequent shallows and channels where contaminants concentrate, are live-bearers, and their entire annual reproductive output (4-36 young annually) can be determined by sampling pregnant females in late winter. Dramatic changes in its population may provide a warning sign that critical habitat and/or availability of prey species have sustained natural or anthropogenic impacts.

Spotted Sand Bass—*Paralabrax maculatofasciatus*

Status: No official status, population managed by the CDFG.

Abundance, Distribution, and Trend: The spotted sand bass is a common sea bass (*Serranidae*) that ranges from Mazatlan, Mexico to Monterey, California (Eschmeyer 1983). This sand bass is usually found on sand or mud bottom near rocks and eelgrass, from the coast to a depth of 60 m. Considered common within San Diego Bay, it occurs only occasionally within near shore coastal waters of the SCB. This species' ability to tolerate large fluctuations of temperature (from 7.5 to 32°C) and survive extreme cold intervals contribute to its preference to bays and harbors within southern California. The greater concentration of preferred benthic invertebrate prey items in bay bottom substrates also contributes to its preference for this habitat. The spotted sand bass has no existing commercial fishery but is actively targeted by sport fisherman. Current CDFG regulations allow for the take of ten spotted sand bass or a combination of spotted sand bass, kelp bass, and barred sand bass. This species ranked third in biomass and tenth in total abundance in bay wide surveys performed by VRG (2006) in 2005, which concurred with earlier investigations by Allen (1999). Current regulations appear generally effective in maintaining a stable population.

Habitat Use: Southern California spotted sand bass populations are typically restricted to sandy or mud bottom habitat within shallow bays, harbors, and coastal lagoons that contain eelgrass, surfgrass, and rock relief. These areas act as warm-water refuges for this generally subtropical species. San Diego Bay regional surveys performed by Allen in 1994-1999, displayed higher populations in the south and south central bay when compared to other regions. Spotted sand bass are an important predator within San Diego Bay and are well adapted to utilize a wide array of bay habitat, taking advantage of diverse fish and invertebrate prey species throughout all bathymetric ranges.

Food Habits and Predation: Spotted sand bass are carnivorous predators that feed mainly on epibenthic invertebrates. This species is a voracious eater and is well adapted to take advantage of changing prey availabilities and localized disturbances. A secretive species, it feeds on small fishes and benthic crustaceans during the day (Heemstra, 1995). Preferred prey items include amphipods, isopods, polychaetes, bivalves, crabs, and fish. Seasonal variations with respect to prey consumption have been observed, with invertebrates, crabs, and fish being important at different times. Smaller spotted sand bass feed mainly on amphipods, isopods, and mollusks, whereas the largest bass feed on larger crabs and octopus. Age class habitat segmentation enables juveniles to avoid predation and find prey within eelgrass or other structure. Adults are better suited to avoid predation and capture larger prey items in deep channels and near coastal waters, allowing the species to reduce interspecies competition. Spotted sand bass are the most important predatory species in San Diego Bay (VRG 2006).

Abundance in the Bay: Specific population estimates for the spotted sand bass within San Diego Bay are not well documented but likely follow trends of similar *Paralabrax* spp. such as the kelp bass (*P. clathratus*) and barred sand bass (*P. nebulifer*). Commercial passenger fishing vessel landings of kelp bass fluctuated, with a general declining trend, from 1993 to 1999. In 2000 and 2001, landings rebounded to previous levels. While this is not a direct measure of abundance, catch trends offer some insight into the overall health of a stock. *Paralabrax* spp. stocks are believed to be stable. The first extensive seasonal sampling of fishes in San Diego Bay was conducted quarterly by Macdonald et al. (1990) throughout the south bay during 1988-1989. The study concluded that the species composition, relative abundance, and biomass characteristics of south bay fishes have remained very similar since 1968. The current population estimate of spotted sand bass within San Diego Bay is 1,966,000 (VRG 2006).

Factors influencing population number: The spotted sand bass population has undergone a dramatic increase in angling pressure in the last 10 years, and it is unclear how the increased pressure will affect the limited, and genetically distinct, southern California population. Studies indicate that most of the spotted sand bass caught by recreational anglers are released. The limited areas inhabited by spotted sand bass tend to amplify the adverse effects of environmental changes and recreational fishing pressure. Factor in sporadic recruitment by spotted sand bass, and the future of this fishery may depend on effective management policy. Waterfront development may permanently alter nursery habitat and poor water quality may negatively impact recruitment, resulting in a negative impact on certain populations (Hovey and Allen 2001). Environmental conditions such as sea surface water temperature may influence recruitment as well. Spotted sand bass have shown a substantial increase in recruitment success during times of elevated sea surface temperatures, which occur in nearshore southern California just after El Niño episodes. In other years, recruitment has been poor. This sporadic recruitment pattern may have an adverse effect on a population that is subjected to an increase in angling pressure and loss of nursery habitat.

Indicator Justification: This species represents a significant biomass within all regions of San Diego Bay and its population is sufficient to be reasonably detected during monitoring. Spotted sand bass rely heavily on San Diego Bay as primary foraging and spawning habitat, utilizing all portions of the bay during different life stages. This species is not normally sensitive to other environmental factors and is well suited for use in determining cause-and-effect relationships. The spotted sand bass's abundance and prey preference, for epibenthic invertebrates, makes it an important species in shaping community structure and for measuring bioaccumulation in predators.

San Diego Coast Horned Lizard—*Phrynosoma coronatum blainvillei*

Both a California and federal Species of Concern (a former federal Category 2), this species is recorded from the San Diego Bay area. Details on extant populations are sketchy, at best, though some may still remain along the Silver Strand and Coronado coastal scrub habitats (Jennings and Hayes 1994). Specific habitat requirements are loose, fine, sandy soils with limited vegetation cover. They may also be found in areas of denser shrub cover where small pockets of open habitat occur, such as those created by fire or other disturbance (Jennings and Hayes 1994). Its range extends through much of southern California west of the deserts, and into Baja California, Mexico, from sea level to 6,500 feet (2,000 m) (Smith 1946; Stebbins 1985). Historically, it was most abundant in riparian and coastal sage habitats of the coastal plains of southern California, but has disappeared from about 45% of the areas it once inhabited (Jennings and Hayes 1994).

The San Diego coast horned lizard is threatened by habitat fragmentation, non-native ant species (causing a degradation of the food base for horned lizards), off road vehicle activity, predation by domestic pets, and especially by collectors, though commercial collecting was banned in 1981 (Schoenherr 1992; Jennings and Hayes 1994). Since horned lizards rely primarily on camouflage to avoid predators, they are very easy for humans to catch, but survival in captivity is poor and few are ever returned to the wild.

Silvery Legless Lizard—*Anniella pulchra pulchra*

The silvery legless lizard is a California and a federal Species of Concern. Historically, the silvery legless lizard was common in areas of suitable habitat, including the Silver Strand. It may still occur there, and at the neighboring NRRF where coastal dune vegetation also occurs, but the species has not been noted at either locale in recent surveys (USDA 1989). There are no other documented occurrences for the legless lizard elsewhere in the San Diego Bay area, and little suitable habitat occurs except along the beaches of the Silver Strand and the Pacific side of Coronado. Preferred habitat appears to be coastal dunes with native shrubs for cover (Jennings and Hayes 1994).

Legless lizards spend most of their time buried in the soil (usually 1–4 inches/3–10 cm deep), emerging onto the surface primarily in the mornings and at night (Stebbins 1985; Jennings and Hayes 1994; Germano and Morafka 1996). They can also be found under surface objects such as logs, rocks, etc. They feed upon insect larvae, small adult insects, and spiders either at the surface or just below it (Stebbins 1985). Primary predators include alligator lizards, snakes, birds, deer mice, and domestic cats (Zeiner *et al.* 1988; Jennings and Hayes 1994). Legless lizards bear one to four young per year between September and November (Jennings and Hayes 1994).

Activities that are likely to result in soil compaction can be expected to negatively impact legless lizards. Also of concern are alterations to the plant community, where removal of vegetation can result in a drying of the soils, or invasion of certain non-native plants (e.g. *Carpobrotus edulis*) can alter the soil structure. *Carpobrotus* and other invasive weeds also tend to support a much lower arthropod community (Nagano 1979; Snover 1992 and unpublished data), providing much less food for lizards and other animals.

Large-Billed Savannah Sparrow—*Passerculus sandwichensis rostratus*

The large-billed savannah sparrow is a federal and California Species of Concern and a winter visitor to the San Diego Bay area. It is found in salt marsh habitats, and from its breeding grounds along the Gulf of California it was known to range eastward from the coast to the Salton Basin, and as far north as the Channel Islands, Morro Bay, and Santa Cruz (Garrett and Dunn 1981; Unitt 1984). It was once fairly common along the coast of California, but depletion of its salt marsh breeding grounds within the Colorado River delta in Mexico led to a drastic reduction in its numbers (Small 1994). The large-billed savannah sparrow is now regularly found in south bay, especially on Christmas bird counts (J. Coatsworth, San Diego Audubon Society, pers. comm.). It can also still be seen in the Salton Basin. Although its numbers have been on the rise, its range is still highly restricted, with California being at the extreme north of that range (Small 1994).

Black Skimmer—*Rynchops niger niger*

The black skimmer is considered a California Species of Concern that has colonized southern California from western Mexico since the 1960s and is now considered native to the area (Kaufman 1996). In San Diego Bay, it nests on the levees at the Salt Works in midsummer (Unitt 1984), where at least 400 nests were established in 1999 (Patton 1999). They are also found at the Salton Sea and Batiquitos Lagoon. Recently a resident population at Mission Bay became established, centered around Kendall-Frost Marsh and the beaches of Crown Point (J. Coatsworth, pers. comm.). Skimmers forage for small fish in tidal channels, diked ponds, shallow subtidal water, and deep water by trawling the water surface with their lower beaks, which are elongated and extend beyond the upper beaks (Small 1994). Preferred prey are northern anchovy, Pacific sardine, and topsmelt (Horn *et al.* 1996).

Black skimmers are threatened by disturbance of their nesting colonies, predation, and bioaccumulation (Kaufman 1996). Skimmer eggs tested in 1997 from the Salt Works were found to have detectable levels of a few organochlorine compounds. The compound with the highest level, *p,p'DDE,* is believed to be the most biologically active of the breakdown products of the pesticide DDT (Carol Roberts, USFWS, *pers. comm.* 2000). Black skimmer eggs from the Imperial Valley have higher levels than those from the Salt Works. In addition, the silty soils present in some of the saltwork levees can become cement-like when dried, decreasing the value of these areas for nesting sites (D. Stadtlander, USFWS, *pers. comm.*). The population at the Salt Works has been growing annually (Unitt 1984), and establishment of further colonies in the San Diego Bay area is possible as the range of the species expands in the west (Unitt 1984).

Burrowing Owl, Coastal Population—*Athene cunicularia hypugaea*

The burrowing owl is a breeding resident of upland areas around San Diego Bay. It is a California Species of Concern that is declining throughout its range, and nearing extirpation in coastal San Diego County (Unitt 1984; E. Copper, pers. comm.). It is also a federal Species of Concern. Burrowing owls form loose colonies, with both resident and migratory components (E. Copper, pers. comm.). Eggs are produced from late March to mid-June, and fledglings are active through August (Unitt 1984).

Occasionally, wintering owls appear at Silver Strand. These come during the months of September and October, and leave in January or February (C. Winchell, USFWS, *pers. comm.*).

The burrowing owls in the San Diego Bay area represent a large part of the population county-wide, with the largest nesting colony in San Diego County on North Island (Unitt 1984; E. Copper, pers. comm.). Throughout their range, burrowing owls are threatened by habitat loss, predation, vehicle impacts, and control programs for ground squirrels (Kaufman 1996). Owl burrows are strongly correlated with ground squirrel burrow complexes.

Double-Crested Cormorant—*Phalacrocorax auritus albociliatus*

The double-crested cormorant is a breeding resident of San Diego Bay, and a California Species of Concern. These cormorants nest and roost mainly on artificial structures, and have been observed avoiding water vessels (USFWS 1995a). They forage for fish in areas of open water. Their nesting schedule in the San Diego Bay area remains undescribed (Unitt 1984).

This species suffered a population decline during the 1960s and early 1970s due to DDT residues in marine food chains, and though there was some recovery in the late 1970s and 1980s, original population levels have not been restored (Small 1994). However, in some parts of its range, the cormorant population has recovered to the point where in March of 1998 the USFWS ruled to establish a depredation order to protect commercial freshwater aquaculture (see http://www.epa.gov for details).

There is only one breeding site currently known in San Diego County, on an old dredge in the Salt Works of south San Diego Bay (Unitt 1984; USFWS 1993, 1995b; E. Copper, *pers. comm.*), where at least 80 nests were found in 1999 (Patton 1999). It once occurred at Lake Henshaw, and could establish itself elsewhere over time (Unitt 1984). The double-crested cormorant is vulnerable to bioaccumulation in its prey and to human disturbance of nesting locales.

Elegant Tern—*Sterna elegans*

The elegant tern is a federal and California Species of Concern and a breeding resident of San Diego Bay.

There were about 1,700 breeding pairs at the Salt Works in 1999, with approximately 3,100 nests at the height of the season (Patton 1999). They also roost on mudflats, sandy beaches, and salt flats. They will utilize subtidal and deepwater areas for foraging. Egg-laying begins in April, but duration of the breeding season is unknown (Unit 1984).

There is one large breeding colony at the Salt Works (Unitt 1984) that has been documented as utilizing much of the south and central bay (USFWS 1995b). One elegant tern nest was found at Zuniga Jetty at the mouth of the bay, but the eggs were predated by June (R. Patton, pers. comm.). This species was nearly undocumented in San Diego Bay prior to 1950, and the San Diego breeding colony was established in 1959 (Gallup and Bailey 1960; Small 1994). This range expansion appears to have been triggered by an increase in anchovy abundance, which may in turn have been a result of the 1957–58 El Niño conditions (Schaffner 1986; Small 1994).

Gull-Billed Tern—*Sterna nilotica vanrossemi*

The gull-billed tern is both a federal and California Species of Concern, as well as a summer breeding species in San Diego Bay. It has only recently colonized the San Diego Bay, with eleven to 20 pairs at the Salt Works, where it nests on the levees in mid-to-late summer (Unitt 1984; Small 1994; Patton 1999). The coastal population appears to have stabilized at between 24-40 pairs (Shuford and Gardali 2008). It forages in marshes and upland transition habitats.

Coastal records are extremely rare, and almost all are from San Diego County, commencing in summer 1985 (Small 1994). From April through August 1987 up to six were at south San Diego Bay, fledging two young. This represented the first U.S. west coast breeding record. By summer 1993, this colony had increased to ten breeding pairs. In 1997, a year when there may have been a food shortage for fish foraging birds in San Diego Bay, gull-billed terns were documented predating on California least tern and western snowy plover chicks at the NAB (M. Kenney, USFWS, *pers. comm.*). Gull-billed terns were recorded in California at the south end of the Salton Sea in 1927 with a nesting colony of 500 pairs. In 1993, only 120 nesting pairs were present there (Small 1994). Erosion and predation at the Salton Sea have been problems for the nesting colonies there.

Gull-billed terns are one of the most important predators of California least terns, especially of eggs and chicks. For California least terns in 2009, 491 (33%) egg predation events and 321 (79%) chick predation events were attributed to gull-billed terns (Marschalek 2010).

Loggerhead Shrike—*Lanius ludovicianus*

The loggerhead shrike is both a federal and California Species of Concern. It is a breeding resident of upland transition habitats of the Bay, and forages over the high salt marsh. The loggerhead shrike was considered a common breeding resident of the San Diego Bay area fifteen years ago, but it is now uncommon to rare with few known nesting locations in the area (E. Copper, pers. comm.), although it is widely distributed throughout much of the county and state (Unitt 1984; Small 1994). This species, along with other shrikes, has been on the decline for some time. Although the reasons for this decline are not clearly known, they may be related to the bioaccumulation of pesticides from its prey (Small 1994; Kaufman 1996). Changes in habitat may also be contributing to this decline (Kaufman 1996).

The shrike requires dense shrubs for concealing its nests, with ample open ground nearby (Unitt 1984). Eggs are laid from early March through mid-June, and chicks are fledged by late July (Unitt 1984). Loggerhead shrikes prey upon insects and vertebrate species, including some of the other sensitive species around San Diego Bay (E. Copper, pers. comm.).

Long-Billed Curlew—*Numenius americanus*

The long-billed curlew is a California Species of Concern. It is a winter visitor to the tidal mudflats, estuaries, and salt marshes with tidal channels, as well as grasslands and sandy beaches (Garrett and Dunn 1981; Small 1994; E. Copper, pers. comm.). Its preferred breeding grounds are grasslands with nearby lakes or marshes (Small 1994). This is one of the largest shorebirds, and its down-curved bill can be up to 8 inches (20 cm) long. It can often be seen with marbled godwits probing in the mud and sand for small prey (E. Copper, *pers. comm.*). One of its favorite prey are ghost shrimp.

This species has decreased through much of its range as a result of loss of habitat at breeding grounds and bioaccumulation (Kaufman 1996; E. Copper, pers. comm.). Also, many populations were subject to heavy hunting pressures in the late 1800s and early 1900s (Schoolnet, web site).

Short-Eared Owl—*Asio flammeus flammeus*

The short-eared owl is a California Species of Concern. It is a rare to uncommon winter visitor in salt marshes, grasslands, and agricultural areas (E. Copper, pers. comm.).

The short-eared owl can still be found at the Sweetwater Marsh (J. Coatsworth, pers. comm.). This species once nested in many areas in California (Unitt 1984), but no longer does so along the southern coastal areas (Remsen 1978). Its numbers in general are declining, especially in coastal areas where it is now considered uncommon (Garrett and Dunn 1981; E. Copper, pers. comm.). Loss of grasslands and marsh habitats to agriculture, pastures, and development have contributed to the decline of this species. Short-eared owls and their chicks are also vulnerable to predation by skunks, feral cats, and dogs (Audubon Watch List).

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Appendix F: Aquatic Invasive Species of San Diego Bay

ALGAE

Phaeophyta

Alariaceae
Undaria pinnatifida

Sargassaceae
Sargassum muticumsargassum

Rhodophyta

Lomentariaceae
Lomentaria hakodatensis

Rhabdoniaceae
Caulacanthus ustulatus

ANIMALS

PORIFERA (SPONGES)

Haliclonidae
Halichondria bowerbankia
yellow sponge

Haliclona sp.
haliclonid sponge

CNIDARIA (JELLYFISHES, CORALS)

Hydrozoa (Hydroids)

Campanulariidae
Gonothyraea clarki

Obelia sp.

Tubulariidae
Tubularia crocea

Anthozoa (Sea Anemones, Corals, Sea Pens)

Diadumenidae
Diadumene lineatu

ANNELIDA

Polychaeta

Eunicidae (Eunicids)
Marphysa sanguinea

Nereidae (Neriids)
Neanthes acuminata

Phyllodocidae (Phyllodocids)
Eteone aestuarina

Serpulidae (Serpulids)
Demonax sp.
Vermiiopsis infundibulum

Spionidae (Spionids)
Polydora ligni
Pseudopolydora paucibranchiata
Streblospio benedicti

Syllidae (Syllids)
Branchiosyllis exilis
Myrianida pachycera
Typosyllis nipponica

Terebellidae (Terebellids)
Nicolea sp. A Harris

ARTHROPODA

Mandibulata

Crustaecea

Ostracoda (Ostracods)

Aspidochoncha limnoriae

Redekea californica

Cirripedia

Balanidae
Amphibalanus amphitrite

Balanus amphitrite
little striped barnacle

Balanus tintinnabulum
red and white barnacle

Malacostraca

Tanaidacea (Tanaids)
Sinelobus stanfordi

Tanaid sp.

Maxillopoda

Oithonidae
Oithona davisae

Oithona similis

Pseudodiaptomus
Pseudodiaptomus marinus

Isopoda

Janiridae (Janirids)
Ias californica
Limnoriidae (Limnorids)
Limnoria quadripunctata

Limnoria tripunciata
Paranthuridae
Paranthura japonica

Sphaeromatidae (Sphaeromids)
Sphaeroma quoyanum
Sphaeroma walkeri

Amphipoda

Gammaridea (Gammarids)

Ampithoidae (Amphithoids)
Ampithoe valida
Aoridae (Aorids)
Aoriodes secunda
Grandidierella japonica
Cheluridae
Chelura terebrans
Corophiidae (Corophiids)
Corophium acherusicum

Corophium heteroceratum
Corophium uenoi
Ericthonius brasiliensis
Monocorophium spp.
Eusiridae
Pontogeneia rostrata
Ischyroceridae
Jassa marmorata (falcata)

Leucothoidae (Leucothoids)
Leucothoe alata
Oedicerotidea (Oedicarotids)
Eochelidium sp. A
Podoceridae (Phodocerids)
Podocerus brasiliensis
Stenothoidae (Stenothoids)
Stenothoe valida
unknown
Elasmopus rapax

Caprellidae (Caprellids, Skeleton Shrimp)

Caprellidae (Caprellids)
Caprella acanthogaster

Caprella scaura

Decapoda

Palaemonidae
Palaemon macrodactylus

Insecta

Hemiptera (True bugs)

Hymenoptera

Apidae (Bees)
Apis mellifera
honey bee

Formicidae (Ants)
Iridomyrmex humilis
Argentine ants

Lepidoptera

Pieridae
(Whites, Sulphurs, and Orange-tips)
* *Pieris rapae*
cabbage butterfly

Dermaptera (Earwigs)

Forficulidae (Earwigs)
Forficula auricularia
earwig

Chelicerata

Arachnida (Spiders, Mites, Pseudoscorpions)

Dysderidae
Dysdera crocata

MOLLUSCA

Gastropoda (Snails, Limpets, Sea Hares, Nudibranchs)

Nudibranchia
Catriona rickettsi

Bivalvia (Clams, Cockles, Mussels, Oysters, Shipworms)

Arcidae
Arca transversa
Mytilidae
Geukensia (Ischadium) demissa
ribbed mussel
Musculista senhousia
Japanese mussel
Mytilus galloprovincialis

Ostreidae
Ostrea edulis
Semelidae
Theora fragilis
clam
Theora lubrica

Teredinidae
Lyrodus pedicellatus
southern shipworm
Teredo navalis
shipworm
Veneridae
Tapes japonica (semidecussata)
venerid clam

ECTOPROCTA (BRYOZOA)

Amathia convoluta
Bowerbankia imbricata
Bugula neritina
Bugula stolonifera
Cryptosula pallasiana
Rhynchozoon bispinosum
Schizoporela unicornis
Tricellaria gracilis
Watersipora arcuata
Watersipora subtorquata
Watersipora sp. A
Zoobotryon verticillatum

CHORDATA

Urochordata (Sea Squirts, Compound Ascidians, Tunicates)

Ascidia zara
tunicate
Ascidia sp.
tunicate
Botrylloides diegensis
tunicate
Botrylloides perspicuum
Botrylloides violaceus
Botryllus firmus
Botryllus schlosseri
tunicate
Botryllus sp.
Ciona intestinalis
tunicate
Ciona savignyi
tunicate
Diplosoma listerianum
Lucania parva
Microcosmus squamiger
tunicate
Molgula ficus
Polyandrocarpa zorritensis
tunicate
Styela canopus
tunicate
Styela clava (formerly *barnharti*)
tunicate
Styela plicata
tunicate
Symplegma brakenhielmi
tunicate
Symplegma reptans

Vertebrata

Osteichthyes (Bony Fishes)

Clupeidae
Dorosoma petenense
threadfin shad
Gobiidae
Acanthogobius flavimanus
yellowfin goby
Tridentiger trigonocephalus
chameleon goby
Hacnulidae
Poecilia latipinna
sailfin molly
Serranidae
Morone (Roccus) saxatilis
striped bass

Appendix G: Ecological History of San Diego Bay

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Table G-1. Ecological History of San Diego Bay.[a]

Natural Formation	Bay formation product of long term geologic process	12–2 million years ago	Bay margin is created in the Pliocene age, the result of subduction of tectonic plates and modified by glacial deposits, as the Ice Age warmed.
Pre-European Settlement	Prehistoric	48,000 years ago	Late in the Ice Age there was no bay; Coronado, North Island and Point Loma were islands. Silt laden waters of the Tijuana River to the south were carried north by natural current action eventually building the Silver Strand and connecting Coronado and North Island. The Pacific shore was 20 miles farther west than today. Ice melt brought muddy San Diego River waters that built up a delta, tying Point Loma to the mainland and creating two bays; Mission Bay on one side, and San Diego Bay on the other.
	San Diego Bay Estuary	10,000 years ago	The ocean had spread inland through a gap in the outer Coast Range, and seawater began to fill the bay. For thousands of years the waters rose at nearly an inch per year, which was enough to advance the shoreline nearly 100 feet each year along the imperceptibly sloping floor of the South Bay. Gradually, the rate of rise slowed. Beginning several thousand years ago, sediments accumulated in the shallows faster than the sea could cover them. These sediments sea level has risen about 400 feet since the last Ice Age supporting the expansion of tidal mudflats and marshes, and filling the Estuary to its current depth.
	Kumeyaay	1000 B.C.	Native American Indians hunted the land, fished the sea and harvested plants. They were attracted to the bay for fish and shellfish resources. “Fish constitutes the principle food of the Indians who inhabit the shore of this port, and they consume much shellfish because of the greater ease they have in procuring them. They use rafts made of reeds, which they manage dexterously by means of a paddle or double-bladed oar. Their harpoons are several yards long, and the point is a very sharp bone inserted in the wood; they are so adroit in throwing this weapon that they very seldom miss their mark” (Captain Vicente Vila 1769, cited in Pourade 1960).
Spanish and Mexican Occupation	Juan Rodriguez Cabrillo discovers Bay	1542	Explorer Juan Cabrillo, of Portuguese birth, set foot at Point Loma laying claim to California lands for Spain. He had found the narrow natural channel opening to an embayment where seven river systems and tidal influences created a shore lined with deltas, mudflats and salt marshes. While sitting out a storm of six days in this well-sheltered bay and before moving north, Cabrillo logged reports of fishing with nets. Cabrillo named the bay San Miguel. It was sixty years before Sebastian Vizcaino returned to rename it San Diego Bay. Vizcaino recorded good water and many fish, along with visits from the native Indian population, with whom he traded skins for beads. With the arrival of Fr. Serra and the establishment of the San Diego de Alcala Mission came a new era of occupation. Use of the bay as an active harbor commenced for the Spanish fleet of wooden sailing vessels. Spanish maritime law forbade foreign traffic in their harbor. Traffic from the French, British, Americans, Dutch and Russian fleets increased with Mexican rule. By the time of settlement, Bay conditions were occasionally influenced by floodwater deposits of silt and clay. This natural process reshaped intertidal habitats and altered the depth of the bay. Turbidity and salinity were changed for short periods of time with temporary loss of marine species. Early settlers noted that the Pacific gray whale used the bay for calving (Scammon, 1968). Whaling in and outside of the bay led to its recognition as a whaling center. Trade in hides also increased commerce. Use of the bay as a harbor and center for whaling and hide trade, to this point, had little effect with a low level of waste from processing of whales and tanning of hides handled by tidal flushing. Whaling was most active from 1850–70 and declined by the 1890’s. Years of Spanish/Mexican rule ended in 1846, when San Diego (**population 500**) was claimed for America. The first Navy boat entered the bay.
	Sebastian Vizcaino renames San Diego Bay	1602	
	Spanish Army constructs military post	1769	
	San Diego mission established by Father Junipero Serra	1769	
	Mexican rule begins	1821	
	Cattle hide export	1827	
	Whaling vessels operated out of San Diego Bay	1830	
	San Diego River silt threatens to choke up San Diego Bay as noted by French attache M.Duflot de Mofra who visited the area	1842	
	John Fremont claimed for America	1846	
	U.S.S. Cyane enters harbor	1846	

Table G-1. Ecological History of San Diego Bay.[a] (Continued)

Bay Front Development, Water Diversion, Dredging Begin	Mail boat arrives	1849
	U.S. Boundary Commission designates U.S./Mexico Border (officially declared 1856)	1849
	"Oregon" first passenger liner to the bay, wooden paddlewheeler	1849
	William Heath Davis builds first wharf	1850
	California statehood, City of San Diego incorporated, San Diego County established	1850
	Derby dike constructed	1853
	Point Loma Light House constructed	1855
	San Diego Bay charted	1859
	Julian gold strike	1870
	San Diego Chamber Of Commerce formed	1870
	Commercial oil production begins in California	1870–1880
	San Diego Water Company established	1872
	First tug boat	1881
	Transcontinental Santa Fe RR completed	1885
	"Della" first Coronado ferry	1886
	Coronado Beach Company buys North Island	1886
	First sewage disposal system	1887
	National City incorporated	1887
	First trash barge	1888
	First dredging	1888
	Cuyamaca Dam diverts freshwater to Chollas Reservoir	1888
	Sweetwater Reservoir built	1888
	Rivers and Harbors Act	1889
	City of Coronado sewage system	1890
	Santa Fe Railroad washed out by flood	1891
	Dixon Crematory built	1897

With statehood, came mandated U.S. Mail delivery and the first steam-powered vessel to the bay. The first pier was constructed in 1850 (end of Market St.) over mudflats and required little dredging or filling. In 1868, piers from the foot of 5th Street (Horton) and from F Street (Culverwell) were constructed, and in 1871 the National City Pier was completed. In 1888, construction began of a 15,000-ton capacity coal bunker wharf by Spreckles at the foot of G Street. Waterfront commerce was developing and changing in an attempt to handle the need for fuel to service a new breed of boat, incoming and outgoing cargo, and needs of the growing community.

The bay charted in 1859 documented 2,674 acres of intertidal salt marsh and 4,057 acres of intertidal mud flats. The wooden piers did not change the shore configuration although water quality began to be impacted with coal dumped directly on wharfs.

Waters of the San Diego River continued to flow over the delta to either bay until the Derby Dike was built in 1853–54 (reconstructed in 1877). The river was forced to Mission Bay, and therefore, San Diego Bay kept from further siltation while the character of the mudflat and salt marsh habitats around the former mouth of the river was changed. By 1915, Mission Bay, or False Bay as it was know to early settlers, was prime habitat for California least tern. At the time, Sechrist described a typical least tern colony with "about 1000 pairs of birds breeding all the way from Pacific Beach down to False Bay with about 500 pairs nesting at the entrance to False Bay".

Diverting the San Diego River was the first reduction of freshwater input. Later, dams were built on the Sweetwater and Otay River affecting inflow of fresh water, as well as siltation. Fresh water for a growing population's needs became an issue and then an industry. Private companies developed mountain reservoirs and sold water to the City under contract. A well was drilled by the San Diego Water Company in Pound Canyon with two reservoirs, and in 1875, an additional well and reservoir at 8th and Hawthorne was drilled. A flood in 1891 was followed by an eleven year drought (1895–1905). Lack of water with infrequent floods had long been San Diego's pattern.

San Diego's population continued to grow encouraged by a Chamber of Commerce that was anxious to promote the city's growth and prosperity. The men who ran the chamber had much to gain having invested in property and wharves, determined to develop the harbor's potential for commerce and industry while selling adjacent land.

The 1880s experienced a land boom.

Building of the Point Loma light house aided and encouraged traffic to the bay. The lighthouse was deactivated in 1891 and replaced by Ballast Point Light House, which was low enough to provide light underneath the fog. The 1848 discovery of gold by James Marshall on the American River set off a huge migration to California, but this had little effect on San Diego until 1870, when gold was discovered in the Cuyamaca Mountains. This discovery brought prospectors, many from San Francisco where the gold rush boom was winding down. The Julian run lasted five years. The transcontinental railroad connection completed to San Diego in 1885, made the area accessible to many more people and increased opportunities for incoming and outgoing trade. San Diego became a fashionable winter resort, owing to the remarkable steadfastness of its climate and was advocated for its healthy climate at a time when tuberculosis was a common affliction.

A survey by Eigenman in 1888 documented 56 species of fish; marine life was continuing to flourish.

Problems related to a fast-growing community became evident. In an effort to keep up with accumulations of garbage, disposal at sea using a garbage scow hauled out past Pt. Loma began. Tidal currents returned garbage to the bay waters making it necessary to travel further out to sea. Scows were unable to handle the volume of garbage which then piled up on docks, creating a terrible stench and eventually becoming a health hazard. When the Dixon Crematory was built to burn rubbish, the scows were discontinued. In 1889, the Harbor Commission wrote an ordinance prohibiting the dumping of garbage into the bay in an effort to legislate control of waste.

In 1887, a new San Diego City sewage disposal system dumped raw waste directly into the bay. This was the beginning of a decline in water quality. Coinciding with the construction of Hotel del Coronado (more bathrooms per room of any building in the U.S. in 1890) the City of Coronado added a sewage system dumping into the bay. With funding from the Improvement Act of 1893, National City built a sewer system which also dumped raw sewage into bay waters.

The first dredging occurred in 1888 in Glorietta Bay, with the use of a steam suction dredge. In order to protect the narrow channel entrance to the bay, the Zuniga jetty was constructed in the years 1893–1907.

Construction of reservoirs on bay watersheds reduced silt supply and natural filling, resulting in a tendency to stabilize some near-shore habitats.

Table G-1. Ecological History of San Diego Bay.[a] (Continued)

Increasing Commerce, Industry and Population	Pt. Loma Navy Coaling Station established	1901	At the turn of the century, San Diego was becoming a major west coast harbor with a **population of 30,000**. Charting by the USCG indicated relatively undisturbed tide flats and salt marshes. Saltworks operations and development of Dutch Flats were offset by changes created when the San Diego River was diverted. Natural sloping conditions of the south bay were ideal for South Bay Saltworks system of dikes forming evaporation ponds to produce salt. The ponds replaced natural areas of salt marsh and mudflats. In the north bay, Campbell Machinery (later converted to a shipyard), Joe Fellows Boat Plant and Benson Lumber Company set up bayside. One to five 900 foot long log rafts/year were brought in by the lumber company from Oregon, until 1941. Industry had been slow to come to San Diego Bay; lack of water supply and shallow waters were problems. Military presence in the bay dated back to 1850, when Davis offered the U.S. Government land near his wharf to build a barracks. Point Loma Naval Coaling Station was the first permanent installation. A Naval Radio Station had also been commission for Point Loma, and Fort Rosecrans protected the harbor. The first military reservation on North Island was built on Zuniga Shoal. Fort Pio Pico was a substation of Rosecrans, and from there work to build a jetty to protect the channel opening took place. In 1907, the channel was dredged to 28 feet. Additional dredging would be necessary for the harbor to be useful for the new, larger, steam-powered, propeller-driven ships. Completion of the Panama Canal would make San Diego the first American port of call. San Diego's Chamber board of directors and more than 100 citizens wrote to the Secretary of the Navy stressing the strategic importance of their Bay encouraging a NTC, Naval Hospital, wireless telegraph station and additional dredging for a dry dock and repair station. In 1912, William Kettner became the first representative to Congress from San Diego and was able to secure funding to improve the harbor for Navy and commercial vessels. Good will between the Navy and San Diegans had been purposefully fostered by Kettner and other city fathers. California state relinquished control of tidelands to the City with terms tied to port improvements. In 1914, a gas powered suction dredge dug a thirty foot channel to the foot of Broadway to construct the first concrete pier. (Broadway Pier) The Panama California Exposition of 1915 celebrated the new route, and was an opportunity for San Diego to gain recognition. In 1916, reservoirs were dry and water supplies diminished. A rainmaker was hired in hopes that he could summon rains. Thirteen inches of rain fell, and floodwaters washed away the salt evaporation ponds. F. Stephens journalized, "The big flood of January, 1916, covered most of the salt marshes near San Diego and drowned most of the Little Black Rails (*Creciscus coturniculus*). I have not been able to find one since the flood." North Island property was offered to Glen Curtis, by the Coronado Beach Company, to set up a flying school and from there the first hydro-aeroplane departed. Aviation camps for the Navy and Army Signal Corps were established. North Island was the birthplace of Naval aviation, and the center of aviation activities in WWI. Open burning of trash and tideland dumping continued at least until 1935, possibly longer, despite building of an incinerator. Differences of opinion over what San Diego's future should be was characterized as "smokestacks vs geraniums." Military presence was perceived by some as a controlled, conservative industrialism.
	Jetty built at Fort Pio Pico	1901	
	South Bay Saltworks operations	1902	
	U.S. Coast Guard and Geodetic Survey chart of San Diego Bay completed	1902	
	Benson Lumber Company set up bayside	1906	
	Campbells Machinery set up bayside	1906	
	Zuniga Jetty built	1893–1907	
	Navy Radio Station commissioned on Point Loma	1907	
	Bay channel dredged to 28´	1907	
	Great White Fleet anchored off Coronado	1908	
	Flying School on North Island initiated	1910	
	First wartime shipyard established	1911	
	First hydro-aeroplane takes off from North Island	1911	
	Legislative grants of tidal and submerged lands made to City and County of San Diego, Cities of Coronado, National City, Chula Vista and Imperial Beach (jurisdiction later transferred to Port District in 1962)	1911	
	Chula Vista incorporated	1911	
	Army Signal Corps establishes aviation camp on North Island	1912	
	San Diego's first Congressman in office	1912	
	Mcguire incinerator built	1913	
	Panama Canal finished	1914	
	First Navy land purchase of Chollas Heights	1914	
	Broadway Pier constructed	1914	
	Panama/California Exposition	1915	
	Flooding, Otay Dam breaks	1916	
	U.S. enters WWI	1917	

Table G-1. Ecological History of San Diego Bay.[a] (Continued)

War, Water and Agriculture	Harbor Commission appointed	1919	In 1917, when the U.S. declared war on Germany, North Island became a permanent Army/Navy aviation school. In 1919, the San Diego Chamber purchased tidelands at the foot of 32nd Street (“Dutch Flats”) for the Navy to dump dredge spoils gained from extending deep water areas. Later, major dredging deposits were used for filling in Spanish Bight on North Island increasing the island by 620 acres. McGrew reported “50,000 to 100,000” Brant in Spanish Bight in the 1880s, and contrasted this to the species’ rarity by the 1920s. The bay was being reshaped to accommodate larger vessels and fill the demand for waterfront development. Shelter Island was created from dredge spoil on mudflats. Spoil was targeted for beaches eroding from the effect of damming the Tijuana River. Damming stopped transport of replacement sand to northern beaches. From 1940 to 1970, 28,300,000 cubic yards of dredge spoils was placed on beaches. South Bay Saltworks was rebuilt over time, eventually occupying 900 acres of diked ponds. Intertidal mudflats and salt marshes were decreased and the bay floor modified, destroying large areas of eelgrass beds. There was some hope that increased depth would serve to lessen the effects of growing waste deposits; however, the added volume actually reduced the natural tidal flushing action. After the war, as expense money diminished, aviation and shipping activities suffered. In 1922, 450,000 tons of U.S. ships were destroyed and hundreds were put into ports and named “moth ball fleets”.(Rush 1958) **Population was approaching 75,000** in 1919, and sewage was still a problem. At five sites: Olive Street, Market Street, Commercial Street, Beardsly and 32nd Street, raw sewage was dumped into the bay from shoreline outfalls. Untreated wastes from the main industries: olive, pimento, citrus, and fish and meat packing, were entering the bay through city sewers or industrial outfalls. The first Chula Vista collector was added in 1926, at the foot of G Street, dumping raw sewage. Primary treatment was added in 1943, and secondary treatment in 1948. By 1930, there were nine sites; two having partial treatment in settling tanks. Sludge was usually pumped directly into the bay at high tide. Deterioration of water quality was becoming a serious problem, but a depressed economy of the 1930’s stalled efforts to upgrade the systems. By 1941, there were more than 26 sewage outfalls serving the San Diego area, at least fifteen entering into the bay. Between 1938–45 sixteen storm drains had been built discharging industrial waste directly into the bay. Other wastes were discharged from military and commercial vessels in the bay. The San Diego City Manager wrote to the Secretary of the Navy, soliciting others to do so as well, informing him of the degraded condition, and asked for federal assistance. A series of projects were funded including construction of a 14 million gallon/day sewage treatment plant completed in 1943. The new plant added clarification and chlorination, using oxidizers for sludge digestion. With the buildup of military personnel as well as defense industries, the **population reached 250,000** in 1942, and the system was almost always overloaded. Many organisms apparently disappeared from the bay due to poor water quality. Garbage continued to be a problem with the incinerator plant having failed. Garbage was dumped on tidelands and burned leaving widespread ash contamination. A new Rubbish Reduction Plant was built. San Diego felt the depression less than most with funded projects banking a payroll. Aviation related industry flourished with Consolidated Aircraft (later General Dynamics) moving its entire plant to San Diego. Ryan Aeronautical and Solar Aircraft Co. manufactured aircraft parts, also a new industry. Charles Lindbergh started his historic transatlantic flight from North Island in the Spirit of St. Louis built by Curtis, out of San Diego. “Dutch Flats” had been converted to a municipal airport and was dedicated Lindbergh Field, later accommodating a USCG Air Station. When war was declared, San Diego was home to six aircraft carriers while Pearl Harbor had ported battleships. The “mothball fleet” ships were re-activated and sent to do battle. Anti-submarine nets were placed across the entrances of San Diego harbor to prevent Japanese hit and run attacks. After the war, the nets were towed out to sea and dropped into deep water (Rush 1958). In 1946, having endured another drought, San Diego bought annexation to the Metropolitan Water District with water rights to the Colorado River that had been granted in 1926. The City exceeded original rights within ten years, and by 1991 was using 562,000 acre-feet, five times the original allocation. Without the aqueduct feed, the San Diego area had no hopes of supporting their growing agricultural industry. Groves and nursery stock along with indoor decorative plants made the county one of the leading farm regions in California.
	Otay Reservoir built	1919	
	Dutch Flat Salt Marsh covered with dredge spoil	1919	
	Salt Works rebuilt	1920–33	
	San Diego: headquarters for 11th Naval District	1922	
	First Chula Vista sewer collector	1926	
	Spirit of St. Louis flight	1927	
	Lindbergh Field dedicated	1928	
	Construction of Hoover Dam initiated	1930	
	Shelter Island created	1934	
	Rubbish Reduction plant in operation	1934	
	Coast Guard Airstation accommodated at Lindbergh Field	1934	
	Consolidated Aircraft relocates to San Diego	1935	
	Naval Air Station North Island established	1935	
	California Pacific Exposition	1935	
	Tijuana River dammed	1937	
	Controls placed on whaling	1937	
	16 storm drains built	1938–45	
	Leading tuna port in the Pacific established	1941	
	North Island increased by 620 acres by the filling of Spanish Bight	1941	
	U.S. enters WWII	1941	
	“No eelgrass in the Bay” reported by Game Warden	1941	
	New sewage plants constructed	1943	
	San Diego Aqueduct Completed	1947	
	Dickey Act of California sets up state and 9 regional water quality control boards	1949	
	Korean War, work on Atlas missile	1950	

Table G-1. Ecological History of San Diego Bay.[a] (Continued)

Pollution Overload	Regional Water Quality Control Board formed	1950	Early in the 1950's, three Chula Vista shoreline outfalls were directly polluting the bay; two with disinfected intermediate effluent from its sewage plants, and the other an adjacent aircraft manufacturing facility discharging untreated, highly toxic chemical waste. Studies began after the SDRWPCB was established in 1950, to determine the extent of the bay's degraded water. Distributions of dissolved oxygen concentrations and coliform densities from 1951–55 were lower than would support most fish and many invertebrates for all of the central bay area and portions of the north and south bay. Coliform bacteria counts were in excess of 10 mpn/ml. Planning had begun for a new Metropolitan Sewage System while the bay continued to degrade. Additional studies found turbidity and discoloration due to blooms of phytoplankton stimulated by nutrients in the sewage effluent. Red tide blooms existed throughout most of the bay. The Regional Board concluded that even secondary treatment with a high degree of disinfection were inadequate to prevent pollution. The bay was no longer able to assimilate the accumulated pollution, and in 1955 quarantine signs were posted along the Coronado coastline. Chlorination programs in 1956 reduced coliform levels, however, by 1960 the bay was again quarantined. Fifty-six million gallons per day of domestic waste were being discharged into San Diego Bay. Over 80% of dissolved oxygen levels were lower that 4mg/l, resulting in disappearance of bait and game fish. The CDFG declared much of the bay a virtual "marine desert." Sludge beds on the east shore had increased in thickness from 3 to 7.5 feet in the twelve years from 1951 to 1963. Pollution peaked in the Late 1950's and early 1960's. There was the putrid smell of algae, oil and sewage. If you had the misfortune of falling overboard, you didn't know whether to hurry home and take a shower, or go to the hospital for a tetanus shot. The health department had posted much of the shore, warning that the water was too contaminated for contact (San Diego Union 1971). The State of California was first to address the bay pollution problem, even before the Federal Clean Water Act was written.In August of 1963, the new San Diego Metropolitan Sewage System with ocean outfall went into operation, and by February of 1964, all domestic sewage was changed over to the new system. The SDUPD was established in 1962 to manage the harbor, operate Lindbergh Field and administer public tidelands on San Diego Bay. Voters passed a bond issue to construct the 10th Avenue Marine Terminal. Large-scale dredging and filling for National City and Chula Vista Bay fronts and Harbor and Shelter islands was begun. The shipping channel was dredged with a turning basin to 42 feet. Coronado Cays was constructed over a previous city burn dump site adjacent to mudflats and salt marsh in 1968, requiring no EIS. SDUPD funds an access channel and L shaped boat basin in the south bay. San Diego Gas and Electric power generating plant was operational in the south bay. Studies monitor effects of the plants operation on surrounding marine life, and the plant adds generating units. Today it takes x-ray eyes to find the scars that were left by more than half a century of sewage disposal (San Diego Union 1971). "In a matter of months a difference in the clarity of water could be noticed, and within a year, fish were seen again breaking the surface and could be caught in the channels. Swimming in the bay could be safely permitted again. Sea lions and porpoises returned to the harbor, pelicans and terns plunged into shoals of anchovy, and San Diegans could congratulate themselves on their bay's salvation." (Herbert L. Mannishly) Nuclear submarines were stationed in the bay, and the industry changed from aircraft to missile production. The Navy installed a million dollar treatment plant to eliminate outflow. The Kelco Company's kelp-processing plant developed a clean-up program to end daily dumping of four million gallons of waste into the bay. In 1971, the Westgate tuna packing plant, the only remaining cannery in the bay, installed a filter system at its unloading docks. The USCG kept an eye on oil spills.
	Sewage plant expanded	1950	
	10th Avenue Marine Terminal approved	1955	
	Landfill site at Miramar	1959	
	Second pipeline for San Diego Aqueduct constructed	1960	
	Large-scale dredge and fill for National City and Chula Vista bay-fronts, Harbor Island and Shelter islands	1960	
	First pipeline for second San Diego Aqueduct	1960	
	Nuclear submarines ported	1960	
	San Diego Gas & Electric operational	1960	
	$42.5 million bond approved for construction of Metropolitan Sewage System	1960	
	Dredge ship channel and turning basin to 42 feet	1961	
	Second generating unit added to SDG&E	1962	
	San Diego Unified Port District established	1962	
	Naval Ocean Systems Center established	1962	
	Metropolitan Sewage System begins operation	1963	
	San Diego Bay Master Plan adopted	1962	
	Third generating unit added to SDG&E	1964	
	Coronado Cays construction begins	1968	
	First phase of L-shaped boat basin in South Bay	1968	
	Coronado Bridge opens	1969	
	Last of major industrial process discharges diverted to sewer	1969	
	California Porter-Cologne Water Quality Control Act	1969	
	Naval discharges eliminated, including that from vessels	1970	
	Fourth generating unit added to SDG&E	1971	
	Federal Clean Water Act	1972	
	Coastal Zone Management Act	1972	In 1972, the federal CWA prohibited discharge of pollutants to waters unless permitted. The act was written with the intent of limiting the impacts of increased development on water resources, and along with the Rivers and Harbors Act of 1899, drives regulation on a federal level with standards, prohibitions, permit review specifications and means of enforcement. §404 of the Act addresses discharges of dredge or fill material. Many other statutes and policies are written to protect the marine environment. Agencies responsible for implementation may be the EPA, USACE, NRCS, NMFS, and USFWS.
	National Environmental Policy Act	1973	IFrom this point forward, the complex bay system is being monitored and studied to build an understanding of the dynamics assuring success in restoring and maintaining a healthy state. A plan written by the Port details efforts to prevent introduction of pollutants and to eliminate degradation of bay waters, sediments and biological resources. The Navy agrees to install a million-dollar treatment plant to eliminate outflow, due to open in 1972 (San Diego Union 1971). Complete tidal flushing in the south bay requires 7–14 days whereas the entrance of the bay may only require 1–2 days. It has been estimated that over the last century, tidal flushing has been reduced by 30% due to dredging and landfill projects (Brown and Speth, 1973). Inadequate tidal flushing can result in the loss of both saltmarsh cordgrass habitat and the invertebrates upon which light-footed clapper rails feed; adequate tidal flow also prevents stagnation of the salt marsh and maintains salinity levels of the soil and water.
	California Bays and Estuaries Policy	1974	From 1977 to 1985, documentation shows a distinct improvement in bay condition. In 1980, when flooding caused an unusual spillover of the lower Otay and Sweetwater dams, monitoring data provided a baseline for determining the effects of the increased sediment load. Currently, Navy ships are no longer required to keep fuel while in Port. They fuel on departure. Also, ships pump bilge into barges. Plans for a bilge only waste transportation system to be at every pier are being considered. Storm water runoff has become a big issue, with more than 200 storm drains emptying into the bay. The bay's response to storm water may be a temporary increase in levels of trash, turbidity, toxic and non toxic chemical counts and bacteria counts.
	California Coastal Act	1976	
	Eelgrass transplants begin in San Diego Bay	1976	
	Magnuson Fishery Conservation and Management Act	1976	
	Formation of Chula Vista Wildlife Reserve	1977	
	Copper ore spill	1979	

Table G-1. Ecological History of San Diego Bay.[a] (Continued)

	Flood	1980	
	Tijuana Estuary designated National Estuarine Sanctuary	1982	
	Endangered Species Act	1987	
	Seal commando operations took place at Coronado	1987	
	Convention Center completed	1990	
	South San Diego Bay Enhancement Plan completed by Port District and Coastal Conservancy	1990	
	USFWS begins study of 5200-acre wildlife refuge proposal for South Bay	1990	
	NMFS Habitat Conservation Policy	1990	
	NMFS, USFWS, CDFG Southern California Eelgrass Policy	1991	
	San Diego Area Contingency Plan	1993	
	State and Regional Watershed Management Initiative Began	1997	In 1997 The SWRCB and San Diego RWQCB began promoting the watershed protection approach through their state and regional plans. In 1998, the San Diego Bay Watershed Task Force was created as an outgrowth of the Bay Panel program by the BPC Chair. Also, in 1998, the SCB Regional Monitoring Program by the SCCWRP evaluated the water, sediment, and biota of SD Bay and other coastal waters. In 2001, the Municipal Stormwater Permit (Order No. 2001-01) was adopted by San Diego RWQCB. The Stormwater ordnance was also was also adopted by the City of San Diego to regulate new construction practices. In 2001, dredging began for a new intertidal mudflat and eelgrass enhancement site in the bay. The completed homeport Island accommodates the U.S. Navy CVN II carrier located near the NAB. In 2002, the first TMDL was adopted for San Diego Bay by the San Diego RWQCB. Also adopted was the Chollas Creek Enhancement Program by the San Diego City Council to aesthetically improve the creek and restore it to a natural setting.
	San Diego Bay Watershed Task Force was created. 1st San Diego County Watershed Leadership and Coordination Conference was held.	1998	
	Census	2000	The Storm Water Standards Manual by the City of San Diego provides information to applicants for project on how to comply with the permanent and construction storm water quality requirements for new development projects. In 2003, California SB 68 was passed directing the creation of the San Diego Bay Advisory Committee for Ecological Assessment (Environmental Committee), which was officially established in 2006. The committee provides funding and decision-making to select and execute projects aimed at improving the condition of the bay and tidelands. The Environmental Fund was established as a program focused on restoration efforts that are beyond compliance and mitigation. The five year trend assessment was repeated for the bay and other coastal waters by SCCWRP. In 2004, the San Diego Bay became one of four harbors to be evaluated for priority pollutants. Today, San Diego Bay is an agricultural trade center, a manufacturing trade center, a transportation hub, a base for fishing fleets, a base for military operations, a first port of call, a center of tourism and recreation, supports a diversity of marine life close to that originally noted in European settlement times, and home to over **three million people**.
	San Diego Bay INRMP completion	2000	
	Port of San Diego adopts a Stormwater Ordinance and Urban Runoff Action Plan	2000	
	Municipal Stormwater Permit for 18 cities, county and Port as co-permittees	2001	
	Stormwater Ordinance adopted by City of San Diego	2001	Adopted by City of San Diego to regulate new construction practices.
	Shipyard Sediment Cleanup Levels for NASSNO and Southwest Marine Shipyards	2001	
	Enhancement Homeport Island	2001	
	TMDL adopted for diazinon in Chollas Creek	2002	
	Chollas Creek Enhancement Program approved	2002	Adopted by San Diego City Council to aesthetically improve and restore the creek to a natural setting.
	San Diego Bay INRMP adoption	2002	
	Storm Water Standards Manual by City of San Diego	2002	
	SB 68 was passed- San Diego Bay Advisory Committee for Ecological Assessment	2003	SB 68 was signed into law, directing the creation of the Committee to conduct and independent assessment of conditions and trends in the bay's health and to issue a report to the legislature and other entities.
	SCB study repeated, including water quality and biotic data for San Diego Bay.	2003	
	An Ecological Assessment of San Diego Bay: A Component of the BIGHT '98 Survey	2003	
	San Diego Bay Watershed Urban Management Program	2003	

Table G-1. Ecological History of San Diego Bay.[a] (Continued)

	Stormwater Manual adopted by City of San Diego	2003	
	Regional Harbor Monitoring Program Begins	2004	San Diego Bay is one of four harbors to be evaluated for priority pollutants.
	SB 68 Report to Legislature	2005	Prepared by the San Diego Bay Advisory Committee for Ecological Assessment. Includes findings and recommendations.
	TDML adopted for dissolved copper in Shelter Island Yacht Basin	2005	Adopted by San Diego RWQCB
	Environmental Committee established by BPC	2006	Created to advise the Board on significant ecosystem and environment issues relating to San Diego Bay. Established an Environmental Fund of $3 million. Approved first projects at cost of $435,000.
	Otay Watershed Management Plan completed	2006	Created by a joint powers agreement among Port, County, and cities of San Diego, Chula Vista and Imperial Beach.
	Establishment of Port of San Diego Environmental Committee	2006	
	Establishment of UPSD Environmental Fund	2006	
	Executive Order by President Bush	2007	Sustainable environmental practices are required by federal agencies.
	State of the Bay - 2007 Report by the Port of San Diego released.	2007	Prepared by the Port to describe the condition of the Bay's water and sediment quality, natural resources, and habitat, as suggested in the INRMP.
	San Diego Integrated Regional Water Management Plan	2007	Prepared by the Regional Water Group and to be submitted for Proposition 50 funding.
	Environmental Committee of Port - Projects Funded	2007	Second round of projects funded.

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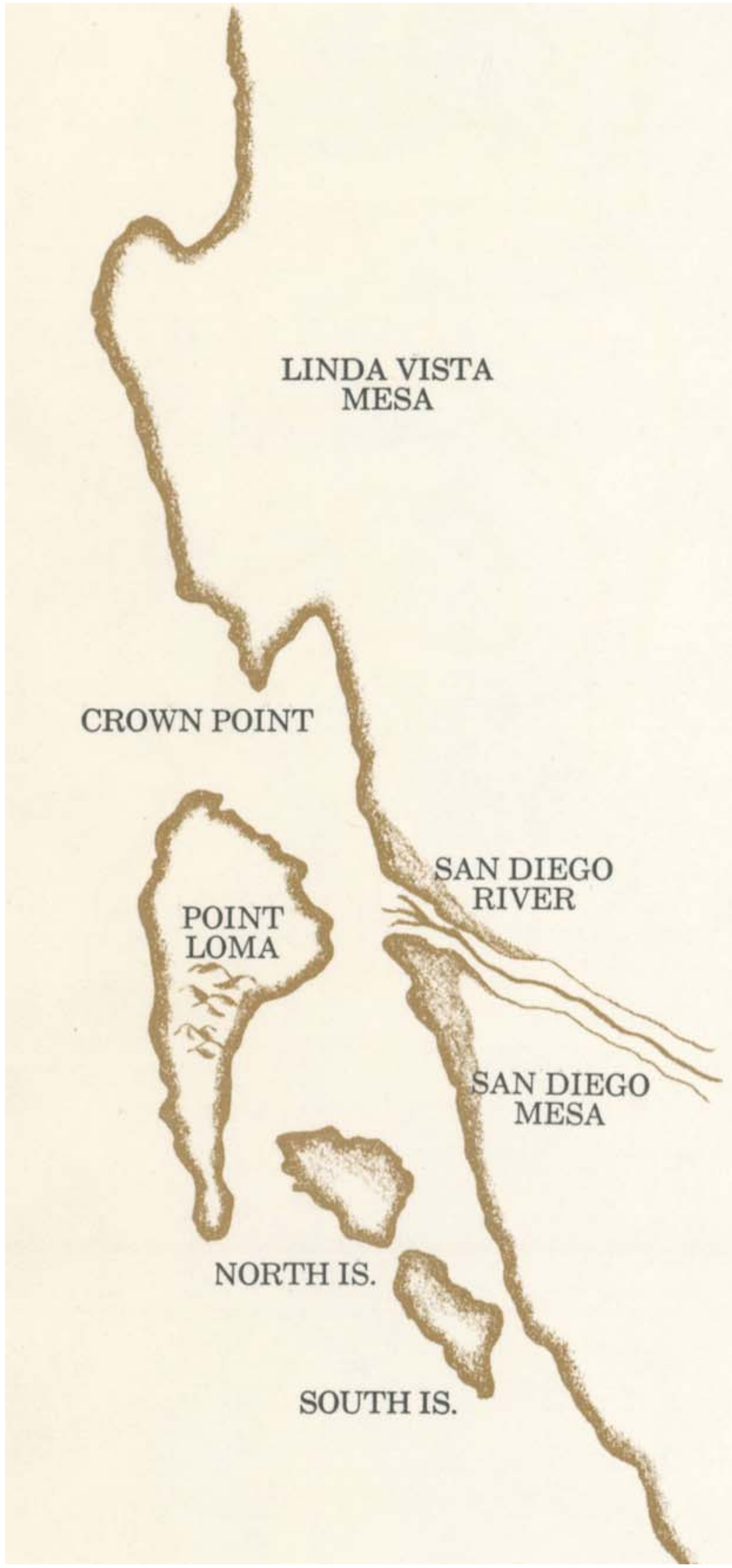
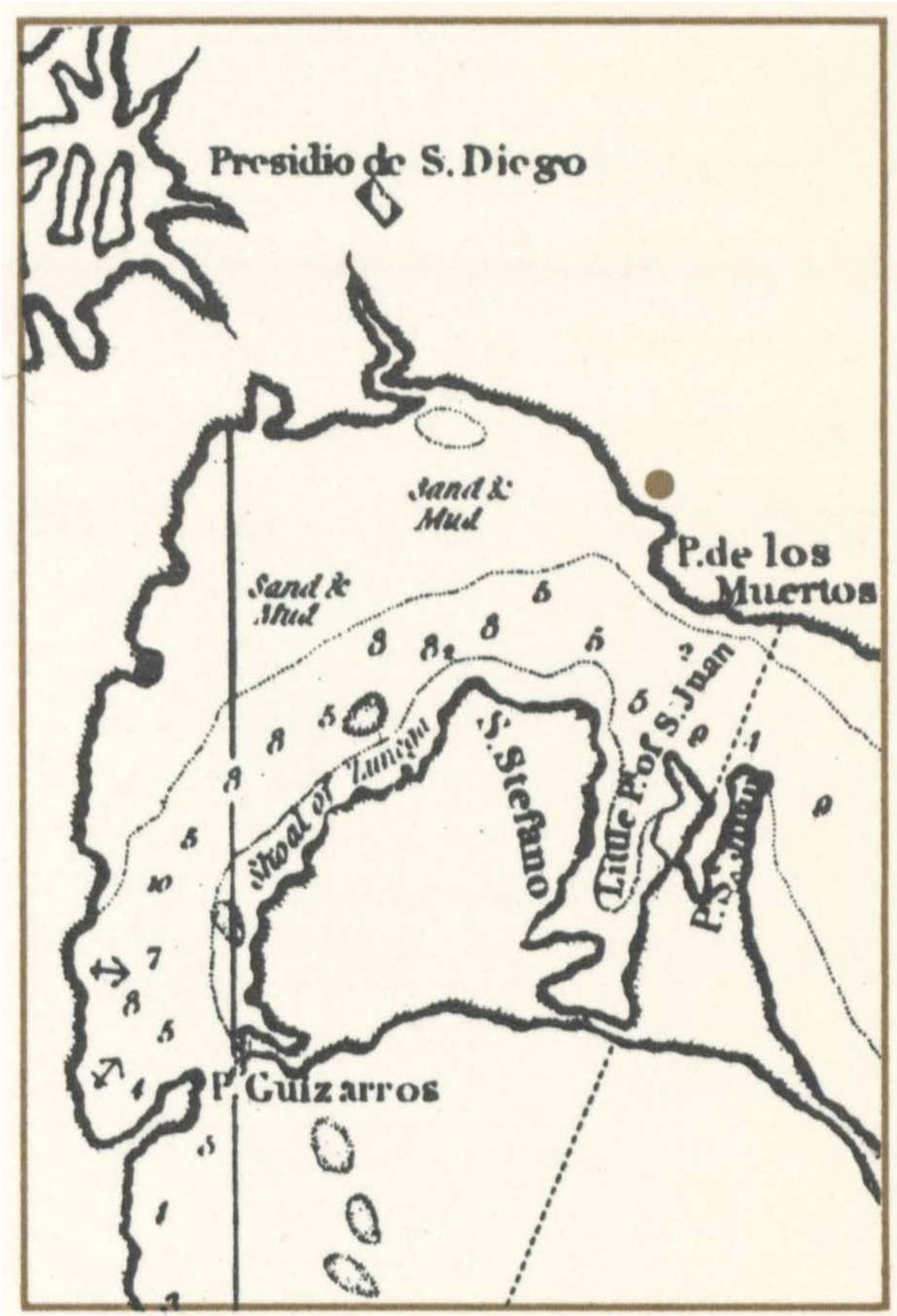
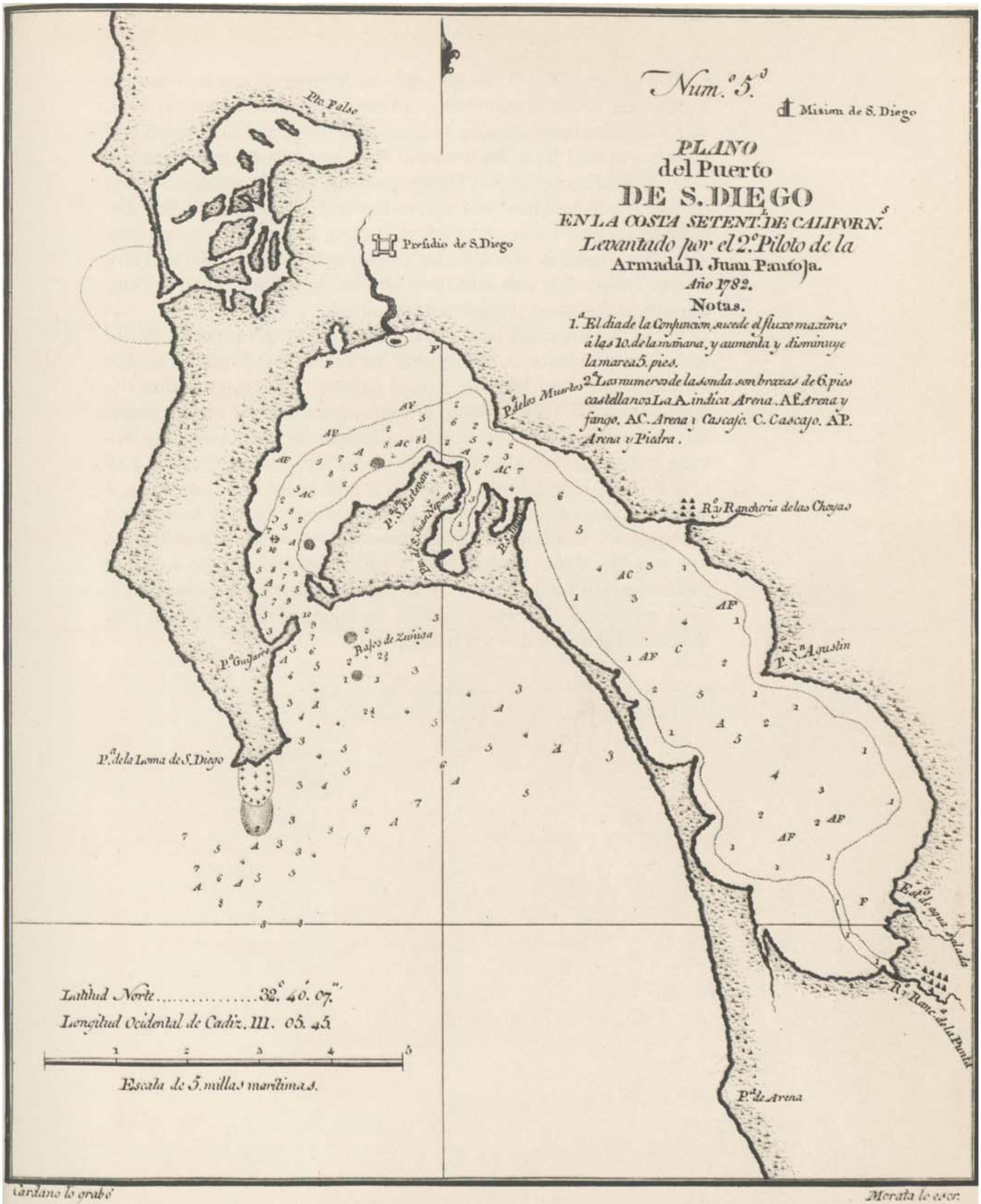


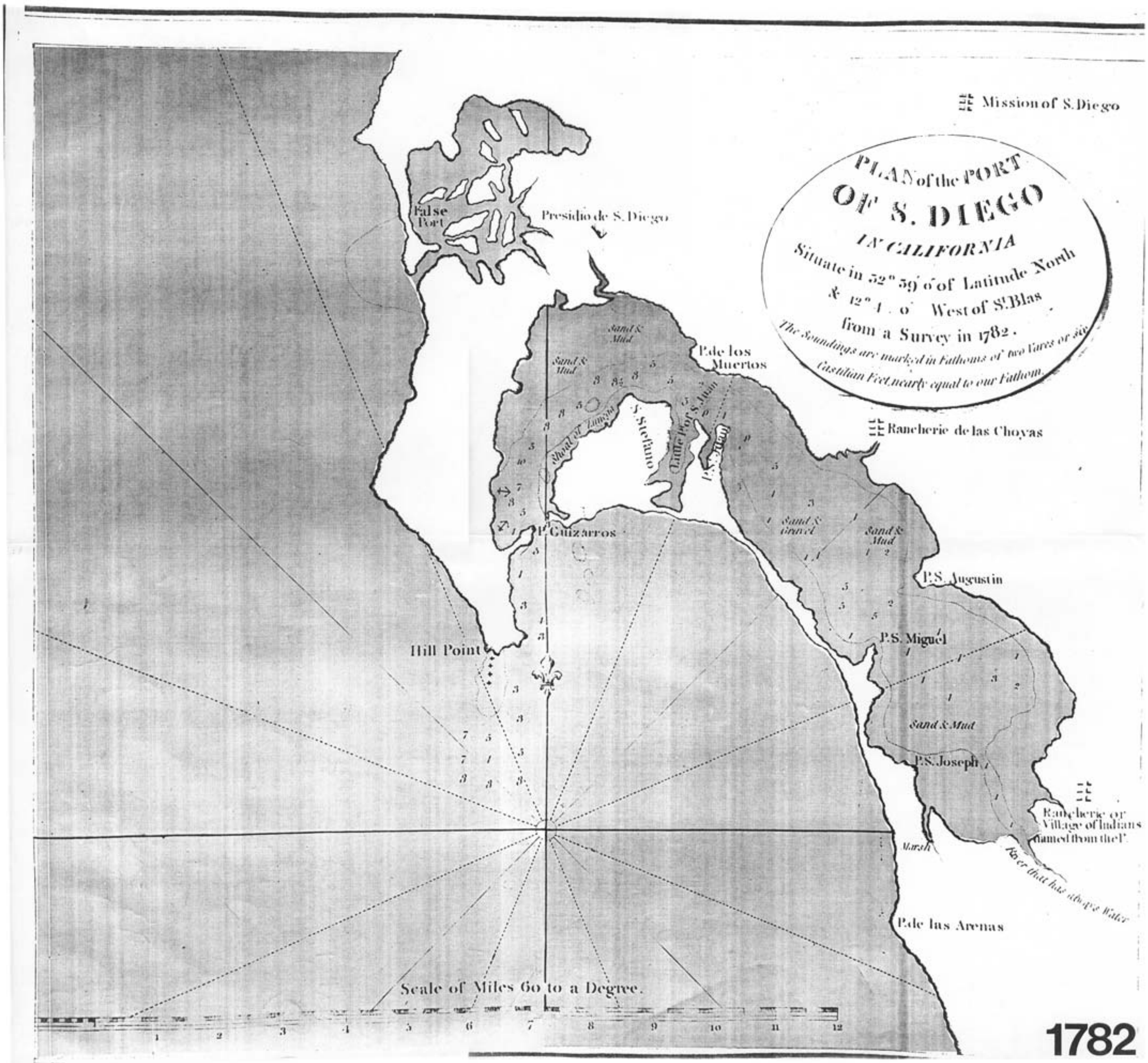
Map G-1. San Diego Ice Age.



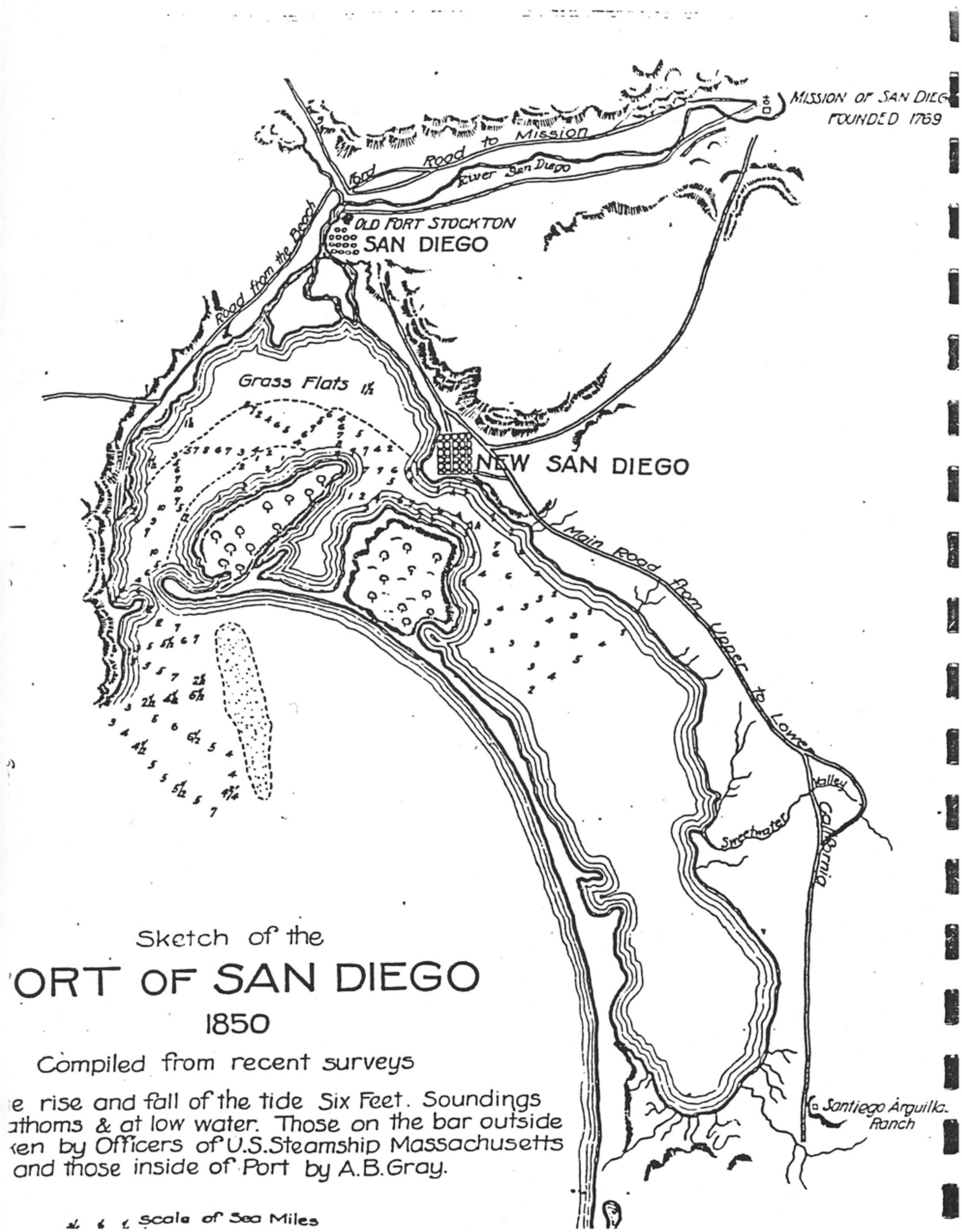
Map G-2. Presidio de San Diego. 1782 San Diego Bay Map.



Map G-3. 1782 San Diego Bay Map.

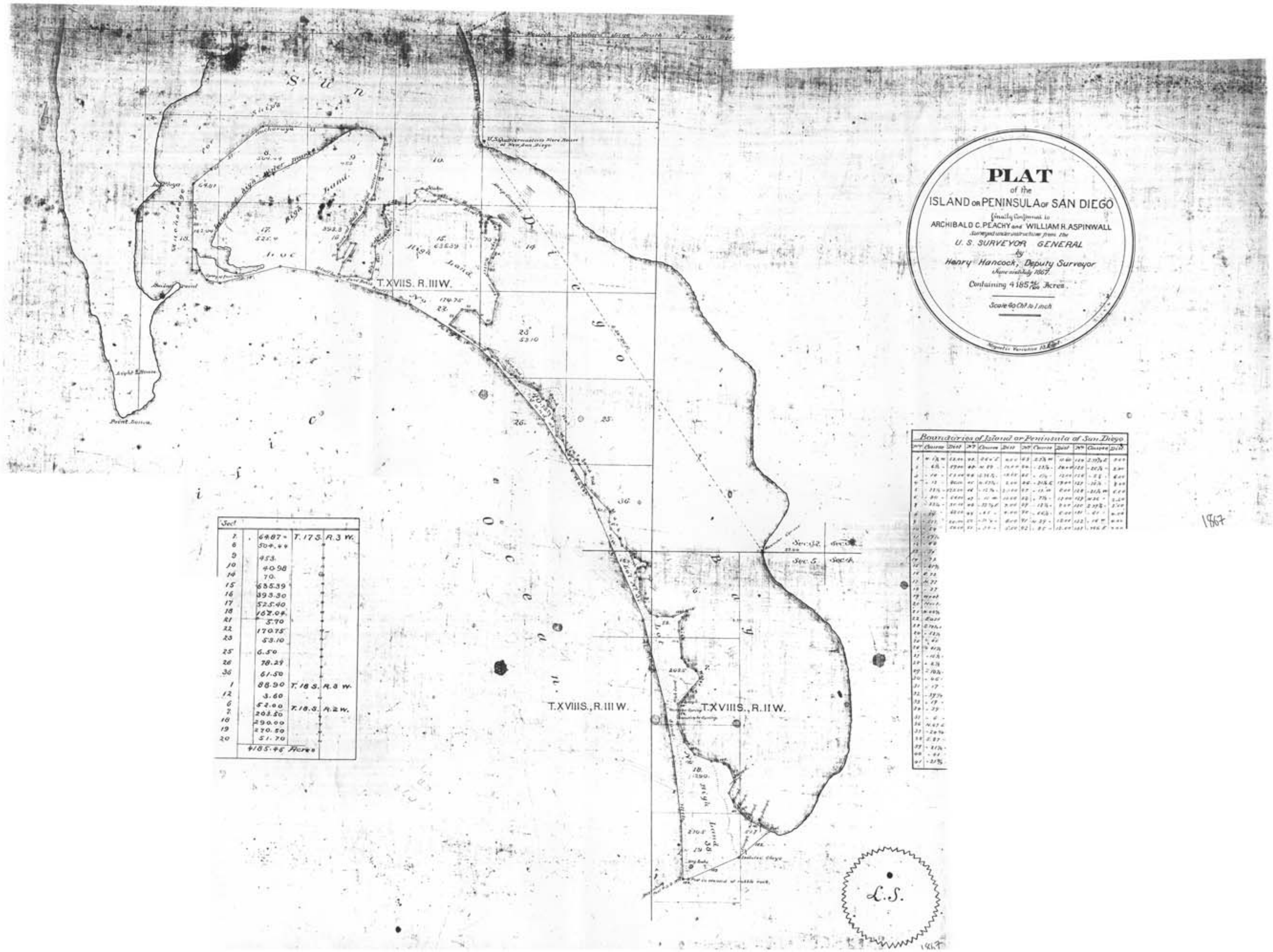


Map G-4. 1782 Port Plan of San Diego.

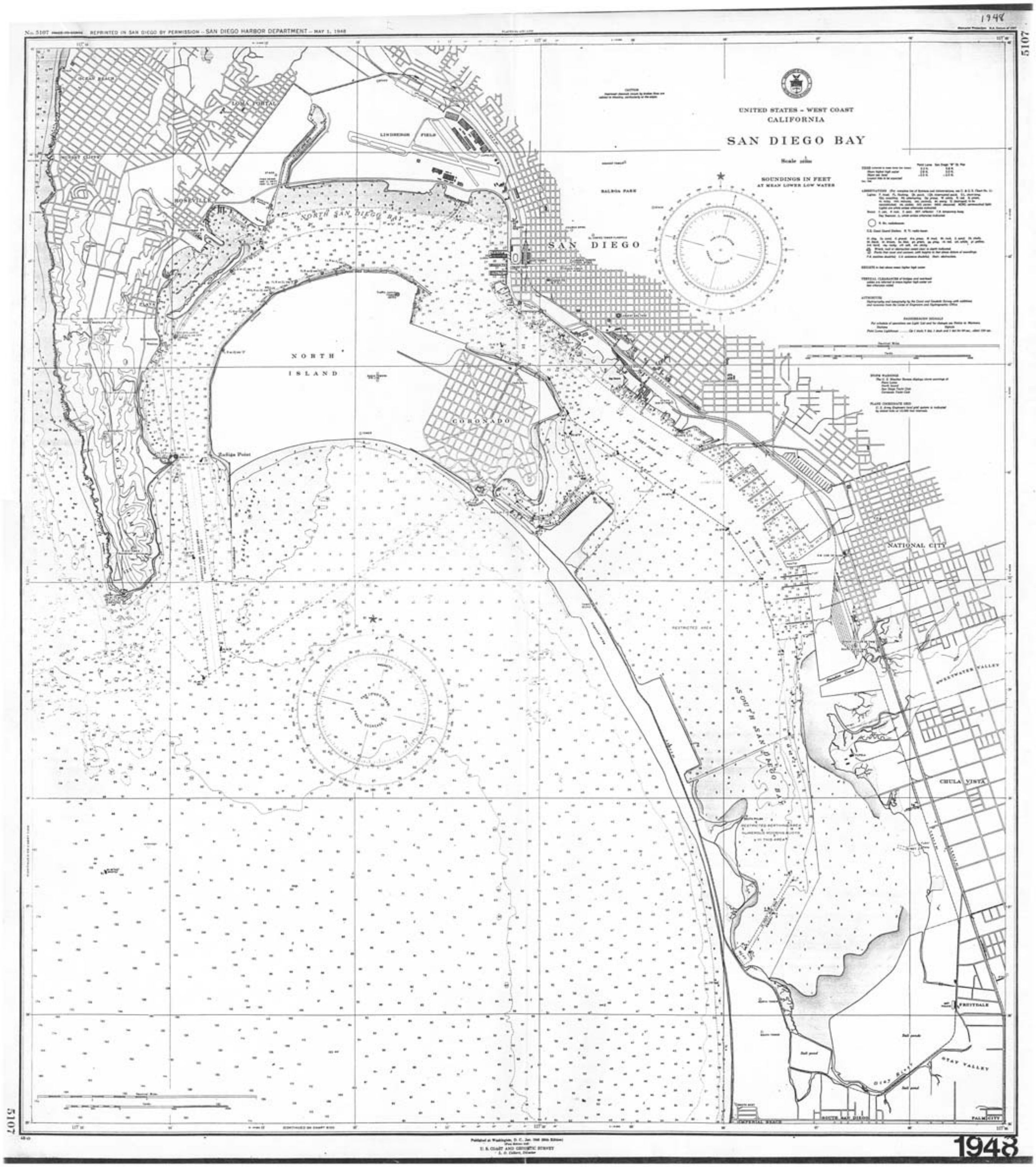


Map G-5. 1850 Port of San Diego sketch.

Map G-6. 1850 Port of San Diego sketch.



Map G-7. 1867 Plat map of San Diego Bay.



Map G-8. 1948 Map of San Diego Bay.

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