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Assessment of Coastal Water Resources and Watershed Conditions at Olympic National Park, Washington

Natural Resource Report NPS/NRPC/WRD/NRTR—2008/068

ON THE COVER
Upper left, First Beach, Photograph by Kristen Keteles
Upper right, Rialto Beach, Photograph by Kristen Keteles
Lower left, Second Beach, Photograph by Kristen Keteles
Lower right, Second Beach, Photograph by Kristen Keteles

Assessment of Coastal Water Resources and Watershed Conditions at Olympic National Park, Washington

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Acronyms & Abbreviations

ACOE	Army Corps of Engineers
ASP	Amnesic Shellfish Poisoning
ATBA	Area to be Avoided
BEACH	Beach Environmental Assessment Community and Health Program
BEACON	Beach Advisory and Closing Online Notification Program
BWTF	The Surfrider Foundation's Blue Water Task Force
C&S	Tribal Ceremonial and Subsistence (use)
COASST	Coastal Observation and Seabird Survey Team
CIG	Climate Impacts Group
CSL	Washington State Sediment Cleanup Screening Level
DA	Domoic Acid
DDT	Dichloro-Diphenyl-Trichloroethane
DG	Data Gap
ECOHAB	Ecology and Oceanography of Harmful Algal Blooms
EMAP	EPA's Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
ERL	NOAA Effects Range Low
ERM	NOAA Effects Range Median
FDA	United States Food and Drug Administration
FIPS	Federal Information Processing Standard
GIS	Geographic Information System
HAB	Harmful Algal Bloom
HPAH	High molecular weight PAH
IMO	International Maritime Organization
LPAH	Low molecular weight PAH
LWD	Large Woody Debris
MCWG	Marine Conservation Working Group
NANOOS	Northwest Association of Networked Ocean Observing Systems
NCCOS	National Center for Coastal Ocean Science
NIX	Nuclear Inclusion X
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRDC	National Resources Defense Council
NWFSC	Northwest Fisheries Science Center (NOAA)
OCNMS	Olympic Coast National Marine Sanctuary
OLYM	Olympic National Park
ORHAB	Olympic Region Harmful Algal Bloom Partnership
PAH	Polycyclic aromatic hydrocarbon
PAR	Photosynthetically Active Radiation
PBDE	Polybrominated Diphenyl Ethers
PCB	Polychlorinated biphenyls
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
PSP	Paralytic Shellfish Poisoning
RL	Reporting Limit

SQS	Washington State Sediment Quality Standard
STORET	Environmental Protection Agency's STOrage and RETrieval database for water quality, biological, and physical data sets contributed by state environmental agencies, EPA and other federal agencies, universities, private citizens, and others.
SW	
TMDL	Total Maximum Daily Loads
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USGS	U.S. Geological Survey
UW	University of Washington
WAU	Watershed Administrative Unit
WDOE	Washington Department of Ecology
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WINWR	Washington Islands National Wildlife Refuge
WRD	Water Resources Division
WRIA	Water Resources Inventory Area
WSCC	Washington State Conservation Commission
WSTMP	Washington State Toxics Monitoring Program
U&A	Tribal Usual and Accustomed (fishing area)

Executive Summary

The purpose of this report is to provide a better understanding of the coastal water resources and watershed conditions within the coastal strip of Olympic National Park (OLYM). To accomplish this task we review the existing literature and summarize what is known about the current condition of the coastal water resources of the coastal strip and the degree to which they may be affected by natural and anthropogenic factors. As a result, this report provides both a status report on water resource conditions as well as an assessment of the present state of knowledge pertaining to known environmental indicators and stressors. We further identify information gaps, topics where data are sparse and inadequate to fully assess resource condition, and make recommendations to fill information gaps necessary to support resource management. While the focus of this effort is on coastal resources within the coastal strip of OLYM, watershed conditions and surface and groundwater in the adjacent watersheds are also considered to a limited extent.

The current condition of the water-related coastal resources at OLYM is based upon an assessment of common ecological indicators and stressors including water quality (e.g., nutrients, dissolved oxygen, fecal bacteria, metals, and toxic contaminants), land use (e.g., timber practices, coastal development), habitat modification (e.g., coastal erosion), commercial and recreational use (e.g., fishing, shellfish harvesting, collection of marine organisms), and other concerns, such as the introduction of non-native and invasive species, harmful algal blooms, and oil and fuel spills.

In Section A, we begin by describing the remote coastal watersheds, coastlines, and offshore islands that characterize OLYM's marine waters as being one of the most relatively undisturbed coastal regions in the continental United States. In 1938, the entirety of OLYM was placed under the administration of the National Park Service, and has since been designated as an International Biosphere Reserve and World Heritage Site. The coastal strip was added to the park in 1953, and in 1988, much of the strip was designated as wilderness. This assessment focuses on the Pacific coastal portion of OLYM, including several watersheds and rivers.

We review the site history and human utilization of the region in Section A. Native Americans settled the west coast of the Olympic Peninsula more than 10,000 years ago. European settlement began in the mid-1850s, encouraged by the 1846 signing of a boundary treaty with Great Britain (Lavender 1956). We document the long and complex history of preserving the outer coast of OLYM with respect to its importance in understanding management of coastal water resources. Management of coastal areas within OLYM has been protection-oriented. The coastal region is under a variety of jurisdictions, including federal, tribal, state, and local. OLYM managers work with surrounding landowners – tribes, private, and state and other federal public land managers – to ensure protection of park lands and resources. The management of fisheries and other living marine organisms for the intertidal and subtidal areas is achieved through cooperation between OLYM and the state and tribal co-managers, Washington Department of Natural Resources, as well as federal managers including the National Marine Fisheries Service and the Pacific Fishery Management Council.

The coastal region that influences OLYM is part of an eastern boundary current system. Eastern boundary currents tend to be shallow, narrow, and rich in mesoscale eddy features. In the region of OLYM, the prevailing system of currents includes the California Current, flowing southward; the Davidson Current, flowing northward in the winter; and the California Undercurrent, flowing northward at intermediate depth. These currents can create complex eddy fields, as well as upwelling and downwelling patterns. The Columbia River Plume seasonally influences coastal regions of OLYM, as do river and sediment flow from the larger rivers on the western slope of the Olympic Mountains. Coastal circulation is also dominated by wind forcing. Equatorward winds drive upwelling from depths of about 200 meters in areas close to the coast, resulting in higher productivity and cooler water along the coastal margin. The strength of such physical forcing varies both seasonally and latitudinally. In addition, topographic features such as submarine canyons influence circulation; in the OLYM region, the Juan de Fuca and Quinault Canyons likely enhance upwelling and may increase local retention.

The temperate onshore winds that drive much of ocean circulation carry substantial amounts of moisture onto the Olympic Peninsula, and the rapid uplift and cooling cause precipitation that produces the famous rainforests of OLYM and maintain significant runs of salmon. More than 70 stocks of salmonids have been identified within park boundaries.

Marine intertidal habitats within OLYM are physically complex, consisting of bedrock, cobble, and sand beaches, as well as small estuaries. The benthic communities that occupy these areas are biologically rich. Important linkages exist between nearshore and offshore areas. Large colonies of nesting seabirds and various species of marine mammals can be found in offshore areas on a seasonal or year-round basis.

With respect to marine water quality, it is apparent that there is a lack of consistent sampling and analysis over time on OLYM's outer coast. We reviewed existing data for bacterial contamination, contaminants, and marine biotoxins/harmful algal blooms. In no case was sampling adequate to provide a reliable baseline for detection of temporal trends. The intermittent point sampling that does exist seems to indicate that water quality is relatively high; however, some water quality standards have been exceeded for various parameters in some places at some times. Therefore, water quality problems may exist but remain undetected due to limited sampling.

The status and trends in water quality among coastal freshwater bodies is equally difficult to establish because of limited sampling. Efforts to systematically rate habitat quality in watersheds that contain spawning salmon provide the best indication of the condition of freshwater resources in coastal areas. The condition of freshwater resources differs among rivers and river reaches depending on the amount of landscape alteration (e.g., land clearing, timber harvest). Freshwater resources typically are in the best condition in areas least affected by landscape alteration. Loss of large woody debris (LWD) in some watersheds is significant. Changes in land use also affect the deposition of LWD on ocean beaches with unknown consequences to nearshore systems. Some watersheds in the region have been rated as temperature impaired relative to Environmental Protection Agency (EPA) standards.

Because there is little commercial or industrial activity near OLYM, there are relatively few point source wastewater discharges. Those that do exist consist of discharges from sewage treatment plants, campgrounds and administrative areas, fish processing facilities, and lodging facilities. Highway and road runoff are a source of non-point source pollution in coastal areas, but this has not been measured in OLYM.

Other areas of concern include harmful algal blooms, non-native and invasive species, harvest and collection of organisms, aquaculture, shoreline development, recreation, habitat modification, coastal erosion, marine debris, fuel and oil spills, land use practices, tsunamis and sea level rise, and climate change.

Harmful algal blooms (HABs) are known to occur off the outer coast and are often produced by phytoplankton that can cause paralytic shellfish poisoning or domoic acid poisoning. The potential health impacts of HABs in commercially- and recreationally-harvested shellfish have motivated monitoring and research activities throughout the region.

OLYM nearshore and intertidal areas were surveyed in a rapid assessment for non-indigenous and invasive organisms in 2001 and 2002 with preliminary results showing 11 non-indigenous and 13 cryptogenic species. From 2001 to 2005, the Olympic Coast National Marine Sanctuary (OCNMS) conducted monitoring for the presence of the European green crab (*Carcinus maenas*); species abundance is below a level at which ecological impact can be measured. OLYM's proximity to the busy shipping lanes of the Straits of Juan de Fuca, however, may pose a threat via the introduction of non-native species by ballast water. Non-native fish and plant species have also been found in Lake Ozette and the Ozette River.

Harvesting and collection of marine organisms occurs in the legal prosecution of co-managed commercial and sports fisheries, in casual collections made by visitors, and, to an unknown extent, from illegal and unreported removals. A few sportfishing charters operate out of La Push, and guided fishing trips for steelhead and salmon occur in the larger rivers. Due to the relatively difficult access to much of the coastal and river areas, recreational harvesting tends to be concentrated in the most accessible areas. However, visitors are frequently unaware of OLYM and other applicable rules and regulations, and enforcement is limited. In addition, little systematic monitoring of harvesting and collection takes place in the region. Besides recreational collection, trampling can also affect intertidal organisms; it can cause direct mortality of the organisms or dislodge them, cause structural damage to algae and animals, or result in the loss of habitat. In addition, recreational activities may result in pollution, the accidental introduction of non-native species, disruption of wildlife behavior, and habitat degradation.

Shellfish and finfish aquaculture occurs in areas outside OLYM boundaries. At current levels, these practices are unlikely to significantly and negatively affect coastal water resources in OLYM; however, the proposed expansion of aquaculture in offshore regions could potentially confer additional risk to coastal resources.

Shoreline development and habitat modification are relatively minor compared with other parts of the state and nation. The primary development is U.S. Highway 101, which runs along, and inland from, the coast. Tourist facilities, campgrounds, and small resorts exist in Kalaloch, La

Push, Mora, and Ozette, and there are scattered residential properties, especially along Lake Ozette. Shorelines are relatively unarmored and unmodified in comparison to shorelines in other areas of the state. Road culverts and some riprap exist on some roads along major rivers in the region, including on the Hoh River and its tributaries where modifications have reduced access to the floodplain, and reduced spawning and rearing habitat for fish. In addition, some modest farming and residential uses have modified riparian habitats while large-scale habitat alteration has occurred in logged areas. Other land use practices, especially those associated with timber harvest, have the potential to impact coastal water resource condition and water quality. For example, road construction and pesticide application in the logging industry have been shown to affect water quality.

Coastal erosion and accretion rates in the region are generally moderate. A USGS survey found that Shi Shi Beach, Ruby Beach, and Rialto Beach were the areas most susceptible to sea level rise. The entire coastal strip is vulnerable to tsunamis generated by earthquakes on the Cascadia Subduction Zone.

Marine debris accumulates on beaches along the length of OLYM, although the source of most of the debris is not local. Annual beach cleanups seek to reduce the debris and potential impacts on marine wildlife and aesthetics. The amount of debris removed during these cleanups suggests that the supply of debris to the coastal strip is substantial and persistent.

Oil and fuel spills pose a chronic low-level threat to OLYM despite efforts to regulate marine transportation by encouraging large ships to transit outside of OCNMS boundaries. Previous spills from the *Nestucca* in 1988 and the *Tenyo Maru* in 1991 resulted in oiled shores within OLYM boundaries.

Biologically significant changes in ocean productivity associated with changes in wind forcing and upwelling can affect seabirds, fish, and other components of the ecosystem. Climate change will likely cause sea level rise, influence storm strength and frequency, increase erosion, and cause changes in water temperature, hydrology, glacier melt, and stream flow, all of which will affect OLYM's living resources.

Based on information currently available, and recognizing the limitations of the data, we summarize the condition of water resources in the coastal strip of OLYM in Table i.

Table i. Condition of water resources in OLYM.

Stressor/ Environmental Indicator	**Lake Ozette**	**Coastal River Drainages***	**Marine Waters**
WATER QUALITY INDICATOR			
Nutrients	ID	ID	OK
Dissolved Oxygen	ID	IP	IP
Fecal Bacteria	ID	ID	IP
Metals	ID	ID	ID
Contaminants/Toxicants	PP	PP	OK
LAND-USE RELATED STRESSORS			
Sedimentation	EP	EP	EP
Septic / Wastewater	ID	PP	PP
Stormwater Runoff	PP	IP	PP
Pesticides	PP	PP	PP
HABITAT MODIFICATION			
Coastal and Marine Habitat Modification	NA	NA	OK
Upland Habitat Modification/Land Use	EP	EP	EP
OTHER STRESSORS/ INDICATORS			
Non-Native Invasive Species	EP	EP	PP
Harmful Algal Blooms	OK	OK	IP
Fuel / Oil Spills	NA	OK	PP

Legend:
EP = existing problem; PP = potential problem; IP = intermittent problem; OK = no detectable problem; ID = insufficient data to evaluate; NA = not applicable
*Sooes, Ozette, Quillayute, and Hoh River drainages, coastal portions only

Based on our review and assessment of water resource condition and threats in coastal areas of OLYM, we offer the following recommendations.

Table ii. Recommendations

- Develop and implement a water quality monitoring program for coastal streams and estuaries. Parameters could include (at a minimum) water temperature, dissolved oxygen, and sediment load. Parameters could be expanded to include nutrients, PCBs, and PAHs.
- Integrate inventory and monitoring activities into natural resources planning and management processes.
- Manage stormwater runoff to reduce impacts to riparian and nearshore environments.
- Measure the amounts of toxins and contaminants introduced to coastal streams and rivers and to beach areas by surface water flow from primary and secondary roadways and parking areas. Determine whether toxins and contaminants from roadway sources impair water resources in OLYM.
- Continue to develop and implement protections for marine intertidal areas.
- Manage shoreline erosion in vulnerable areas, especially around Mora and Kalaloch.
- Pursue opportunities to reduce degradation in Lake Ozette, for example by acquisition of key watershed parcels.
- Develop a plan for managing non-indigenous marine and estuarine species.
- Partner with watershed groups in WRIAs 20 and 21 and continue to partner with coastal tribes to restore impaired stream habitats in coastal areas. Protect and restore sensitive shoreline areas that provide essential fish habitat.
- Partner with OCNMS and others (e.g., ORHAB; ECOHAB) to monitor coastal water conditions. Track development and implementation of NOAA’s Ocean Observing System via NANOOS (Northwest Association of Networked Ocean Observing Systems).
- Track NOAA’s planned project for Biogeographic Assessment of Living Marine and Cultural Resources of the OCNMS. Identify shoreline resources within OLYM that could be included in the Biogeographic Assessment of OCNMS.
- Track the OCNMS Management Plan Review Process. Identify synergies between OCNMS and OLYM planning and management, and provide input to the OCNMS planning process where appropriate.
- Track revisions to the State of Washington’s Oil Spill Contingency Plan rule. Consider whether the definition of sensitive areas under the Contingency Plan rule could be expanded to include shoreline areas of OLYM beyond National Wildlife Refuge sites.
- Continue to participate in the annual Olympic Coast Cleanup to remove marine debris from beaches.

A. Park and Regional Description

A.1. Background

This section provides an overview of the location of OLYM, describes its general features, reviews the history of the site, and covers human uses of the area through time.

A.1.a Olympic National Park Regional Description

Olympic National Park (OLYM) occupies much of the Pacific coastline, offshore rocks and islands, interior forests, and mountains on the Olympic Peninsula in northwestern Washington State (Figure 1). The park preserves a wide range of floral and faunal diversity distributed among coastal habitats, temperate rainforests, and the Olympic Mountains. Here we describe and assess the coastal water resources of OLYM and the factors that influence them. We restrict our assessment to coastal areas of OLYM that lie within the coastal strip of the park (Figure 1), and to the islands immediately offshore.

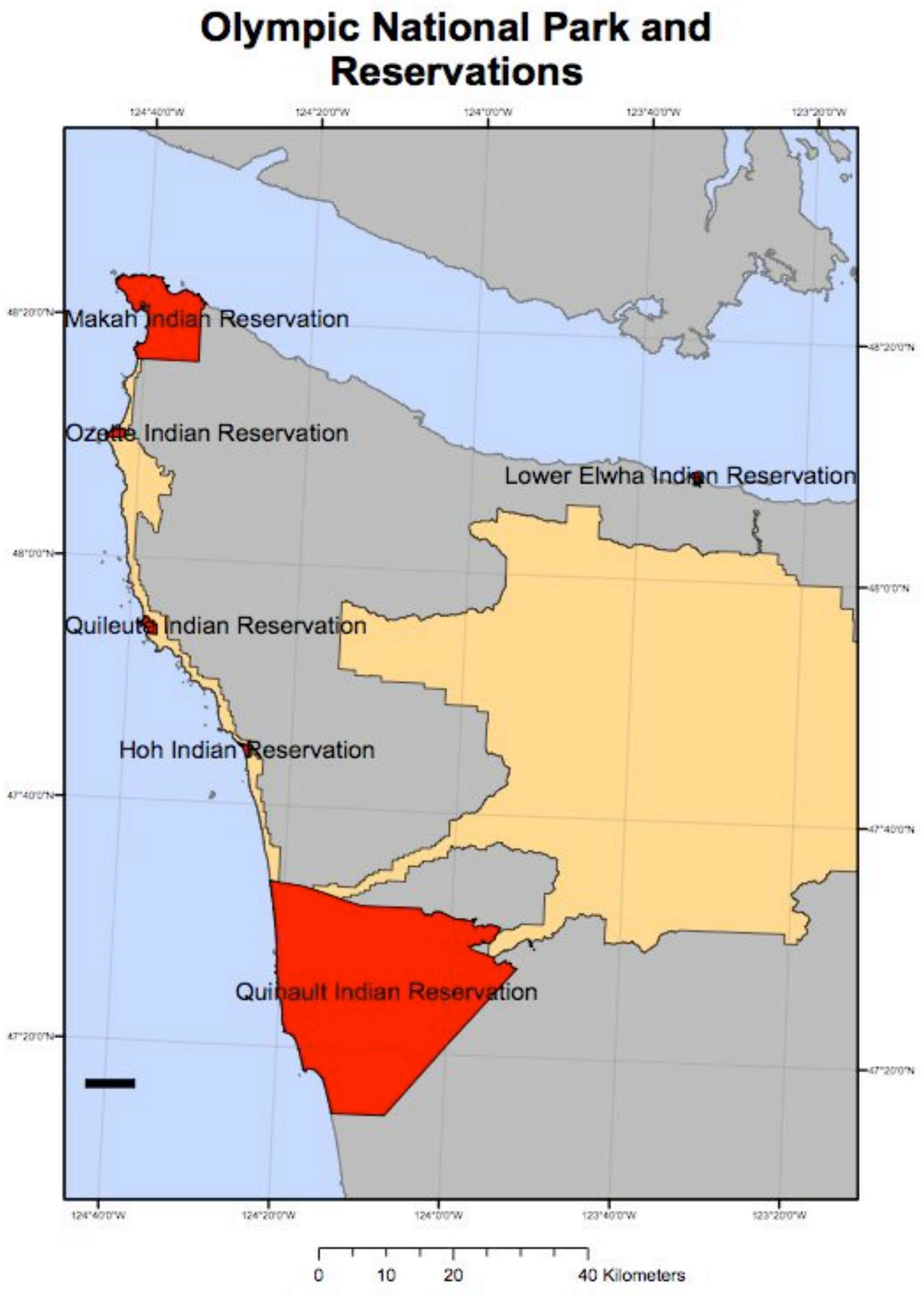

Figure 1. Regional setting of OLYM, showing the main body of the park (yellow, center right), the coastal strip (yellow, left), and tribal reservations (map created by authors).

Geologically, the Olympic Mountains are very young, the result of subduction of the Juan de Fuca plate beneath the North American plate beginning about 35 million years ago (Pendleton *et al*. 2004). The resultant landscape is young and geomorphologically variable, having been further modified by ice during the Pleistocene glaciations. The

Fraser Glaciation occupied much of the northeastern and mountainous parts of the Park from about 21,000 to 10,000 years B.P. but did not cover the west coast lowlands, creating a glacial refugium (NPS 2006a). [Note that during the Pleistocene era, sea level was approximately 300 feet lower than today]. In the current era, glaciers contribute substantially to flow in coastal rivers such as the Hoh and Bogachiel during the late summer and early fall. Throughout the region, heavy rains fall in late autumn through spring. The steep slopes of the Olympic Mountains combine with the heavy onshore flow of moist air from the Pacific to produce a local climate along the coastal strip that is extremely wet. Precipitation averages more 100 inches per year at the coast, 142 inches at the Hoh Ranger Station, and considerably more in the headwaters of the coastal rivers (Fagerlund 1965).

The marine biota of coastal OLYM is diverse. Intertidal communities are especially rich, with more than 350 species of invertebrates and algae distributed among rock, cobble, and sandy habitats. Numerous species of birds and mammals occupy the area either year-round or seasonally. Nesting colonies of some species of seabirds are the largest in the continental United States. Several species of birds and mammals are species of concern. Three bird species that occur on or adjacent to the coastal strip are listed as endangered under the federal Endangered Species Act: the brown pelican (*Pelecanus occidentalis*), marbled murrelet (*Brachyramphus marmoratus*), and bald eagle (*Haliaeetus leucocephalus*). The Ozette stock of salmon is listed as threatened under the Endangered Species Act. Six species of birds and mammals are listed in Washington State's Priority Habitats and Species Program categories: Brandt's cormorant (*Phalacrocorax penicillatus*), Cassin's auklet (*Ptychoramphus aleuticus*), common murre (*Uria aalge)*, peregrine falcon (*Falco peregrinus*), tufted puffin (*Fratercula cirrhata*), and sea otter (*Enhydra lutris*). The Steller sea lion (*Eumetopius jubatus*) is listed as threatened under both federal and state categories as well.

A.1.b. Site History

Proposals to designate OLYM were made as early as 1890 and continued into the early 1900s. Most of the area in the present-day OLYM was part of the National Forest Reserve established in 1897 by President Cleveland. In 1909, President T.R. Roosevelt designated Olympic National Monument under management by the U.S. Forest Service until 1933. Reorganization under President F.D. Roosevelt subsequently placed the administration of Olympic National Monument under the National Park Service (NPS) (NPS 2006b). Congress established OLYM in 1938 after a contentious debate among resource users and early conservationists who variously advocated forest protection, protection of the Roosevelt elk, and preservation of scenic areas over maximization of timber production (Lien 1991). Considerable interest was expressed for setting aside the undeveloped Olympic coastal areas but this was not the driver behind Congressional action. The stated purpose for OLYM was "for the benefit and enjoyment of the people" (US Statutes At Large, Vol. 52:1241). In 1976, the United Nations designated OLYM as an International Biosphere Reserve and as a World Heritage Site in 1981 (OLYM 1992).

Initially, the intent had been to designate a significant portion of the outer coast of the Olympic Peninsula as part of the park but those proposals were limited by Congressional restrictions on park size. In the meantime, support for the coastal additions came from both those who wanted to preserve the area and those who wanted to develop a scenic road along the coast to promote tourism (Lien 1991). The coastal strip was added to OLYM in 1953 by Executive Order of President Truman (NPS 2006b), but the approach to management remained unspecified. Historic outings led by Supreme Court Justice William O. Douglas brought pressure to bear on maintaining the coastal strip as a roadless area. In 1976, Congress added seven miles of coast and uplands to OLYM in the area north of the Ozette River to Shi Shi Beach and including the Point of Arches, with the objective of maintaining the wilderness character of the area. Congress again acted in 1986 (Public Law 99-635:Nov 7, 1986) to add the Quillayute Needles and Flattery Rocks to OLYM as well as most of the area surrounding Lake Ozette that until then had been an enclave within OLYM owned mostly by Washington State. In the 1986 act, adjustments were also made to place OLYM and Olympic National Forest boundaries along hydrographic divides (Soest 1998). This act also included the transfer of intertidal lands from Washington State to the NPS and included two specific covenants: 1) the property shall continue to be open to fishing and the taking of shellfish; and 2) the NPS shall consult with Washington State prior to any changes in regulations or management policies. It should be noted that the terrestrial portion of offshore rocks and islands (above mean high water) in the area added to OLYM remains under the jurisdiction of the U.S. Fish and Wildlife Service (Lien 1991). The intertidal zone within these areas is within the jurisdiction of OLYM. In 1988, much of the coastal strip was designated Wilderness.

While the boundaries on land were slowly rationalized, the seaward boundary for OLYM ended at mean high water. The intertidal zone remained under state ownership and was administered by the Washington Department of Natural Resources (WDNR). It was not until the 1988 Washington Parks Wilderness Act that Congress authorized the NPS to use appropriated funds to purchase lands to exchange with Washington State to gain title to the intertidal zone along the Pacific Coast (Dyer 1998).

A.1.c. Human Utilization

Archeological research indicates a very complex and sophisticated cultural history for the coastal region that now comprises OLYM, and the park is embedded within a patchwork of Native American, federal, state, and private land ownership. Native American tribal reservations of the Makah, Quileute, Hoh and Quinault border OLYM. These tribes and nations maintain legal Treaty rights dating from 1855 and are the legal co-managers of fisheries. Olympic National Forest is the primary federal landowner outside OLYM. WDNR is the primary state landholder in areas adjacent to OLYM; commercial timber companies own other adjacent land. The OLYM coastal strip and offshore islands consist of approximately 43,000 acres of estuaries, headlands, rocky, cobbled and sandy intertidal areas. Park jurisdiction extends to the extreme low tide line in the coastal strip. The coastal strip is bordered by state waters (from 0-3 nautical miles) and by the Olympic Coast National Marine Sanctuary (OCNMS), with boundaries extending as much as 40 nautical miles offshore. Intertidal areas of the Washington Islands National Wildlife Refuge (WINWR) lie within OLYM, with emergent portions of rocks, sea stacks and islands (those above the intertidal zone) remaining under the jurisdiction of the U.S. Fish and Wildlife Service.

Native Americans have occupied coastal areas of OLYM for as much as 10,000 years (NPS 2006c), living on fish, shellfish, seals and whales, as well as terrestrial flora and fauna. The coastal tribes of the Makah, Quileute, Hoh and Quinault are the keepers of tribal traditions and occupy the remnants of tribal lands on reservations. The early peoples of the Pacific Northwest at one time constituted some of the densest settlements in North and South America (Ames and Maschner 1999). Those who later came in the "White Drifting Ships" (Quileute Tribe, http://www.quileutetribe.org) admired the adaptations made by the coastal tribes. In fact, until the introduction of horses in the Pacific Northwest after 1680, the pandemic of European diseases in the region about 1775, and the arrival of fur hunters and trading in the 1820s-1830s, native peoples appear to have maintained a remarkably consistent subsistence and barter existence (Ames and Maschner 1999).

European exploration may have come as early as 1592 by Juan de Fuca but is clearly documented in the ship logs of Juan Perez (1774), Bruno Heceta (1775), James Cook (1778), Manuel Quimper (1790), and from a fort built by Salvador Fidalgo at Neah Bay in 1792. More detailed exploration took place at the beginning of the 1800s by Gray and Vancouver (NPS 2006b). A key resource sought by early explorers and traders was the high-value pelt of the sea otter. Other resources such as fresh water, firewood and dried salmon were taken for provisions. Decline in abundance of sea otters, changing tastes in fashion, and conflicts between the United States and Britain discouraged settlement in the region for a period (OLYM 1992).

In comparison to most temperate regions, European settlement was relatively late in the Pacific Northwest (Ames and Maschner 1999; Lavender 1956). At the time the boundary between Great Britain (Canada) and the United States was settled in 1845, for example, there were no European settlers on the west coast of the Olympic Peninsula. The settlement that eventually occurred was based primarily on coastal water access, which was much easier than overland travel. A trading post was established at Neah Bay in 1850 followed by construction of the Cape Flattery lighthouse in 1857. The first settlers on the coast took advantage of the natural harbor at the mouth of the Quillayute River to establish homesteads among the Native American settlements. Later, settlements were established farther up coastal rivers and in the vicinity of Lake Ozette, where by 1900, some 50 to 60 families were homesteading (Kirk 1962). Settlement was facilitated by treaties signed among the coastal tribes and the United States in 1855 (OLYM 1992) as it determined which lands were open to homesteading as part of the public domain. However, the designation of the Olympic Forest Reserve in 1897 limited the ability of settlers to construct roads for more convenient access. Despite the removal of the settled lands in the Lake Ozette area from the Reserve (1900), the persistent difficulties of existence in this remote area discouraged settlement and the homesteads gradually were vacated (OLYM 1992).

Economic activity in the early years was based primarily on subsistence farming; no mineral deposits were discovered and manufacturing activities were constrained by lack of access to resources and markets. The single resource that the Olympic coast had in abundance was timber, but milling and export of logs was much more easily performed in the inland waters of Washington than along the outer coast. This situation persisted until additional road and port infrastructure was established in the early to mid-1900s. Coastal rivers supported salmon and trout, but not in the abundance comparable to the larger rivers in Puget Sound, the Columbia-Snake River, and the Fraser River in Canada. Thus, commercial fisheries and shellfisheries were also slow to develop.

Current economic activity in the coastal region includes tribal subsistence, commercial and sport fishing, and employment by social services and public works. The largest economic driver is the highly seasonal tourist industry. Approximately 3.5 million people visit OLYM each year with an estimated one-third visiting the Pacific Coast portions. Because much of the coastline is in either dedicated or *de facto* Wilderness, visitor access is limited in extent and location.

A.2. Hydrology

A.2.a. Oceanographic Setting

The OLYM coastal strip is located in an oceanographic region that is dominated by features associated with the North Pacific Gyre, a circular flow formed by the California, Alaska, and Davidson currents. These currents can vary significantly on interannual, seasonal, and multi-day timescales, creating complex eddy fields, as well as upwelling and downwelling patterns. The major large-scale oceanographic features of the region have been described by Hickey and Banas (2003).

The coastal ocean that influences OLYM is embedded within an eastern boundary current system. Eastern boundary currents tend to be shallow, narrow, and rich in mesoscale eddy features. In the region of OLYM, the prevailing system of currents includes the California Current, the Davidson Current, and the California Undercurrent. The California Current is a south-flowing offshore current apparent from the surface to 500 meters depth. It is balanced in part by the north-flowing California Undercurrent, which is narrower and faster, and generally occurs at intermediate depths, between 100 and 400 meters. Both the California Current and Undercurrent are generally stronger in summer than in winter. The Davidson Current also flows north, but is primarily a fall/winter feature. Topographic features such as submarine canyons also influence circulation. In the OLYM region, the Juan de Fuca and Quinault canyons likely enhance upwelling and may increase local retention.

Coastal circulation is dominated by wind forcing. Equatorward winds force upwelling from depths on the order of 200 meters in areas close to the coast. Upwelling contributes to higher productivity and cooler water along the coastal margin and controls variability in water properties (Hickey and Banas 2003).

Eddies and other mesoscale features are characteristic of the region (Figures 2 and 3). Among the most prominent is the Juan de Fuca eddy, seasonally formed by a combination of upwelling, tidal, and other forces (Marchetti *et al.* 2004). The Juan de Fuca eddy tends to be rich in nutrients and has been postulated to be the source of harmful algal blooms that impinge on the OLYM coastline (Trainer *et al.* 2002; MacFayden *et al.* 2005; Evans *et al*. 2005).

The coastal ocean in the vicinity of OLYM exhibits variability across multiple spatial and temporal scales. Hickey and Banas (2003) provide a general picture of seasonal variability. Under fair weather conditions (e.g., those that exist during the summer), the near-surface flow is to the southwest, the Columbia River Plume flows to the south, the Juan de Fuca Eddy is present, and upwelled water near the coast is relatively cold, salty, and nutrient-rich. Under stormy conditions (e.g., those that exist during the winter), the near-surface flow is to the northeast, the Columbia River Plume flows to the north and is trapped close to the coast, the Juan de Fuca Eddy is absent, and downwelled water along the coast is relatively warm, less saline, and nutrient-poor. Variability in ocean circulation and water properties can influence local food webs and the condition of nearshore organisms, including those within shoreline areas of OLYM.

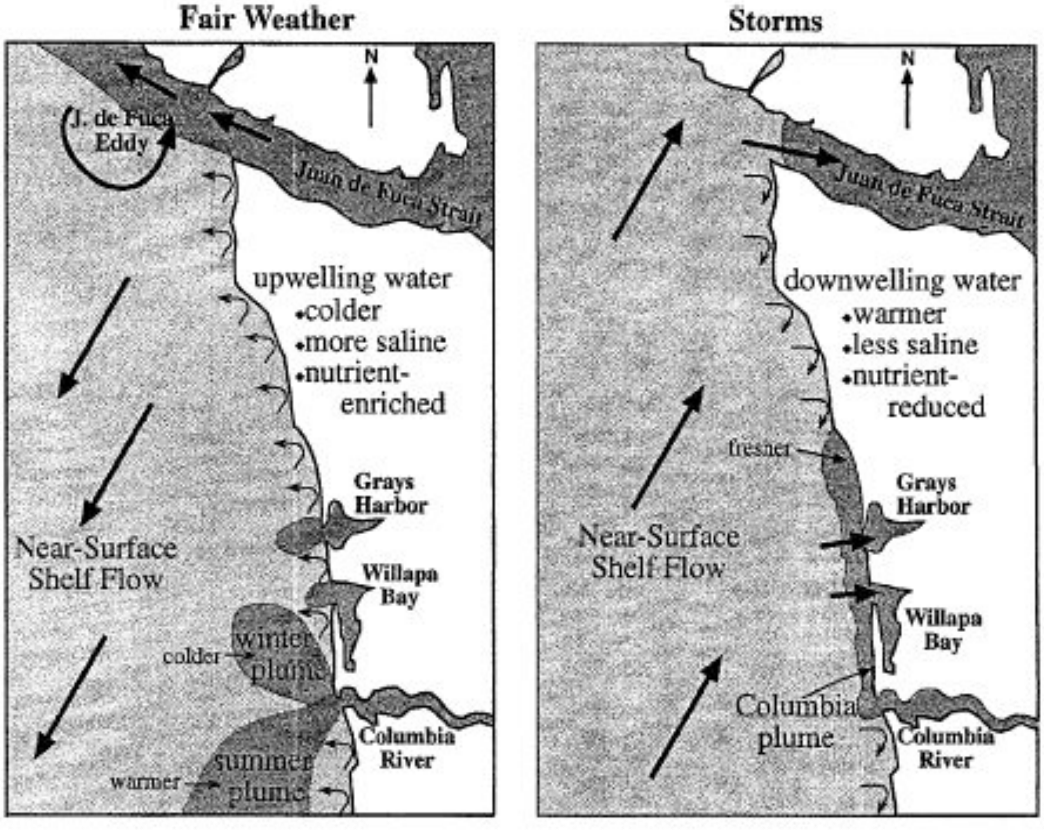

Figure 2. Schematic of wind-driven coastal circulation in the Pacific Northwest illustrating the offshore and southward-directed surface currents and upwelling along the coast that occur in response to an upwelling-favorable wind stress (left panel, fair

weather) and onshore and northward-directed surface currents and downwelling along the coast in response to downwelling-favorable winds (right panel, storms) (Hickey and Banas 2003).

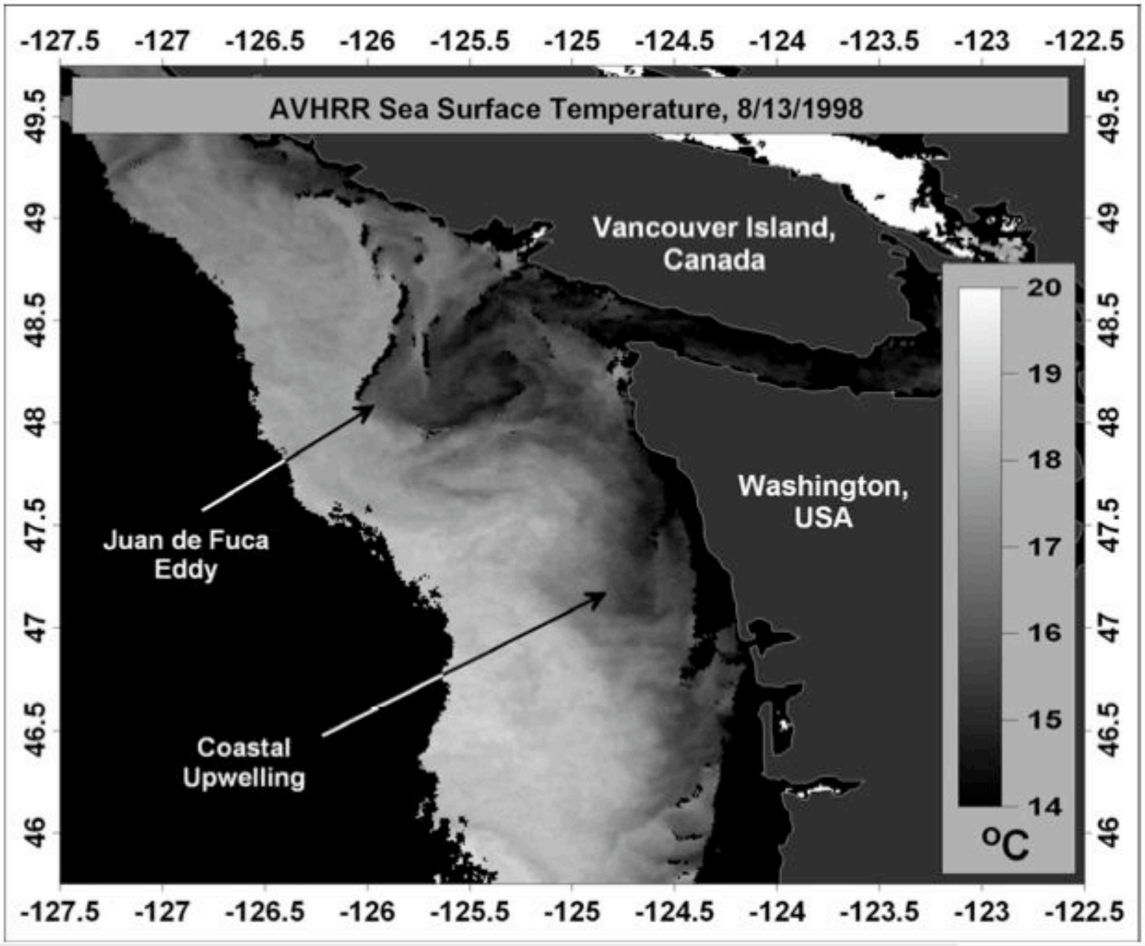

Figure 3. Sea surface temperature along the Washington Coast, as shown by AVHRR (Advanced Very High Resolution Radiometer) imagery. The Juan de Fuca Eddy and coastal upwelling are evident (Evans *et al*. 2005).

Hypoxia is known to occur in coastal waters in the vicinity of OLYM (Figure 4). Hypoxic conditions were reported from coastal Oregon in the summers of 2002-2007. Hypoxic conditions in summer 2006 extended to the southern boundaries of OLYM in the vicinity of the Quinault Indian Nation. Benthic or water column respiration, combined with changes in summer wind forcing and associated alterations in upwelling patterns have been proposed as a mechanism for observed hypoxic events.

Figure 4. Satellite image of the Olympic Coast showing surface expression of mesoscale features. Image courtesy of OCNMS (http://www.oceanexplorer.noaa.gov/explorations/).

A.2.b. Hydrologic Setting

Climate in the coastal region of OLYM is characterized by moderate air temperatures and high levels of precipitation. At Forks, the average air temperature measured between 1976 and 2005 was 49.1°F. The maximum daily mean temperature for 2005 was 57.3°F; maximum daily mean temperatures ranged from 46.6°F in December 2005 to 69.2°F in August 2005 (National Climatic Data Center 2006). Minimum daily mean temperatures in 2005 ranged from 33.7°F in January 2005 to 49.9°F in August 2005. Temperatures in coastal areas of OLYM are likely to be similar to those recorded at Forks.

Average annual precipitation measured at Forks between 1976 and 2005 was 102 inches. Rainfall is highest in the winter (Nov-Jan) and lowest in the summer (Jun-Aug). Annual precipitation on the coast is likely to be less than what is measured in Forks due to differences in elevation (Phillips and Donaldson 1972). High levels of precipitation combine with steep, complex regional topography to create a landscape that is dominated by surface water features and high regional stream density.

The water resources of OLYM are diverse, and include high- and low-elevation lakes, ponds, bogs, springs, glacial- and non-glacial rivers and streams, a reservoir, and a dam (Jenkins *et al.* 2003), as well as coastal water resources that are fully marine or marine-influenced. Twelve major river basins and more than 3500 miles of rivers and streams distributed across eleven watersheds are among the freshwater resources of OLYM (NPS 2006c). Several major rivers cross the coastal strip (Figure 5).

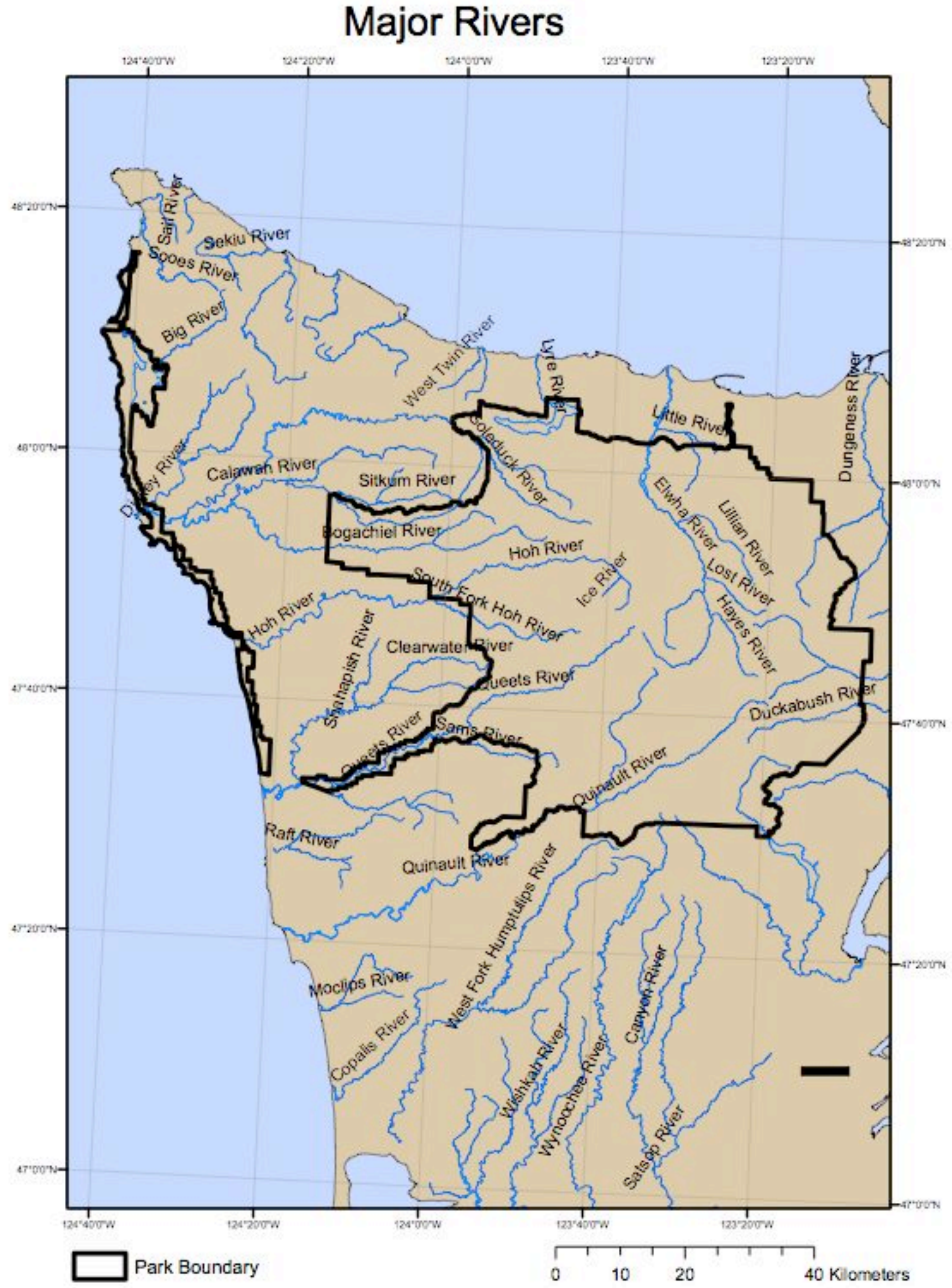

Figure 5. Major rivers of the western Olympic Peninsula (map created by authors).

According to park personnel, monitoring protocols currently are being developed for high lakes, rivers, streams, large lakes, and intertidal habitats within OLYM. As part of this protocol development, "preliminary" monitoring data are currently being collected, and full scale monitoring efforts will be implemented in the near future. Now, a fully integrated, mature water resource monitoring program does not exist; consequently, the condition of water resources within OLYM is not completely known.

Among the threats to water resources within OLYM are climate change and its associated stressors (e.g., changes in temperature, hydrology, and disturbance) and atmospheric contamination (Jenkins *et al.* 2003). Human activities outside park boundaries, including those associated with land management practices, constitute threats to water resources both within and outside the OLYM. For example, at several locations outside park boundaries (most notably in the coastal strip and Lake Ozette, but also in the Queets, Hoh, and Sol Duc Rivers) the uplands are managed by private, state, or federal agencies for commercial timber production, with subsequent effects on waters within OLYM.

While we recognize the extraordinary diversity and importance of water resources within OLYM, in this report we focus on coastal water resources, with a primary focus on water resources within the coastal strip of OLYM. We discuss watershed conditions that impact coastal water resources where appropriate.

Land Cover Types

Land cover types as designated by the National Wetlands Inventory (NWI) are shown for the coastal strip (Figure 6) and main body of the park (Figure 7). Associated acreages are given in Table 1.

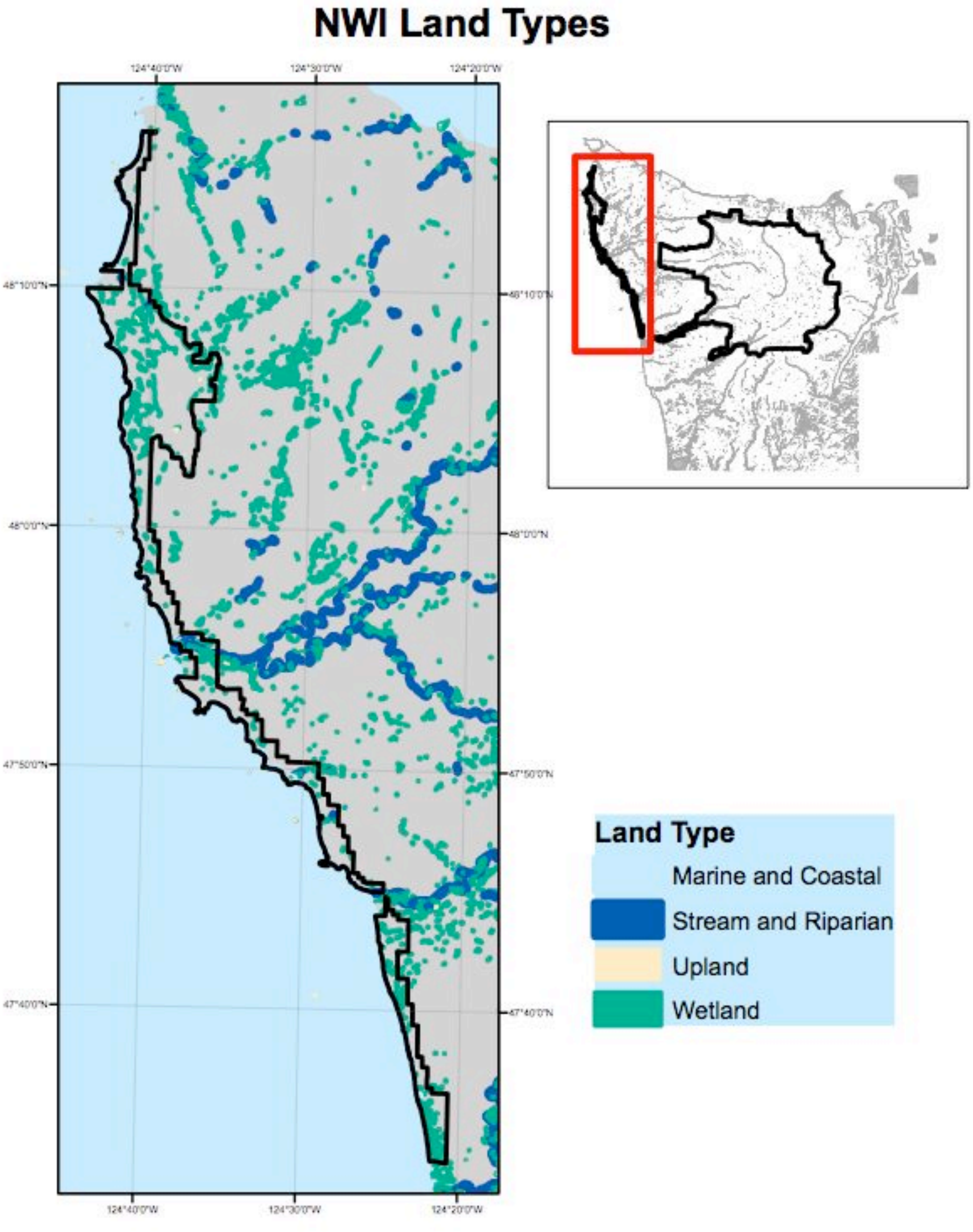

Figure 6. NWI land type distribution in the coastal strip of OLYM (map created by authors from NWI data).

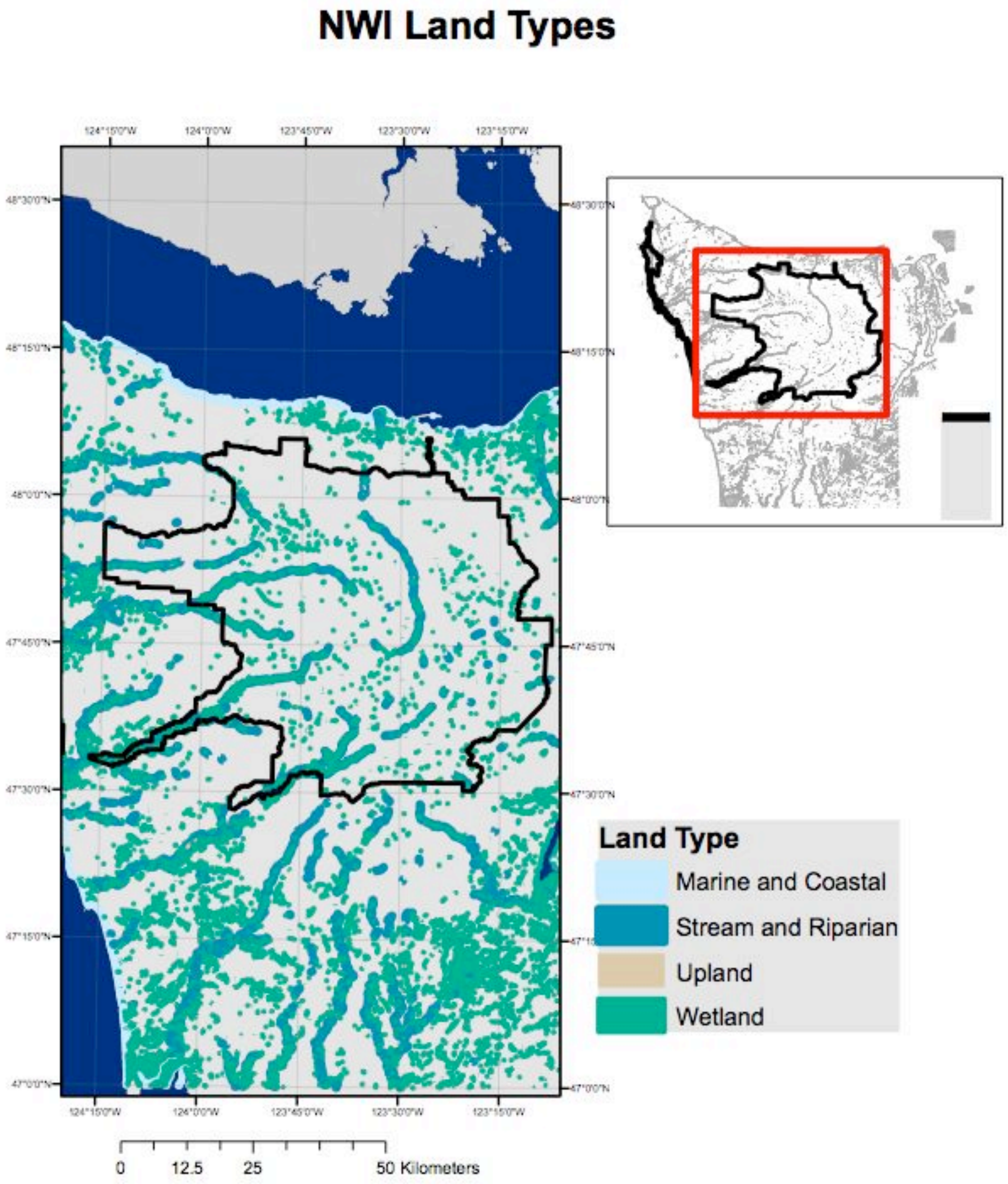

Figure 7. NWI land type distribution in the main body of OLYM (map created by authors from NWI data).

Table 1. National wetlands inventory land type size and distribution for OLYM (area is based on land type distribution in Figures 6 and 7).

NWI Land Types	Area (acres)
Marine and coastal	477
Wetland	10,954
Stream and riparian	6,105
Upland	462

Watershed Delineation

The U.S. Geological Survey (USGS) delineates watersheds using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloging units. A hierarchical hydrologic unit code (HUC) consisting of two digits for each level in the hydrologic unit system is used to identify any hydrologic area. The six digit accounting units and the eight digit cataloging units are generally referred to as basin and sub-basin, respectively. HUC is defined as the Federal Information Processing Standard (FIPS) and generally serves as the backbone for the country's hydrologic delineation.

OLYM is located within the Washington Coastal accounting unit (171001), encompassing the drainage into the Pacific Ocean from the Strait of Juan de Fuca drainage boundary to the Columbia River Basin boundary. The total area of this unit is 6240 sq. mi. The coastal strip of OLYM lies within Hoh-Quillayute cataloguing unit (17100101), which has a total acreage of 1230 sq. mi.

Watershed Resources Inventory Areas

The Washington State Watershed Management Act of 1998 (ESHB 2514) delegated watershed planning to the local level in each of 62 state-defined Watershed Resources Inventory Areas (WRIAs). Coastal areas of OLYM lie largely within WRIA 20; the southernmost coast areas (those in the vicinity of Kalaloch) lie within WRIA 21 (Figure 8). WRIAs 20 and 21 are located entirely within Washington Coastal accounting unit 171001. We focus here primarily on WRIA 20 because it has the highest degree of spatial overlap with coastal areas of OLYM.

Figure 8. Water resource inventory areas (WRIAs) in the vicinity of OLYM (map created by authors).

An initial hydrologic analysis and assessment for WRIA 20 was published in 2005 (Lieb and Perry 2005). [Note: an equivalent assessment has not yet been published for WRIA 21]. The report covers an area bounded by the Wa'atch River to the north and the Hoh

River to the south (Figure 9), including the Lake Ozette and the Quillayute River stream systems. The report contains an appraisal-level overview of watershed condition and streamflow volumes and discharges based on measurements made from October 1961-September 1999 and 2000. Streamflow in watersheds that include high elevation areas are dominated by runoff from spring snowmelt and winter precipitation (Lieb and Perry 2005). Winter precipitation alone dominates flow in lower elevation streams.

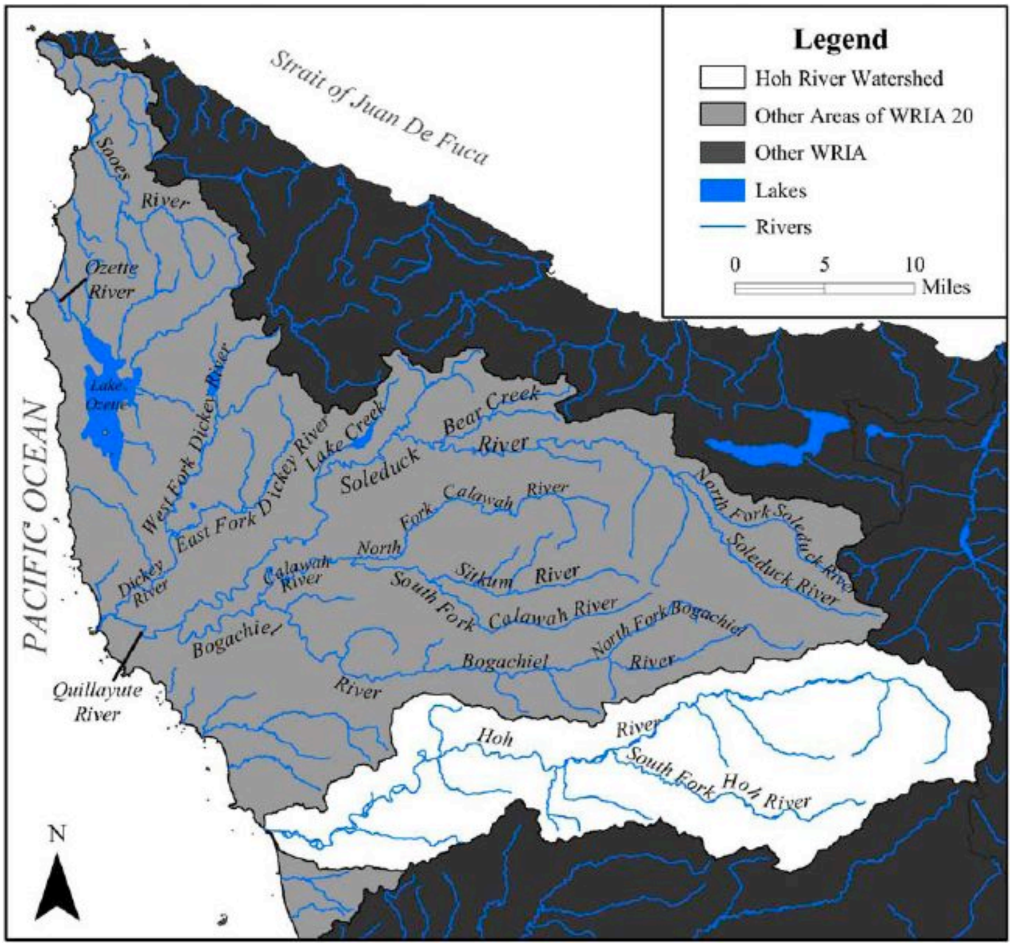

Figure 9. Water Resource Inventory Area 20. WRIA 21 borders WRIA 20 to the south (Lieb and Perry 2005).

Lieb and Perry (2005) consider four major watersheds within WRIA 20. From north to south, these are the Sooes River watershed, the Ozette River watershed, the Quillayute River watershed, and the Hoh River watershed. The authors further divide the Quillayute River Watershed into five sub-watersheds: the Quillayute, Dickey, Soleduck, Calawah, and Bogachiel River watersheds. We briefly describe each major watershed below, based on information reported by Lieb and Perry (2005).

Sooes River Watershed

The Sooes River Watershed is located to the north of the OLYM coastal strip, immediately north of the Ozette River watershed (Figure 10). A very small portion (0.008%) of the watershed falls within OLYM. The majority of the watershed (nearly

80%) is privately owned; the Makah Nation owns the majority of the remaining land within the watershed. The total area of the watershed is 41.9 sq. mi.; 84% of this is classified as coastal lowland watershed (Lieb and Perry 2005). Average annual precipitation ranges from approx 85-120 inches. A more comprehensive description of the watershed can be found in Lieb and Perry (2005).

Lake Ozette and Ozette River Watershed

Lake Ozette is the largest lake within OLYM, and the third largest lake in Washington state. The lake provides important habitat for six species of native salmonids (Chinook, sockeye, coho, and chum salmon, and steelhead and cutthroat trout). Among these, the Ozette stock of sockeye salmon is listed as threatened under the Endangered Species Act. Salmon spawning habitat within Lake Ozette and its tributaries appears to have been reduced over the past several decades due to land use practices such as timber harvest that reduce riparian vegetation, alter sedimentation and erosion regimes, and cause increases in water temperature and turbidity.

The Ozette River watershed drains the area surrounding Lake Ozette, comprising an area of 88 sq. mi. (Figure 10). The Ozette River itself flows a relatively short distance, from Lake Ozette to the Pacific Ocean (Figure 11). Southeastern portions of the watershed lie within OLYM; these include 8.4 sq. mi. (9.6%) of the watershed acreage, and an additional 11.6 sq. mi. contributed by Lake Ozette. The majority of the watershed (69.5%) is privately owned. Most of the drainage (78.8%) is characterized as lowland watershed (Lieb and Perry 2005). Average annual rainfall ranges from 73-103 inches (Lieb and Perry 2005).

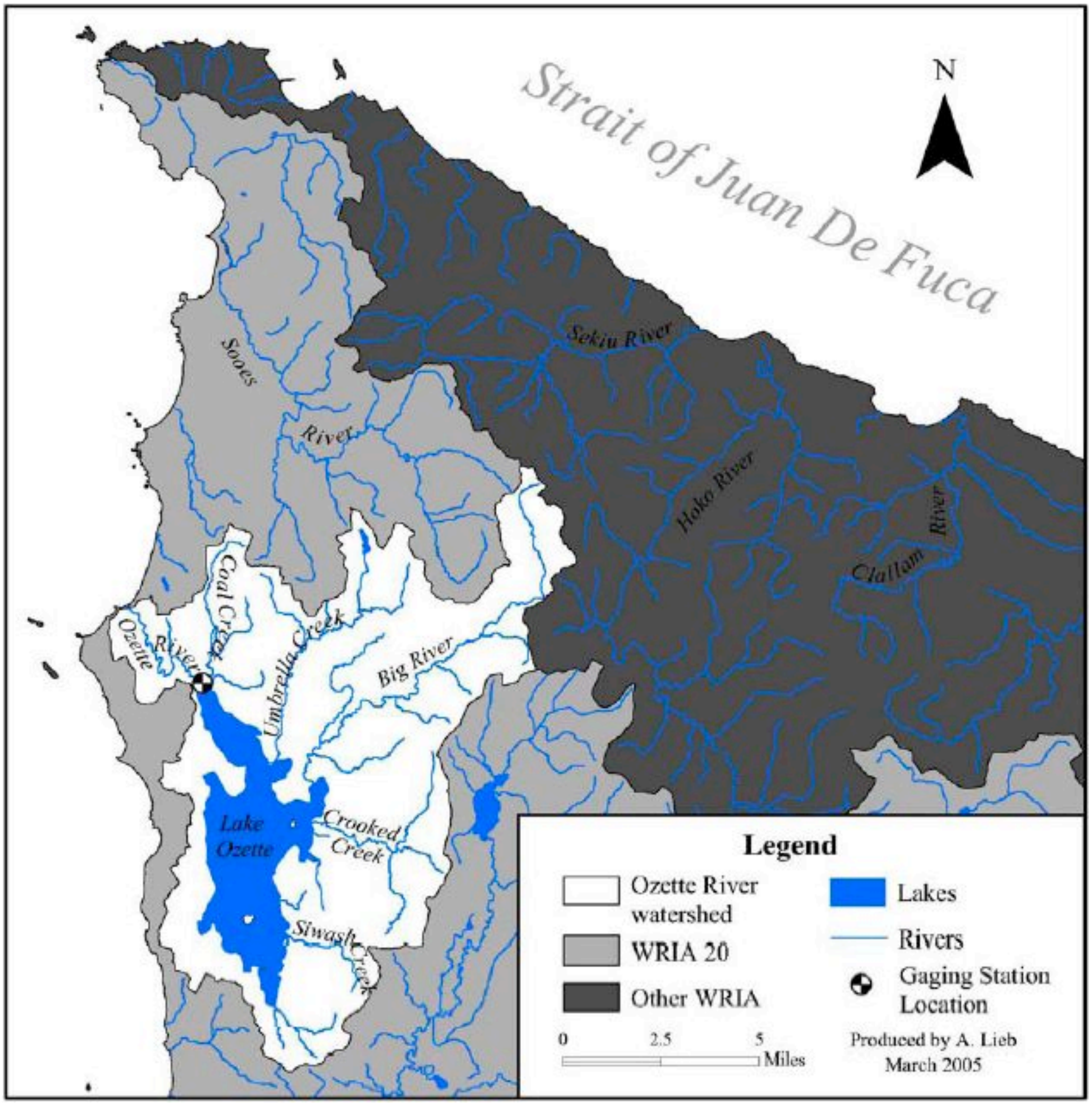

Figure 10. Ozette River Watershed (Lieb and Perry 2005).

Figure 11. Ozette River at mouth (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

Quillayute River Watershed

The Quillayute River watershed drains a large area on the western edge of the Olympic Mountains (Figure 12). The total area of the watershed is about 628 sq. mi.; this is divided between several sub-watersheds consisting of several rivers that ultimately contribute to the Quillayute River itself. Among the substantial tributaries of the Quillayute River are the Soleduck, Bogachiel, and Dickey Rivers; another river, the Calawah, is a large tributary of the Bogachiel River. The Quillayute River empties into the Pacific Ocean at the town of La Push on the Quileute Indian Reservation (Figure 13).

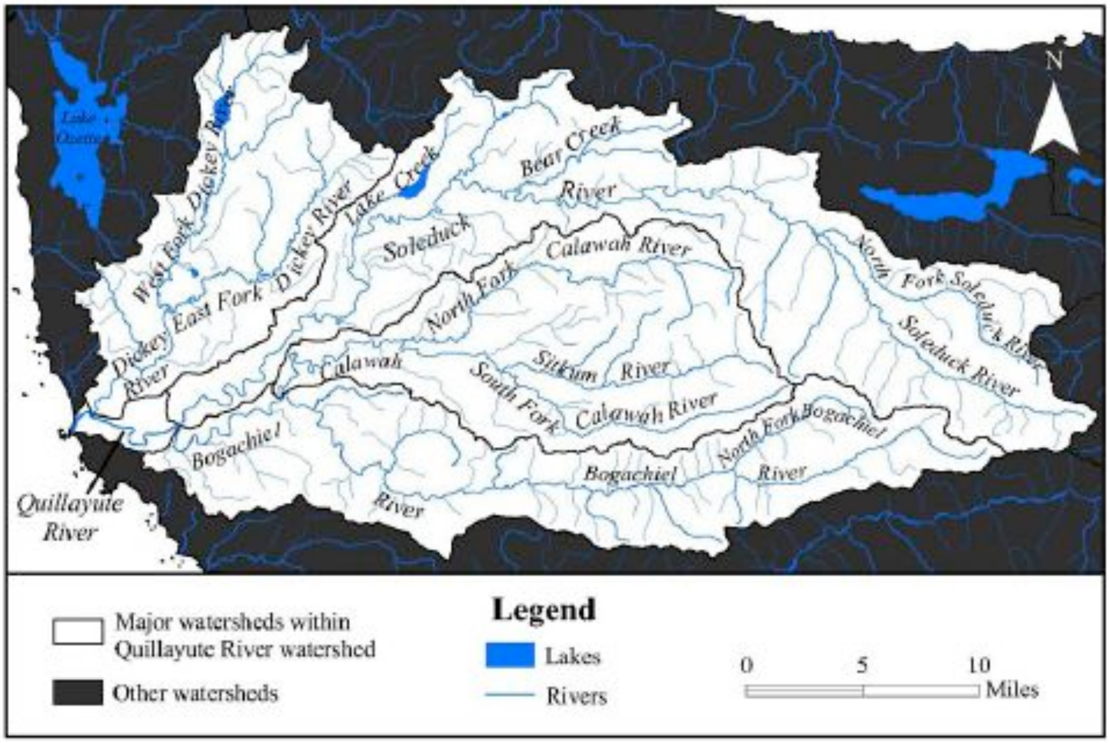

Figure 12. Quillayute River Watershed (Lieb and Perry 2005).

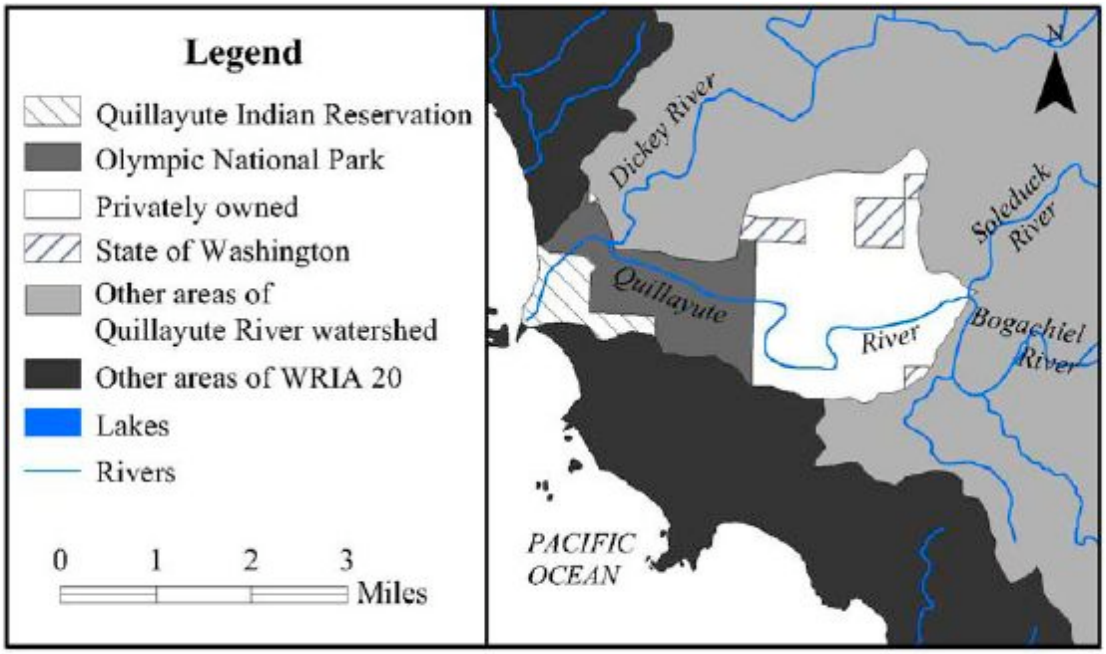

Figure 13. Quillayute River Sub-watershed (Lieb and Perry 2005).

The Quillayute River (Figures 14 and 15) itself is relatively short, flowing 6.5 miles from the point of its formation at the confluence of Bogachiel and Soleduck Rivers to its coastal outlet (Lieb and Perry 2005). The Quillayute River sub-watershed is correspondingly small, comprising 6.9 sq. mi. The largest portion of the sub-watershed

(56.6%) is privately owned. Twenty-seven percent of the sub-watershed lies within OLYM. The drainage is characterized as coastal lowland sub-watershed (Lieb and Perry 2005). Within the sub-watershed, average annual precipitation ranges from 74-87 inches.

Figure 14. Quillayute River near mouth (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

Figure 15. Quillayute River at mouth (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

Hoh River Watershed

The Hoh River watershed is the southernmost watershed in WRIA 20, bounded on the north by the Quillayute River waters and on the south by the Queets River Watershed, which lies within WRIA 21 (Figure 16). The river flows to the west and discharges directly into the Pacific Ocean (Lieb and Perry 2005; Figure 17). Average annual precipitation varies from about 93-240 inches, depending on location, and is lowest at the mouth of the river. The size of the watershed is approximately 298 sq. mi. Upper portions of the watershed lie within OLYM, constituting 171.7 sq. mi. or 57.6% of the total watershed. The State of Washington is the second largest landholder in the watershed, administering 72.6 sq. mi. (24.4%). The watershed is characterized as 41.7% highland, 27.5% upland, and 30.8% lowland.

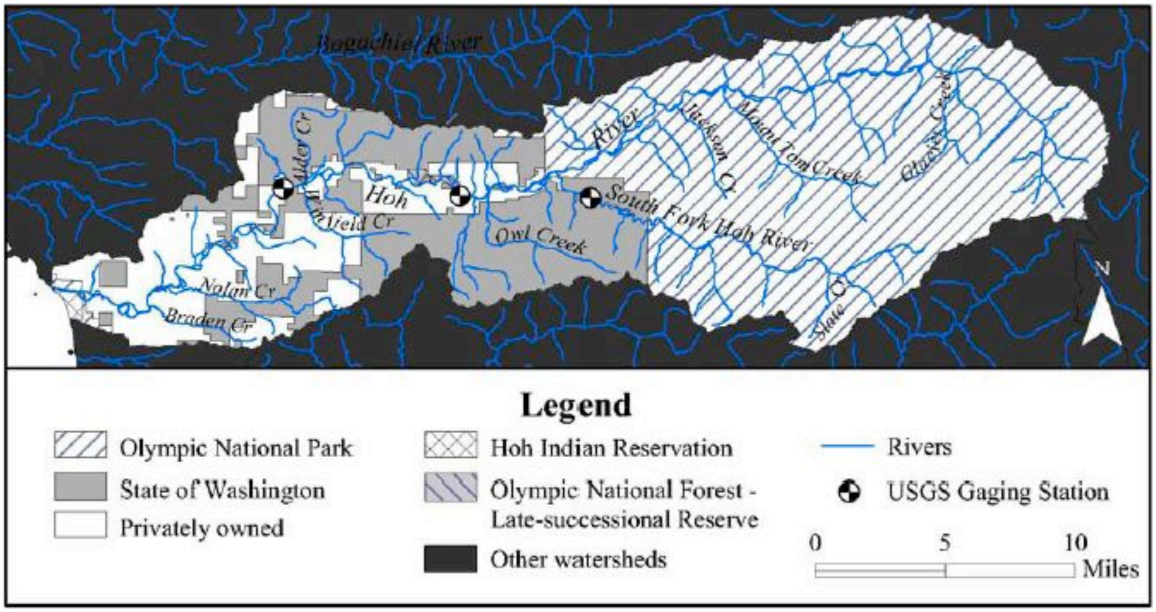

Figure 16. Hoh River Watershed (Lieb and Perry 2005).

Figure 17. Hoh River at mouth (WDOE Aerial Shoreline Photos, http://apps.ecy.wa.gov/shorephotos/).

A.3. Aquatic Habitats and Biological Resources

A.3.a. Marine Intertidal and Shallow Subtidal Habitats

The coastal strip and offshore islands of OLYM comprise about 1,400 square miles of shoreline habitat (NPS 2006c). Among these, the intertidal and shallow subtidal habitats of OLYM are characterized by bedrock, cobble and sand (Figures 18-22, organized from north to south). Intertidal habitats and their constituent communities are summarized by Fradkin in Jenkins *et al*. (2003), and are described in detail by Dethier (1988, 1991). Characterization of the fully marine habitats typical of OLYM is given in Table 2 (excerpted from Dethier 1991).

Table 2. Intertidal habitat types and definitions (excerpted from Dethier 1991).

Intertidal Habitat	**Examples of Common Species**
Rock (Solid bedrock)	
Exposed (wave action)	• California mussel *Mytilus californianus* • sea palm *Postelsia palmaeformis* (most exposed areas only) • gooseneck barnacle *Pollicipes polymerus* (= *Mitella polymerus*), (and in low zones) • kelps in the genera *Laminaria* and *Lessoniopsis*.
Partially exposed	• kelp *Hedophyllum sessile* • surfgrass *Phyllospadix scouler* • chiton *Katharina tunicata* (all low zones) • cloning anemone *Anthopleura elegantissima* (mid zone).
Semi-protected and Protected	• brown rockweed *Fucus gardneri* (=*distichus*) • red algae *Porphyra* spp. and *Mastocarpus papillatus*, • snails *Littorina* spp. (all high zones) • whelk *Nucella lamellosa*.
Boulders	No specific surveys have been done, but the following species are more common.
Exposed	• red algae *Plocamium cartilagineum* and *Prionitis* spp. • limpet *Tectura persona* • turban snail *Tegula funebralis* (outer coast only) • shore crab *Hemigrapsus nudus* • red rock crab *Cancer productus* • anemones *Metridium senile*, *Urticina crassicornis*, and *Anthopleura xanthogrammica* (outer coast) • tunicates *Pyura haustor* • intertidal sponges *Halichondria panicea*, *Haliclona permollis*, and *Ophlitaspongia pennata.*
Partially exposed	
Semi-protected	
Hardpan	• boring clam *Adula californiensis* • urchin *Strongylocentrotus purpuratus* • red alga *Halosaccion glandiforme.*
Cobble	
Partially exposed	• *Littorina* spp. • *Hemigrapsus nudus* • *Macoma inquinata* • *Mysella tumida*.
Mixed-Coarse	
Semi-protected to Protected	• *Fucus gardneri*, *Mytilus edulis*, *Protothaca staminea*.
Gravel	

Partially exposed	• Gammarid amphipods *Paramoera mohri*, and *P. serrata* n.sp., *Traskorchestia traskiana*.
Semi-protected	• isopod *Exosphaeroma inornata* (=*media*) • polychaete *Hemipodus borealis*.
Sand	
Exposed and Partially exposed	• Phoxocephalid amphipods and *Eohaustorius* spp. • polychaete *Paraonella platybranchia* • mysid *Archaeomysis grebnitzkii* • olive shell *Olivella biplicata* • razor clam *Siliqua patula* (locally abundant on the outer coast) • juvenile Pacific tomcod and English sole, Pacific staghorn sculpin, sand sole, and redtail surfperch.
Semi-protected	• The clams *Macoma secta*, *Tellina bodegensis* and *Transennella tantilla* • burrowing sea cucumber *Leptosynapta clarki* • lugworm *Abarenicola claparedi* • tanaid crustacean *Leptochelia savignyi* • sand sole.
Mixed-Fine	
Semi-protected and Protected	• *Zostera marina* (low zones) and *Z. japonica* (higher) • red alga *Gracilaria pacifica* and ulvoids • clams *Macoma nasuta* and *balthica*, *Tresus capax*, *Clinocardium nuttallii*, and *Cryptomya californica* • hard shell clams *Protothaca staminea*, *Saxidomus giganteus* • phoronid worm *Phoronopsis harmeri* • crabs *Hemigrapsus oregonensis*, *Cancer magister*, *C. productus* • ghost shrimp • polychaetes *Lumbrineris* sp., *Axiothella rubrocincta*, and *Owenia fusiformis* • juvenile Pacific tomcod and lingcod, tube-snout, bay pipefish, shiner perch, snake prickleback, saddleback gunnel, silverspotted sculpin, sharpnose sculpin, Pacific staghorn sculpin, tidepool sculpin, sturgeon poacher, Pacific sanddab, surf smelt, juvenile English sole, and starry flounder.
Mud	
Protected	• *Zostera marina* • clam *Macoma nasuta* (especially in freshwater inflow) • polychaete *Polydora* (*Pseudopolydora*) *kempi japonica* • mud shrimp *Upogebia pugettensis*.

Substrata (definitions as used by Dethier 1991):

- Bedrock
- Boulders: Rocks >256 mm (=10") diam.
- Hardpan: Consolidated clays forming a substratum firm enough to support an epibenthos and too firm to support a normal infauna (clams, worms, etc.), but with an unstable surface
- Cobble: rocks <256 mm but >64 mm (2.5") diameter
- Mixed-coarse: substrata consisting of cobbles, gravel, shell, and sand (no one substratum type exceeding 70 percent surface cover)
- Gravel: 4-64 mm diam.
- Sand: .06-4 mm
- Mixed-Fine: mixture of sand and mud, with little gravel, likely to change seasonally
- Mud: fine substrata <.06 mm, usually mixed with organics

- Organic: substrata composed primarily of organic matter such as wood chips, leaf litter, other detritus
- Artificial

Marine Intertidal Energy Categories:
- Exposed: Highly exposed to oceanic swell and wind waves. Wind fetch virtually unlimited
- Partially exposed: Oceanic swell attenuated by offshore reefs, islands, or headlands, but shoreline substantially exposed to wind waves.
- Semi-Protected: Shorelines protected from sea swell, but may receive waves generated by moderate wind fetch.
- Protected: No sea swell, little or no currents, and restricted wind fetch.

Estuarine Energy Categories:
- Open: Shorelines exposed to moderate to long fetch and receiving some wind waves and/or currents, but still diluted by freshwater as defined under Estuarine. Headlands and many beaches within Puget Sound fall within this category.
- Partly Enclosed: Bays or river mouths partially enclosed by headlands, bars, spits, or artificial obstructions reducing circulation. Minimal wave action or currents. Drift algae and seagrass often concentrate here.
- Lagoon: Protected, largely-enclosed pond or embayment, flushed regularly or irregularly because tidal influence is partially blocked by a spit.
- Channel/Slough: Open or blind narrow inlets, (e.g., abandoned stream channels) constantly submerged and with tidal backup water at high tide. Subtidal channels are deeper areas carrying much of the water mass discharged from a river.

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Figure 18. Rocky headland at Cape Johnson (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

Figure 19. Bedrock and cobble beaches north of Rialto Beach (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

Figure 20. Bedrock and sandy beaches at Teawhit Head (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

Figure 21. Bedrock, sandy beaches, and offshore rocks at Toleak Point (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

Figure 22. Sandy beaches at Kalaloch (WDOE Shoreline Aerial Photos, http://apps.ecy.wa.gov/shorephotos/).

The geomorphology of the intertidal and shallow subtidal zones tends to be complex, often with abrupt transitions between substrates. Schoch (unpublished database) performed a geomorphological characterization of intertidal sites within OLYM. An analysis of intertidal habitat type by region (or shoreline segment; Figure 23) is provided in an unpublished report (OCNMS 2003) based on the unpublished data of Schoch, as summarized in Table 3 for four shoreline segments. Physical factors influencing benthic community structure in intertidal areas include wave run-up, tidal range, precipitation, air temperature, water temperature, upwelling, salinity, and sand scour (Schoch *et al*. 2006).

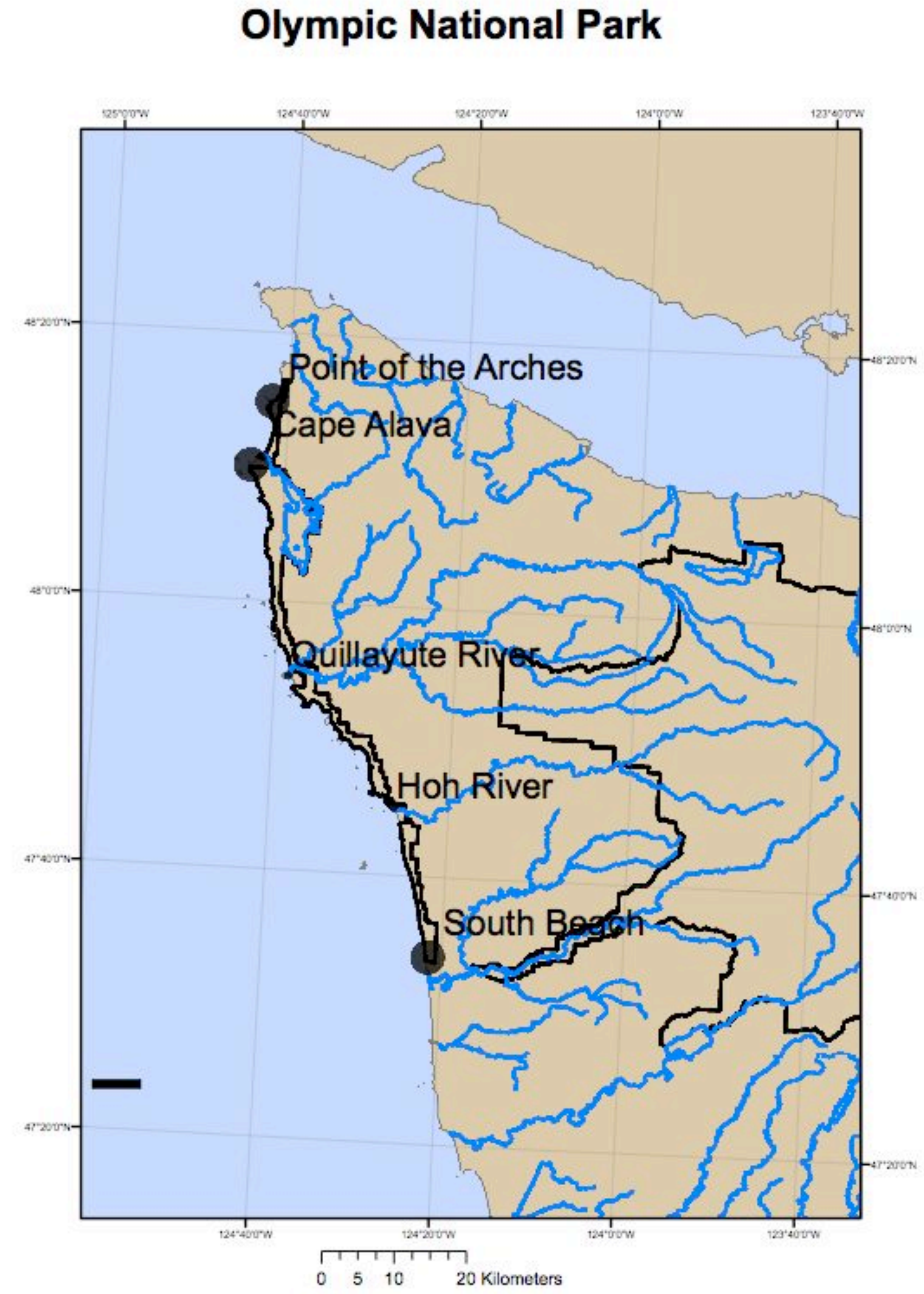


Figure 23. Place names and locations of shoreline segments described in Table 3 (map created by authors).

Table 3. Proportion of habitat type by shoreline segment (north to south) (OCNMS 2003).

Shoreline Segment	Habitat Type	Percent of Shoreline
Point of Arches-Cape Alava	Rock ramp	16
	Rock cliff	1
	Mixed gravel	48
	Sand	32
	Estuary	4
Cape Alava-Quillayute River	Rock ramp	0
	Rock cliff	0
	Mixed gravel	60
	Sand	39
	Estuary	1
Quillayute River-Hoh River	Rock ramp	0
	Rock cliff	12
	Mixed gravel	22
	Sand	63
	Estuary	3
Hoh River-South Beach	Rock ramp	0
	Rock cliff	0
	Mixed gravel	18
	Sand	78
	Estuary	4
Total OLYM Shoreline	Rock ramp	2
	Rock cliff	4
	Mixed gravel	38
	Sand	53
	Estuary	2

The marine intertidal communities of OLYM are typical of high-exposure, outer coastal intertidal communities throughout the region. Although an inventory of marine biodiversity has not been performed, studies in intertidal areas indicate that species richness is relatively high: "…in studies at over 50 rocky intertidal sites that span 1,200 miles of coast from California to Washington, the highest biodiversity was found at sites in Washington..." (OCNMS 2003). The findings of Schoch *et al*. (2006) corroborate and expand on these observations, and in particular demonstrate that species richness in low intertidal areas tends to be high at northern latitudes within the California Current system. Within OLYM, species richness tends to be higher in rocky areas than in sandy areas (Dethier 1991).

Marine intertidal community composition at several sites within OLYM has been reported by Dethier (1988, 1991; Appendices B and C) and others (e.g., Fitch, unpublished; Appendix D). OLYM now is engaged in the NPS Natural Resource Challenge Long-Term Ecological Monitoring Program, a major monitoring effort currently being implemented across the entire NPS. As part of that program, OLYM currently monitors rocky platform sites, sandy beach sites, coastal geomorphology, and intertidal temperature (Jenkins *et al.* 2003). Preliminary analyses of legacy intertidal monitoring data (e.g., Dethier's 1990s dataset) have been conducted to guide refinements of the OLYM intertidal monitoring program. In 2006, OLYM conducted a survey of hardshell clams in the coastal strip (report forthcoming). Additional intertidal surveys have been performed in some recent years by the Partnership for Interdisciplinary Studies of Coastal Ocean (PISCO 2006). Despite the existence of considerable descriptive data, status and trends of intertidal resources within OLYM have not been identified, nor has a dedicated inventory of marine biodiversity in OLYM been performed. Inventory data to date have been limited to narrowly focused inventories (e.g., invasives, edible bivalves, etc.) and preliminary monitoring efforts.

NPS personnel conducted an intertidal fish inventory from 2001-2005 (report forthcoming). Fish were sampled from tidepools in rocky habitats and by beach seine from sand, gravel, cobble, and rocky habitats. Sixty-two species were documented and vouchered, including a range extension of the spotfin surfperch (Appendix E).

Shallow subtidal resources have been surveyed directly by the Washington Department of Fish and Wildlife (WDFW) and remotely by the WDNR Shorezone program. The distribution of 'chocolate-brown' kelp (stipitate kelps excluding *Nereocystis luetkeana*), razor clams, and smelt are shown in Figures 24-26.

NOAA is planning to conduct a Biogeographic Assessment of Living Marine and Cultural Resources of the OCNMS in the near future. This project will focus on subtidal areas of the Sanctuary, but nearshore and intertidal areas could be included in the assessment.

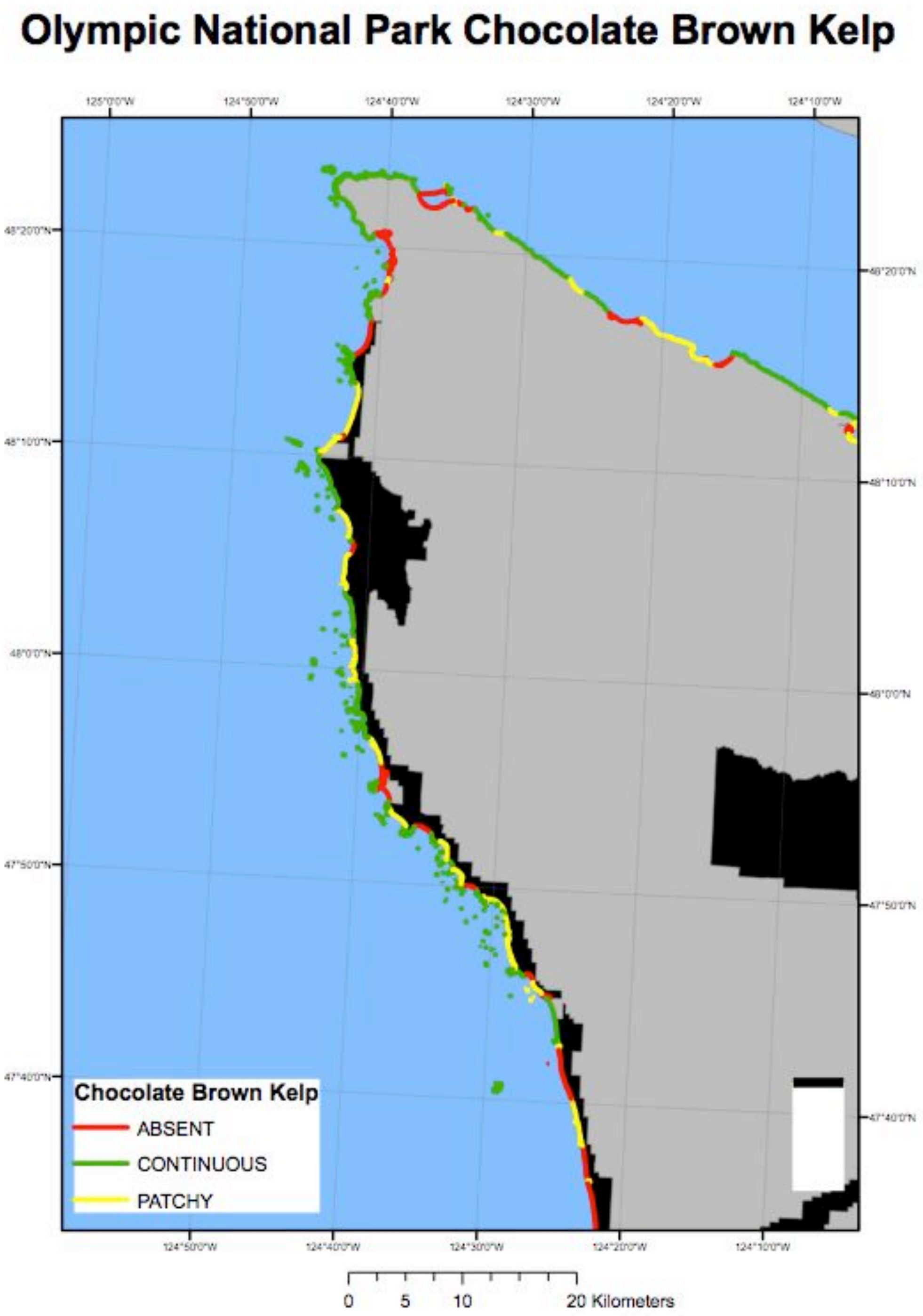


Figure 24. Distribution of chocolate brown kelp in OLYM (map created by authors using Washington State Shorezone Atlas).

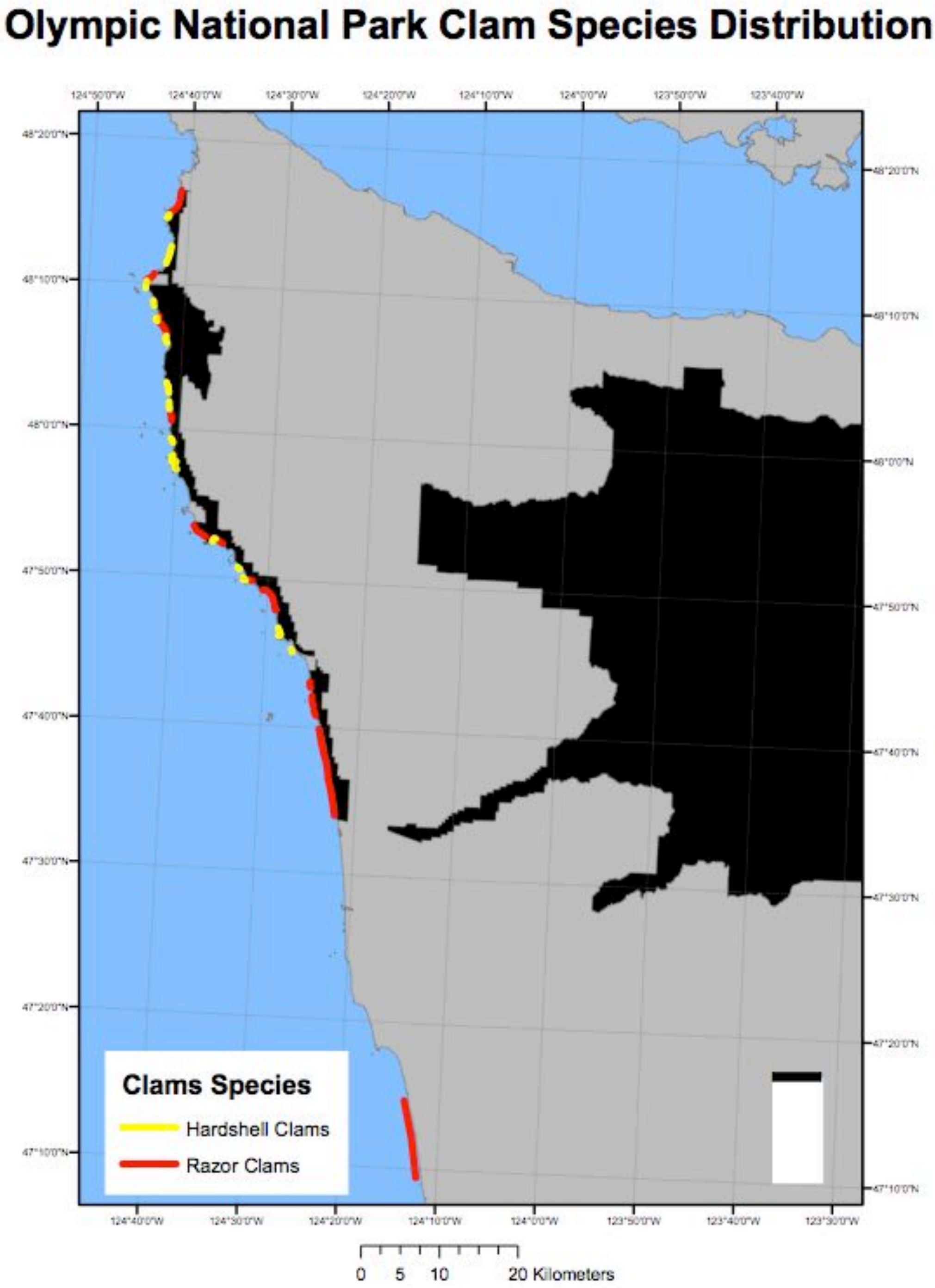


Figure 25. Distribution of clam species in OLYM (map created by authors using WDFW geospatial data).

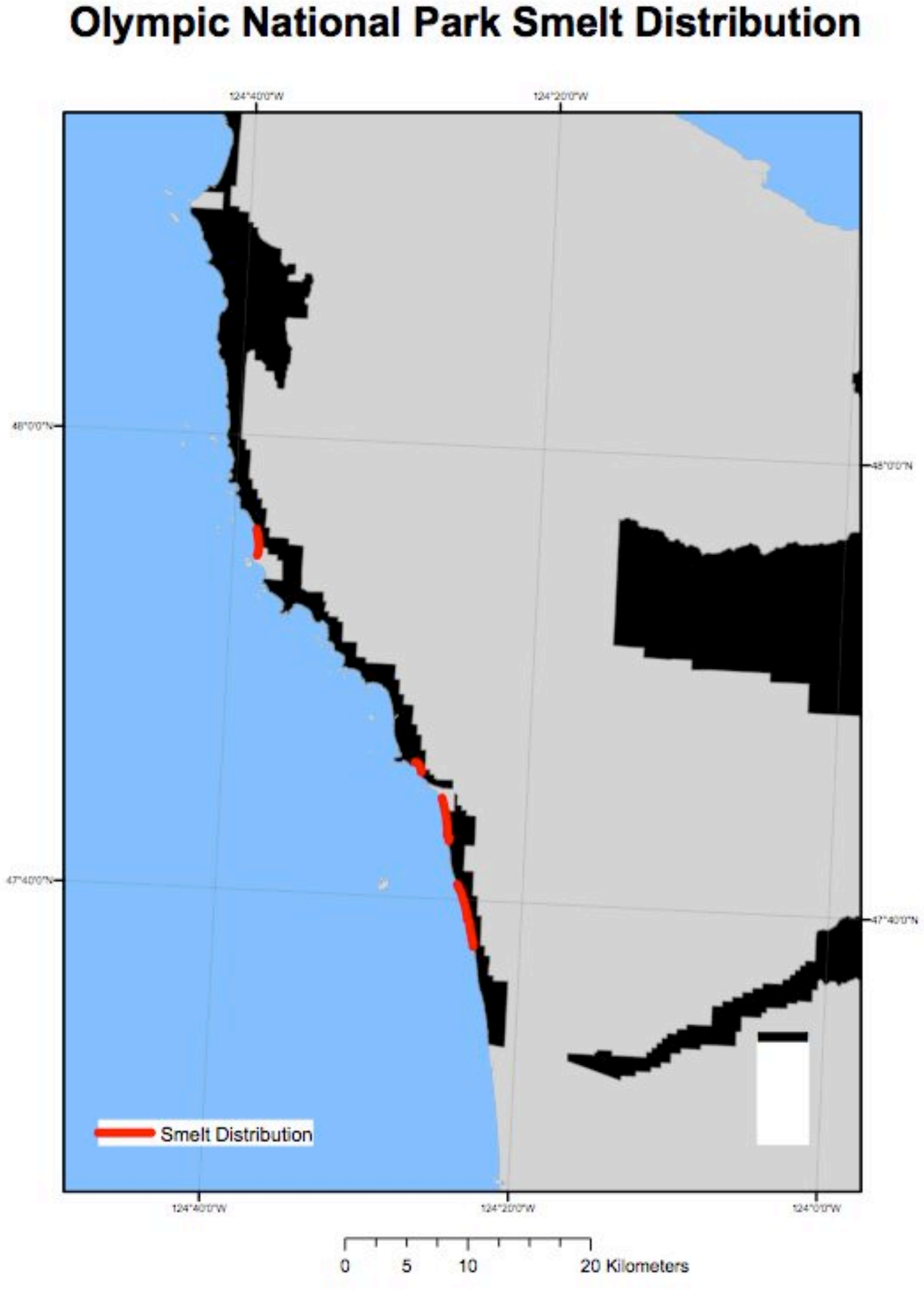


Figure 26. Distribution of smelt in OLYM (map created by authors using WDFW geospatial data).

A.3.b. Other Aquatic Habitats

Estuaries

Estuaries comprise a relatively small portion of the OLYM shoreline. Estuarine habitats are limited to 2% of the total OLYM shoreline, accounting for only 2,558 meters of the more than 104,000 shoreline meters within the park (OCNMS 2003). The estuaries tend to be small, forming at the mouths of the larger rivers.

Salmonid species are known to use estuarine areas within OLYM. For example, adult bull trout (*Salvelinus confluentus*) frequently move between freshwater and the Pacific Ocean and between watersheds within the region (Brenkman and Corbett 2005). Radiotelemetry showed that 47 of 82 bull trout tagged in the Hoh River and Kalaloch Creek were anadromous. Of these, 23 individuals were eventually relocated in five other estuaries up to 47 kilometers distant from the location of tagging. The authors demonstrated that bull trout generally enter the Hoh River between May and July, move up to 78 kilometers upstream to spawning areas by September, and return to the ocean to overwinter. The authors stress the conservation importance of coastal estuaries to the recovery of bull trout, and speculate that estuaries serve as important refugia and provide important foraging habitat for this species.

Offshore Areas

A large number of offshore islands, islets, pinnacles, and emergent rocky bedforms exist in areas offshore of the OLYM coastal strip. Most emergent offshore features are designated National Wildlife Refuge (NWR) sites. The WINWR consists of the Copalis, Quillayute Needles, and Flattery Rocks NWRs, and includes more than 600 islets, islands, and emergent rocky bedforms. The sites are designated as Wilderness for the protection of nesting and breeding areas for seabirds, pinnipeds, and other marine wildlife. Upland areas of the NWRs are closed to entry without permit (USFWS 2005).

Collectively, the WINWR sites support some of the largest seabird colonies in the continental United States, providing habitat for 72 percent or more of Washington’s nesting seabirds. Among seabird species breeding within the WINWR are fork-tailed and Leach’s storm petrels, three species of cormorants, black oystercatchers, three species of gulls, common murres, pigeon guillemot, ancient murrelets, rhinoceros and Cassin’s auklets, and tufted puffins. Bald eagles and peregrine falcons also nest within the WINWR. Sea lions and harbor seals use the areas as haul-outs. Four species currently listed under the ESA use the Refuge sites: brown pelican, marbled murrelet, Steller sea lion, and bald eagle. Six or more species designated as endangered, sensitive, or candidate species under the Washington State Priority Habitats and Species Program use the Refuge sites: Brandt’s cormorant, Cassin’s auklet, common murre, peregrine falcon, tufted puffin, and sea otter.

B. Water Resources Assessment

B.1. Water Quality

In formulating this assessment, we reviewed multiple sources of marine and freshwater data for the OLYM coastal strip, including information collected by federal and state agencies, Native American tribes, non-profit environmental organizations, and citizen science groups. We utilized a previous water quality assessment, the NPS's Water Resources Division's Baseline Water Quality Data Inventory and Analysis for OLYM (NPS 1999), as a reference.

B.1.a. Data Sources

The water quality data discussed in this report were extracted from number of sources, including:

- Washington State Department of Health (WDOH)
- Washington State Department of Ecology (WDOE)
- Washington State Department of Fish and Wildlife (WDFW)
- Washington State Conservation Commission (WSCC)
- Washington State Toxics Monitoring Program (WSTMP)
- NOAA's National Center for Coastal Ocean Sciences' (NCCOS) Center for Coastal Monitoring and Assessment
- Clallam County
- Coastal Observation and Seabird Survey Team (COASST)
- The Environmental Protection Agency's STOrage and RETrieval database (STORET)
- The Beach Environmental Assessment, Communication and Health (BEACH) Program, jointly administered by WDOH and WDOE
- EPA's Beach Advisory and Closing Online Notification (BEACON) Program
- EPA's Environmental Monitoring and Assessment Program (EMAP)
- The Surfrider Foundation's Blue Water Task Force (BWTF) and Rashguard.org; and
- Natural Resources Defense Council's (NRDC) report *Testing the Waters: a Guide to Water Quality at Vacation Beaches.*

B.1.b. Marine Water Quality

In October 1999, the NPS's Water Resources Division (NPS WRD) completed a baseline water quality data inventory and analysis report for OLYM (NPS 1999). The report describes existing data on surface water quality (both marine and freshwater) collected by various agencies and housed in the EPA national databases, including STORET. The data, covering the years 1901-1997, were evaluated against published EPA water quality criteria and instantaneous concentration values selected by the NPS WRD to identify potential water quality problems within the study area. Fourteen parameters exceeded water quality criteria at least once. For freshwater aquatic life, exceedances were found for chlorine, cadmium, copper, lead, mercury, silver, and zinc; dissolved oxygen and pH exceeded their criteria for both freshwater and marine aquatic life (NPS 1999). The EPA drinking water criteria were not met with respect to chlorine, cadmium, lead, mercury, thallium, and zinc (NPS 1999). Total coliform, fecal coliform, and turbidity "exceeded the WRD screening limits for freshwater and marine bathing, and aquatic life, respectively" (NPS 1999). The report, however, mainly concentrated on those areas of OLYM outside of the coastal strip.

Bacterial Contamination

The Washington Beach Environmental Assessment, Communication and Health (BEACH) program was developed in response to the BEACH Act of 2000. This legislation "required states with coastal recreational waters to adopt new or revised water quality standards by April 2004 for pathogens and for pathogen indicators for which the EPA has published criteria under the Clean Water Act" (NRDC 2006). The program is jointly administered by WDOE and WDOH, and monitors high-risk beaches for enterococci, bacteria considered to be indicators of water quality. The criteria for acceptable *Enterococcus* levels were established by the EPA in 1986 and have not been changed officially since then. Possible public health action (such as posting warning signs or closing beaches) is recommended if *Enterococcus* levels exceed the EPA criteria of "104 colonies of *Enterococcus* bacteria per 100 milliliters of water for a sample event or a geomean of 35 colonies of *Enterococcus* per 100 milliliters of water for a five-week time period" (WDOE 2006a).

The BEACH program monitors beaches in both Clallam and Jefferson counties; however, only five sites are located on the outer coast of the Olympic Peninsula, all of which are within Clallam County. Three sites (Sooes Beach, Hobuck Beach, and Neah Bay; Figure 27) are located north of the OLYM coastal boundary within the Makah reservation; sampling there is conducted by the Makah Tribe. Two additional sites are located in La Push (Figure 27) on the Quileute Tribe's reservation where sampling is conducted by the tribe. The La Push sites are bordered by the park on both sides. Due to the direction of prevailing currents, results from all sampling sites could be relevant to OLYM water quality concerns. Results are summarized in Table 4 below.

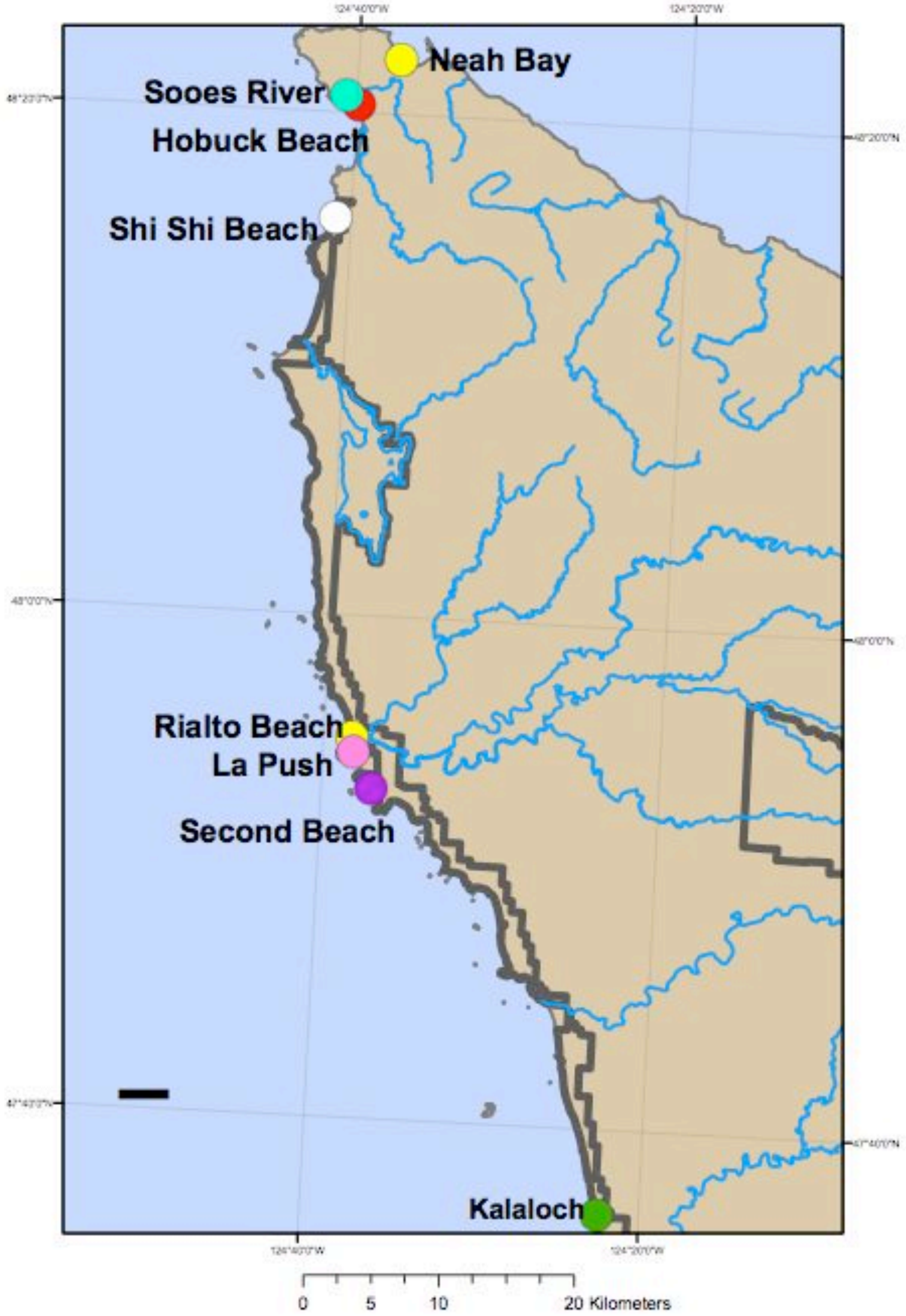


Figure 27. Sites monitored by the BEACH program and by the Surfrider Foundation for bacterial levels (map created by authors).

Table 4. Bacterial levels at Clallam and Jefferson County locations. Shaded boxes indicate exceedances (WDOE 2006a).

Date	**# of *Enterococcus* colonies/ 100mL H_20**				
	Sooes Beach	**Hobuck Beach**	**Neah Bay**	**La Push #1**	**La Push #2**
10/30/2006	13	51	13	N/A	N/A
10/25/2006	16	10	68	N/A	N/A
10/20/2006	<10	<10	16	N/A	N/A
12/20/2005	<10	30	77.7	<10	53.3
12/14/2005	<10	<10	65	<10	<10
12/8/2005	<10	<10	<10	N/A	N/A
12/7/2005	N/A	N/A	N/A	<10	<10
12/1/2005	10	<10	89	N/A	N/A
11/29/2005	N/A	N/A	N/A	10	<10
11/22/2005	<10	<10	<10	20	<10
11/17/2005	<10	13	10	N/A	N/A
11/15/2005	N/A	N/A	N/A	13	27
11/10/2005	<10	26	312	N/A	N/A
11/8/2005	N/A	N/A	N/A	219	10
11/2/2005	35	10	35	N/A	N/A
11/1/2005	N/A	N/A	N/A	155	52
9/15/2005	<10	13	<10	N/A	N/A
9/8/2005	<10	<10	<10	N/A	N/A
9/1/2005	<10	<10	<10	N/A	N/A
8/26/2005	<10	<10	<10	N/A	N/A
8/19/2005	<10	<10	<10	N/A	N/A
8/11/2005	<10	<10	13	N/A	N/A
8/4/2005	<10	13	<10	N/A	N/A
7/28/2005	<10	<10	<10	N/A	N/A
7/20/2005	<10	13	<10	N/A	N/A
7/14/2005	<10	<10	<10	N/A	N/A
7/7/2005	<10	<10	13	N/A	N/A

The results shown are the average of three samples; values that exceed the recommended level are highlighted in gray. In three instances in November 2005, *Enterococcus* levels exceeded EPA closure criteria of 104 colonies/100mL H_2O. The same bacterial beach water quality information is displayed for the public on the Earth911 Beach Water Quality website with results by location updated on a Google map (Earth911 2006).

In May 2006, WDOE solicited public comment regarding prioritization of beaches to be monitored weekly for bacteria; there was sufficient state funding to test about 65 out of the 900 or more beaches throughout the entire state (WDOE 2006b). Public opinion is one of over 60 parameters that are used to determine which beaches are chosen for testing; others include usage and potential fecal contamination sources. The BEACH program released a proposed list of beaches to be monitored; those within OLYM included First Beach and Second Beach both of which are on Quileute tribal lands (WDOE 2006b).

The Surfrider Foundation, in collaboration with Rashguard.org, also tracks and posts water quality information on their website (Surfrider 2006a). Several beaches within Clallam and Jefferson counties are listed; however, none fall within the OLYM coastal strip. Two sites (Hobuck Beach and Sooes Beach) are located just north of OLYM's northern coastal boundary in or near Makah Bay. Longitudinal water quality data for the sites are not listed; instead, daily updates on indications of water pollution are posted, for example from polluted runoff in the coastal zone after a rainfall event, sewage spills, or other acute incidents.

Surfrider's Olympic Peninsula chapter collaborated with OLYM to test bacterial levels at five beaches in OLYM (Table 5 and Figure 27) over the period 2003-2005 (Surfrider Blue Water Task Force 2006). Water samples were collected by Surfrider volunteers; the OLYM Lake Crescent water treatment plant conducted the bacteriological analyses. This sampling was conducted for approximately one year to provide background information regarding coastal bacterial levels. Given the low bacterial levels detected, the park chose a periodic monitoring approach in which sampling will occur at 5-10 year intervals.

Table 5. Summary of water quality sampling performed by Surfrider in partnership with OLYM, 2003-2005 (Surfrider.org).

	***E. coli* index samples**		***Enterococcus sp.* index samples**		
Location	**# Low/very low**	**# Moderate to high**	**# Low/very low**	**# Moderate to high**	**Total # of sample testing dates**
Shi Shi Beach	8	--	5	1	8
Rialto Beach	9	--	9	--	10
La Push	--	--	7	--	7
Second Beach	9	--	8	1	10
Kalaloch	4	--	4	--	4

Contaminants

NOAA's National Center for Coastal Ocean Science's (NCCOS) Center for Coastal Monitoring and Assessment maintains a 20-year database (1986-present) associated with the Mussel Watch program. Mussel Watch monitors bivalve and sediment samples for chemical contaminants at locations that are thought to be representative of coastal regions. The spatial and temporal nature of the database permits the determination of the coastal areas at greatest risk concerning environmental quality. While none of the Mussel Watch sampling sites are located within OLYM, sampling sites are located in areas within the region, specifically Willapa Bay, Grays Harbor, Cape Flattery, and Neah Bay (Figure 28) (NOAA NCCOS 2006). Currently there appear to be limited data available for the Washington coastal region.

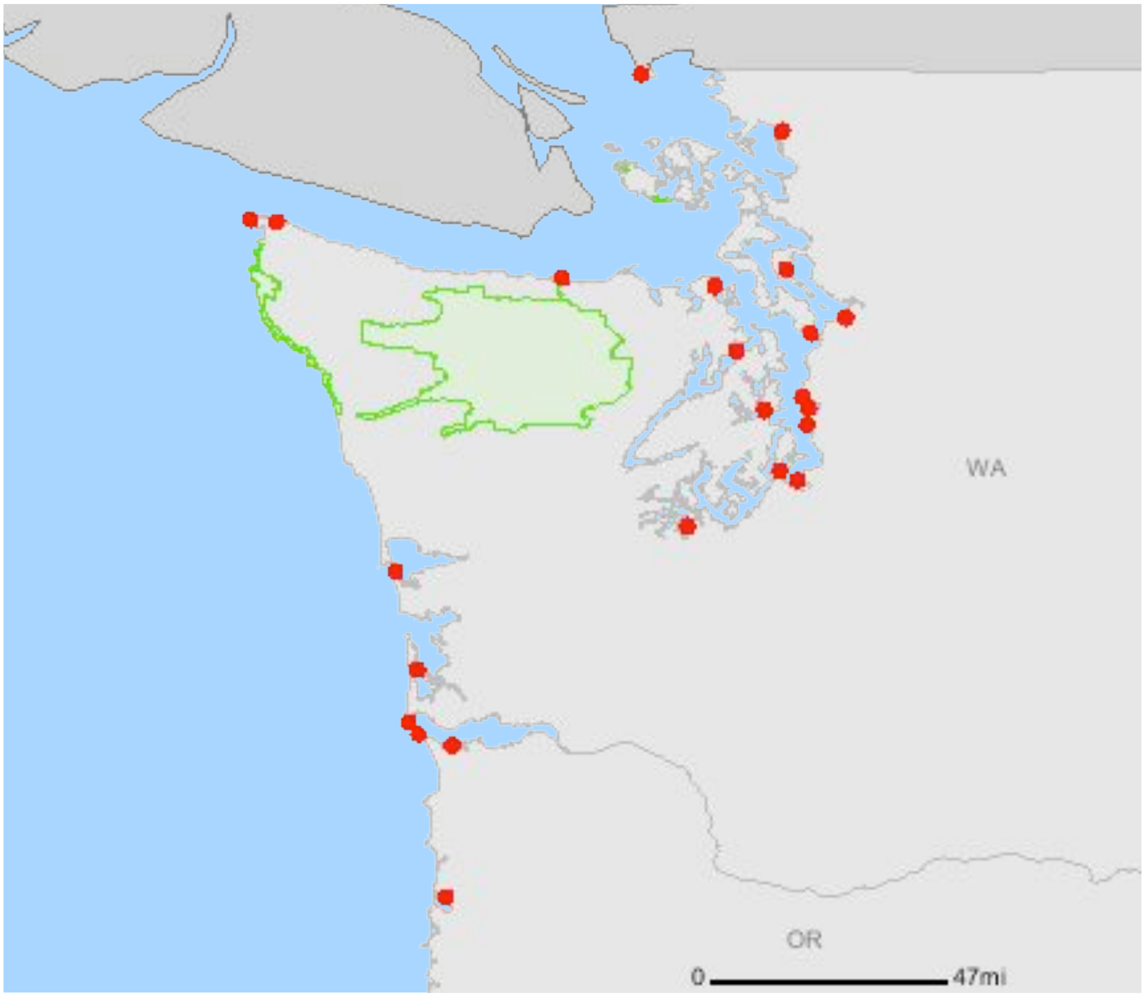


Figure 28. NCCOS Mussel Watch Sites (NOAA NCCOS 2007).

While the WDOE does maintain a Marine Sediment Monitoring Program, all of the current sampling locations are within the Puget Sound region, and therefore not relevant to the coastal strip (WDOE 2006c).

Marine Biotoxins/Harmful Algal Blooms
WDOH manages a general biotoxin monitoring program on the outer coast in which state, tribal, county, and local agencies, as well as commercial shellfish ventures and federal agencies, collect samples from various bivalve species. Samples are analyzed for the presence of paralytic shellfish poison (PSP) and domoic acid (DA). When the level of PSP in a single sample of a particular shellfish species exceeds the U.S. Food and Drug Administration (FDA) action level of 80 micrograms of PSP toxin in 100 g of shellfish tissue, WDOH closes commercial and recreational harvest areas for that species. DA closure levels were reassessed by WDOH in September 2000 and established at 20 ppm in sample tissue. Closed areas are reopened only when continued monitoring assures a return to safe conditions (Determan 2003).

We obtained WDOH biotoxin data collected through the general biotoxin monitoring program from 1990 through October 2005 (WDOH, Jerry Borchert, pers. comm., 11/10/05). A total of 1745 samples from locations within or adjacent to OLYM were reviewed. PSP and DA were detected on the outer coast as early as 1992. Over the period sampled, PSP levels exceeded health standards 21 times; DA levels exceeded health standards 195 times over the same period (Figures 29-32).

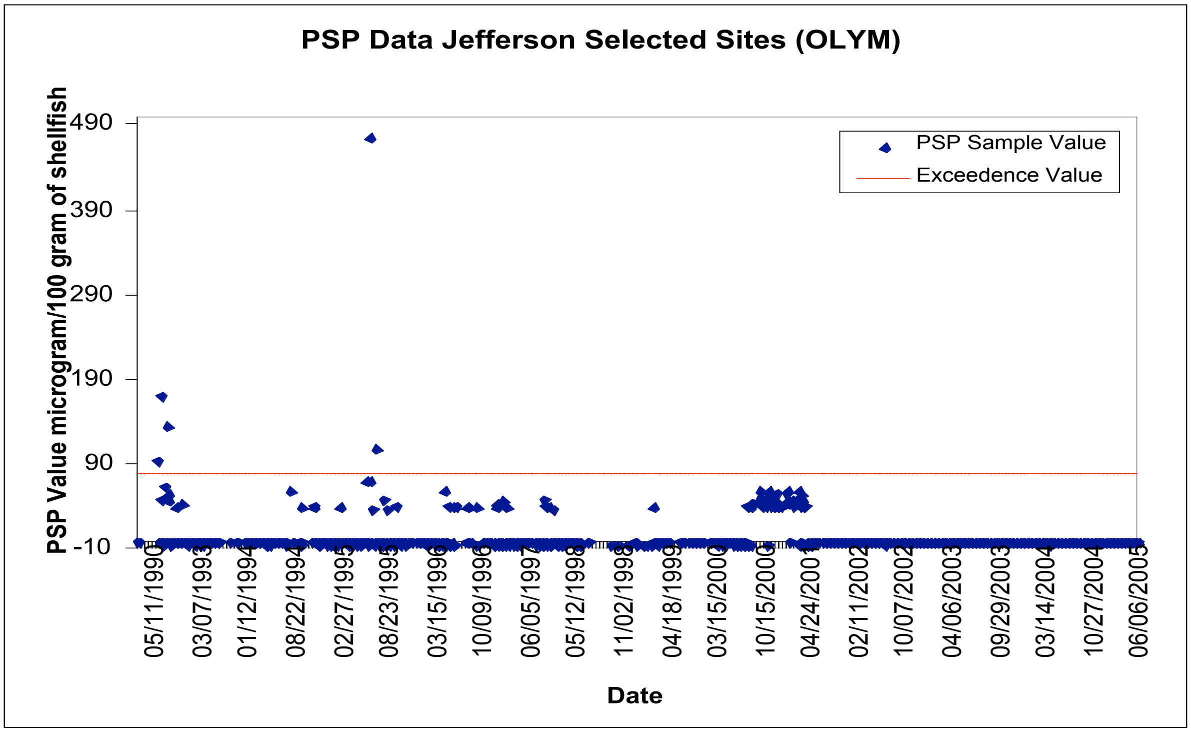


Figure 29. PSP exceedances Jefferson County Sites, 1990-2005 (WDOH).

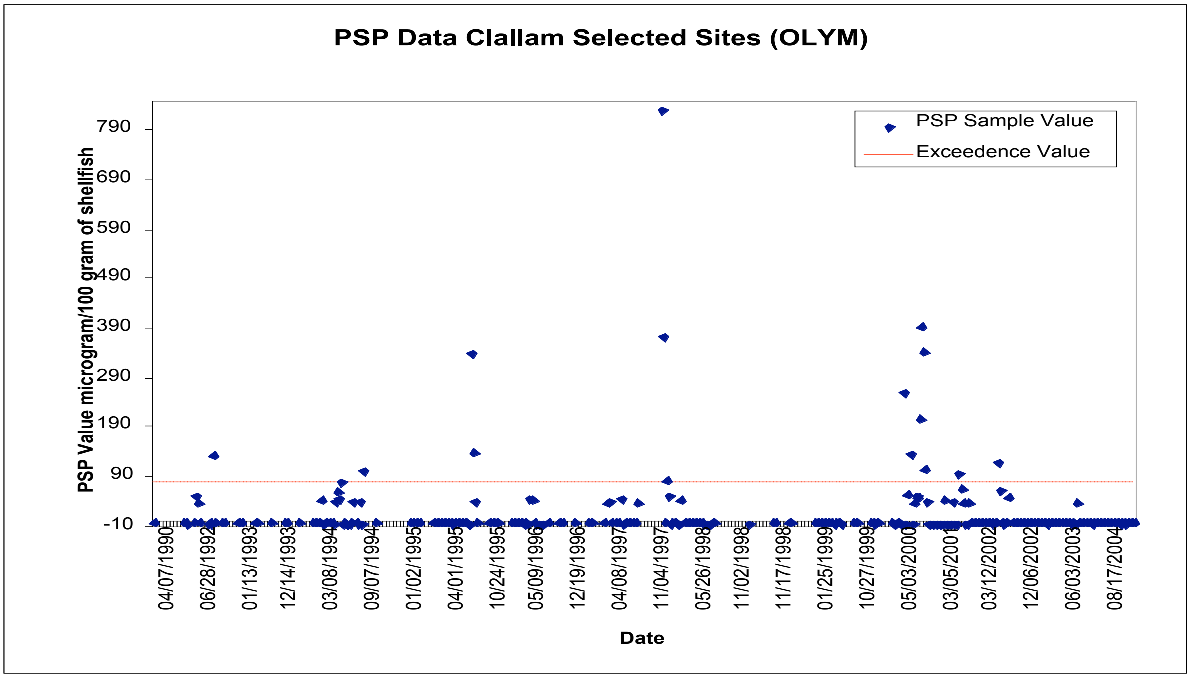


Figure 30. PSP exceedances Clallam County Sites, 1990-2005 (WDOH).

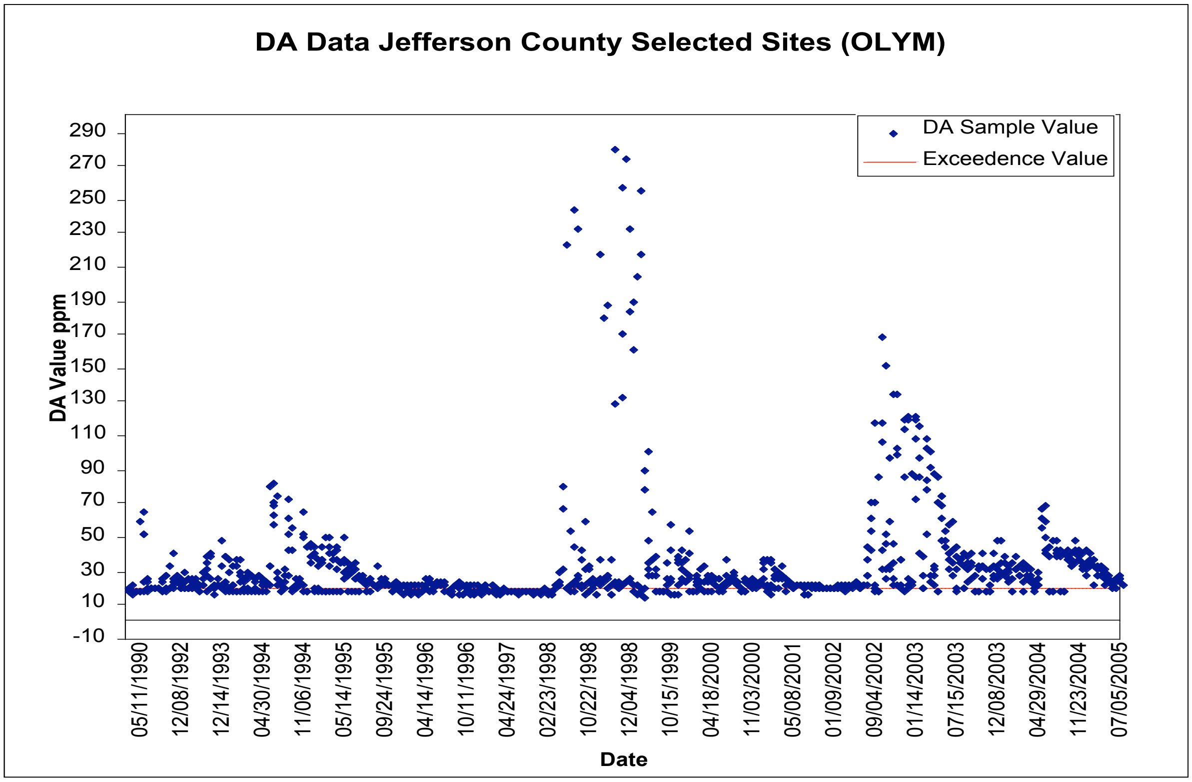


Figure 31. DA exceedances Jefferson Sites, 1990-2005 (WDOH).

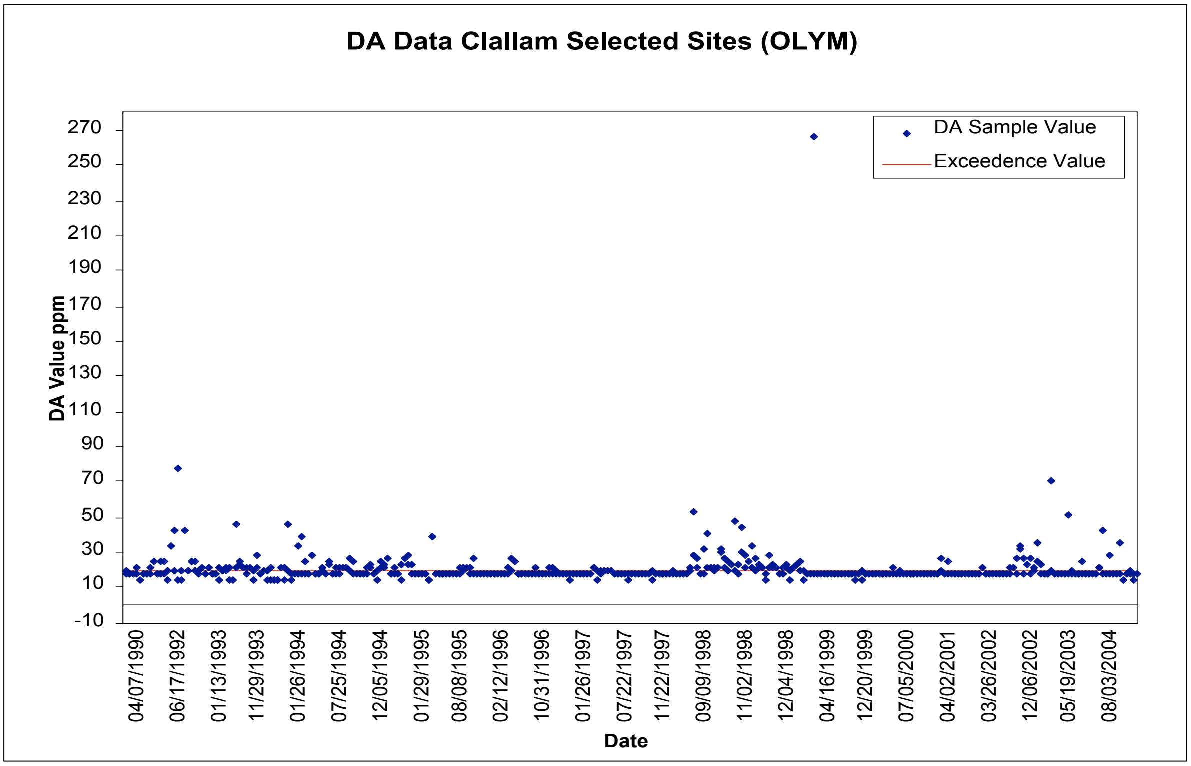


Figure 32. DA exceedances Clallam County Sites, 1990-2005 (WDOH).

WDOH monitors molluscan shellfish tissue samples taken from shellfish growing areas and recreational harvesting areas for marine biotoxins, specifically saxitoxins (algal compounds responsible for PSP) and DA (WDOH 2006a). Outer coast shellfish are monitored for the presence of biotoxins by WDOH and the Olympic Region Harmful Algal Blooms (ORHAB) program. (The risk of HABs to the Olympic coast is discussed further in Section C.1.).

WDOH data indicating threats to shellfish growing areas are available from 2001-2004; no threats to shellfish growing areas on the outer coast were detected in 2001 and 2002, although locations *within* Grays Harbor and Willapa Bay were characterized as threatened. The “threatened” status indicates declining water quality or identified pollution sources. This characterization means that these pollution sources may affect that status of the growing area waters. Grays Harbor is listed in the 303(d) list for fecal coliform. In 2003 and 2004, threats to growing areas were detected both on the outer coast and within Grays Harbor and Willapa Bay. While all threatened areas were located to the south of OLYM, the ocean conditions responsible for such threats could possibly extend to OLYM beaches (WDOH 2006b). WDOH also maintains a website indicating recreational shellfish beaches closed due to biotoxins or pollution (WDOH 2006c).

In April 2006, an “’unexpected population decline’” in razor clams (*Siliqua patula*) on Kalaloch Beach caused the closure of the fishery until at least October 2006. The fishery was reopened in March 2007 to allow a two-day razor clam dig (NPS 2006d). In response to this decline, WDFW, the Quinault Nation, and OLYM collected and tested about 60 razor clams and found that approximately half the clams were infected with NIX (nuclear inclusion X), a disease that can cause mortality in razor clams. NIX is a poorly understood disease caused by a procaryotic parasite that interferes with gill function in razor clams (Elston 1986). The origin of the parasite is not known; however, warmer ocean water temperatures, for example those associated with from El Niño events, may increase the frequency of the parasite (Olson and Pierce 1988). The disease is harmless to humans.

NIX was responsible for killing 95% of the WA coastwide population of razor clams in the late 1980s. It is estimated that the clam population declined from 20 million clams in June of 1983 to less than one million in February of 1984 (Elston 1986). Elston (1986) collected and examined 147 razor clams from Washington Beaches and found 100% prevalence of infection; no samples were taken from beaches within OLYM.

Dissolved Oxygen

Hypoxic conditions were reported from coastal Oregon in the summers of 2002-2007. Hypoxic conditions in summer 2006 extended to the southern boundaries of OLYM near the Quinault Indian Nation. Benthic and water column respiration, combined with changes in summer wind forcing and associated alterations in upwelling patterns have been proposed as a mechanism for observed hypoxic events.

Since 2004, OCNMS has conducted seasonal monitoring of dissolved oxygen (DO) levels in Sanctuary waters adjacent OLYM. DO concentrations were determined from shipboard surveys in the summer and early fall of 2004 and 2005. Moorings capable of continuous monitoring of DO were deployed during the summer and early fall of 2006 and 2007. Measurements from moorings were augmented by shipboard surveys, which were continued at a reduced level of effort in 2006 and 2007. Hypoxic conditions (DO <2mg/L) were not observed in 2004 or 2005, although near-hypoxic conditions (DO <3mg/L) were observed frequently in 2004 and occasionally in 2005 in areas to the south of OLYM. In 2006, hypoxia was observed in May and June extending from northern areas of OLYM (Cape Alava) to areas south of OLYM (Cape Elizabeth). Hypoxic conditions were again observed in June and July 2007 in areas to the south of OLYM (Cape Elizabeth). Crab mortality (presumably associated with hypoxia) was observed as far north as Kalaloch Beach in June 2007.

B.1.c.Freshwater Water Quality

Washington State 303(d) Water Quality Assessment

In order to meet the requirements of Section 303(d) of the Clean Water Act, Washington State is required to submit water quality assessment reports to the EPA. Water bodies are divided into five classification categories, ranging from 1 (water meets tested standards) to 5 (standards violated). Streams in both WRIA Areas 20 and 21 (Figure 8) were listed according to Section 303(d) requirements in the 1998 WDOE report. Of interest in the more recent WDOE 2004 report are Category 5 waters. Category 5 waters are those "from which at least one characteristic or designated use is impaired, as evidenced by failure to attain the applicable water quality standard for one or more pollutants" (WDOE 2006e).

2004 Category 5 listings for freshwater bodies in WRIA 20 (Soleduck-Hoh) and WRIA 21 (Queets-Quinault) are listed in the assessment (WDOE 2006e; WDOE 2006f). Tables 6 and 7 provide details on these listings. [Note that although each of these rivers crosses the coastal strip, all exceedances were measured in river reaches outside OLYM boundaries].

Table 6. 2004 Category 5 listings in WRIA 20 (Water Medium) (WDOE 2006e)
* *Continuous temperature measurements were taken, but results were reported as single day maximums. A Category 5 listing is continued from the 1998 assessment based on multiple excursions from continuous monitoring.*

Waterbody Name	Parameter	Details
Alder Creek	Temperature*	7-day mean of daily maximum temperature of 17.8 °C during 1992 (Hoh Tribal data)
Anderson Creek	Temperature*	7-day mean of daily maximum temperature of 16.6° C during 1992 (Hoh Tribal data)
Bear Creek	Dissolved oxygen	Four samples beyond the criterion collected on the following days: 8/2/2000, 9/15/2001, 10/12/2002, 8/16/2002 (Streamkeepers data)
Beaver Creek	Temperature*	44 excursions out of 80 samples near the mouth the criterion during 1994 (Quileute Tribe data)
Big River	pH	Four excursions beyond the criterion out of 16 samples collected between 01/93 - 12/97 (STORET) Three excursions beyond the criterion out of 16 measurements collected in 1993 and 1994 (Meyer and Brinkman 2001)
Bogachiel River	Temperature*	Between 1992 and 1995, Quileute Tribe data show: • Six excursions beyond the criterion out of seven samples at RM 0 • Two excursions beyond the criterion out of 2 samples at RM 8.7 • Six excursions beyond the criterion out of seven samples at RM 9 • Four excursions beyond the criterion out of five samples at RM 9.8 • Two excursions beyond the criterion out of two samples at RM 12.6 • Five excursions beyond the criterion out of six samples at RM 15.7 • Five excursions beyond the criterion out of five samples at RM 20
Calawah River, S.F.	Temperature*	Olympic National Forest unpublished data show: 7-day mean of maximum daily temperature of 18.7° C on the week ending 8-9-2000, with a maximum daily temperature of 19.6° C from continuous measurements

		collected in 2000 at RM 5.96 (ONF provide rationale that the measured excursions are a natural condition) 7-day mean of maximum daily temperature of 19.48° C on the week ending 7-27-2002, with a maximum daily temperature of 20.31° C from continuous measurements collected in 2002 at RM 5.96 (listing reviewed by WDOE for natural conditions, but possibility that human activities contributed to excursions could not be ruled out) 7-day mean of maximum daily temperature of 17.7° C on the week ending 7-12-2001, with a maximum daily temperature of 18.9° C from continuous measurements collected in 2001 at RM 5.96 (station ID SF Calawah)
Coal Creek	pH	Six excursions beyond the criterion out of 14 samples collected between 01/93 - 12/97 (STORET) Two excursions beyond the criterion out of three samples collected between 01/93 - 12/97 (STORET) Six excursions beyond the criterion out of 14 measurements collected in 1993 and 1994 (Meyer and Brinkman 2001)
Coal Creek	Temperature*	Numerous excursions beyond the criterion between 6/23/92 and 9/28/92 (Quileute Tribe data)
Crooked Creek	pH	Eight excursions beyond the criterion out of 15 samples collected between 01/93 - 12/97 (STORET) Eight excursions beyond the criterion out of 15 samples collected in 1993 and 1994 (Meyer and Brinkman 2001)
Crooked Creek, N.F.	Temperature*	Numerous excursions beyond the criterion between 6/23/92 and 9/28/92 (Quileute Tribe data)
Dickey River	Fecal Coliform	WDOE Ambient Monitoring Station 20D070 (Dickey R nr La Push) shows a geometric mean of 51 exceeds the criterion and that 33% of the samples exceeds the percentile criterion from three samples collected during 1996. In 1997, the same station shows a geometric mean of 13 does not exceed the criterion and that 22% of the samples exceeds the percentile criterion from nine collected samples (Hallock 2001)
Dickey River, E.F.	Temperature*	Numerous excursions beyond the criterion between 7/19/90 and 9/20/90 (Quileute Tribe data)
Dickey River, E.F.	Temperature*	Numerous excursions beyond the criterion between 7/19/90 and 9/20/90 (Quileute Tribe data)
Dickey River, M.F.	Temperature*	Two excursions beyond the criterion between 7/24/91 and 7/30/91 (Quileute Tribe data)
Dickey River, W.F.	Temperature*	Numerous excursions beyond the criterion between

		7/19/90 and 10/14/91 (Quileute Tribe data)
Elk Creek	Temperature*	10 excursions beyond the criterion out of 62 samples (16%) at RM 1.8 during 1994 (Horrocks and Lombard 1995)
Fisher Creek	Temperature*	7-day mean of daily maximum temperature of 19.8° C during 1992 (Hoh Tribal data)
Lake Creek	Dissolved oxygen	Seven excursions beyond the criterion out of seven samples at RM 2 between 1994 and 1995 (Quileute Tribe data) Four samples beyond the criterion collected on the following days: 8/3/2000, 8/5/2001, 8/24/2003, 10/15/2002 (Streamkeepers data) Eight excursions beyond the criterion out of 20 samples at RM 2.75 between 1992 and 1995 (Quileute Tribe data)
Lake Creek	Temperature*	Five excursions beyond the criterion out of seven samples at RM 2 between 1994 and 1995 (Quileute Tribe data) Criterion was exceeded on the following four days: 8/3/2000, 8/5/2001, 9/15/2001, 8/24/2003 (Streamkeepers data)
Line Creek	Temperature*	7-day mean of daily maximum temperature of 17.7° C during 1992 (Hoh Tribal data)
Maple Creek	Temperature*	7-day mean of daily maximum temperature of 16.1° C during 1992 (Hoh Tribal data)
Maxfield Creek	Temperature*	Numerous excursions beyond the criterion between 6/22/92 and 9/28/92 (Quileute Tribe data)
Nolan Creek	Temperature*	7-day mean of daily maximum temperature of 18.7° C during 1992 (Hoh Tribal data)
Owl Creek	Temperature*	18 excursions beyond the criterion in 1991 (Hatten 1992) 7-day mean of daily maximum temperature of 18.1° C during 1992 (Hoh Tribal data)
Sitkum River	Temperature*	Olympic National Forest unpublished data show a: 7-day mean of maximum daily temperature of 20.44° C on the week ending 7-27-2002, with a maximum daily temperature of 21.64° C from continuous measurements collected in 2002 at RM 0.108 (Ecology staff reviewed this listing in 2003 for natural conditions, but could not rule out the possibility that human activities contributed to the excursion(s).) 7-day mean of maximum daily temperature of 19.1° C on the week ending 8-9-2000, with a maximum daily

		temperature of 20.2° C from continuous measurements collected in 2000 at RM 0.108 7-day mean of maximum daily temperature of 20.4° C on the week ending 7-29-1998, with a maximum daily temperature of 21.8° C from continuous measurements collected in 1998 at RM 0.108
Siwash Creek	Dissolved oxygen	One sample beyond the criterion collected on 10/8/2002 (Streamkeepers data) Two excursions beyond the criterion in 1993 and 1994 (Meyer and Brinkman 2001)
Soleduck River	pH	Between 01/93-12/97, high pH was measured: • Two excursions out of three samples collected (Sol Duc River at the Resort Trailer Park); • Three excursions out of three samples (Sol Duc River at Hot Springs Resort Pool Outlet); • One excursion out of three samples (Sole Duc River at the Resort Concrete Bridge) This may be a natural condition. It is unclear whether the high pH readings are the result of anthropogenic sources or due to natural geothermal activity. More study is needed (STORET)
Soleduck River	Temperature*	Between 1992 and 1995: • Three excursions beyond the criterion out of four samples at RM 6.5 • Three excursions beyond the criterion out of three samples at RM 13 • Two excursions beyond the criterion out of three samples at RM 19 • Three excursions beyond the criterion out of three samples at RM 22.1 • Two excursions beyond the criterion out of two samples at RM 23.75 • Three excursions beyond the criterion out of three samples at RM 44.9 (Quileute Tribe data)
South Creek	Dissolved oxygen	One sample beyond the criterion collected on 01/24/05 (Streamkeepers data) Seven excursions beyond the criterion out of 14 samples collected during 1993 and 1994 (STORET) Seven excursions beyond the criterion in 1993 and 1994 (Meyer and Brinkman 2001)
Split Creek	Temperature*	7-day mean of daily maximum temperature of 22.2° C during 1992 (Hoh Tribal data) 47 excursions beyond the criterion in 1991 (Hatten

		1992)
Willoughby Creek	Temperature*	16 excursions beyond the criterion in 1991 (Hatten 1992) 7-day mean of daily maximum temperature of 18.1°C during 1992 (Hoh Tribal data)
Winfield Creek	Temperature*	7-day mean of daily maximum temperature of 18.6° C during 1992 (Hoh Tribal data)

Table 7. 2004 Category 5 listings in WRIA 21 (Water Medium) (WDOE 2006f)

Waterbody Name	Parameter	Details
Kalaloch Creek	Temperature	Hoh Tribe data shows a 7-day mean of daily maximum temperature of 16.6°C during 1992, and 10 excursions beyond the criterion between 7/1/92 and 8/31/92.

WDOE River and Stream Water Quality Monitoring

WDOE posts its River and Stream Water Quality Monitoring data on its website (WDOE 2006g). Data from five Queets River sampling sites in WRIA 21 are available on this website, but the data are intermittent and none are recent. The most recent data available for four of the Queets River locations are from 1974 and 1981; the most recent data from the fifth sampling location were collected in 1994. Due to age and inconsistency, the Queets River sampling data are not incorporated into this document. However, more recent data are available for a Hoh River sampling site in WRIA 20 and are summarized here.

The Hoh River water quality monitoring station 20B070 is located near the DNR campground just before the Hoh River bridge on Highway 101 (WDOE 2006h). Sampling at this location occurred intermittently from 1960 to 1993 and has been continuous from 1994 to 2006. WDOE rates general water quality using a formula to derive a Water Quality Index (WQI) score. WQI scores can range from 1 to 100; scores below 40 indicate poor water quality, whereas scores between 40 and 79 indicate moderate water quality. Scores between 80 and 100 indicate good water quality that meets expectations.

Constituent attributes measured by WDOE include fecal coliform bacteria, dissolved oxygen, pH, suspended solids, temperature, total persulf nitrogen, total phosphorous, and turbidity. These constituents were measured at station 20B070 on a monthly basis every year from 1994 to 2005. Suspended solids and turbidity were rated as poor in 1997, 1999, 2004, and 2005. In 2004, total phosphorus also was rated as poor. The remainder of the constituents was rated as either moderate or good between 1994 and 2005.

Constituent scores were combined into overall water quality index (WQI) scores for each year from 1994 to 2005. The results are shown in Figure 33 below.

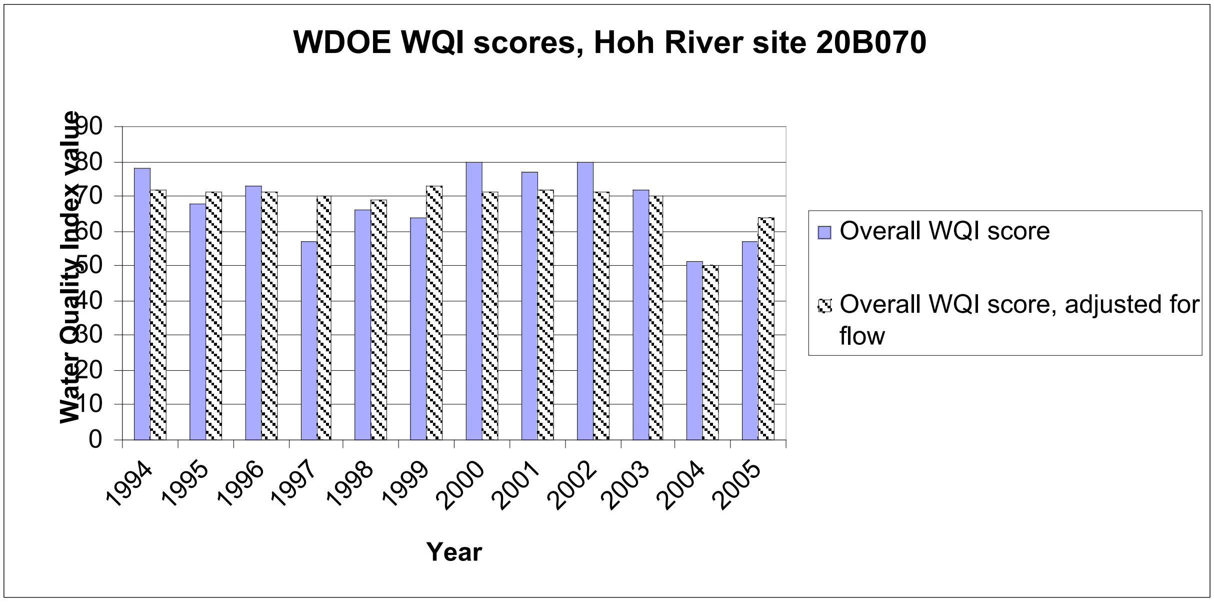


Figure 33. Water quality index scores for the Hoh River site (WDOE 2006h).

Streamkeepers of Clallam County Monitoring

Streamkeepers (2004) published a preliminary evaluation or “report card” to enable citizens to evaluate the health of watersheds throughout Clallam County. The report summarizes the status of water quality and habitat conditions in a non-technical format, identifies factors of particular concern, and makes watershed-specific recommendations to address factors of concern. Sampling was conducted at stations throughout the county (Figure 34).

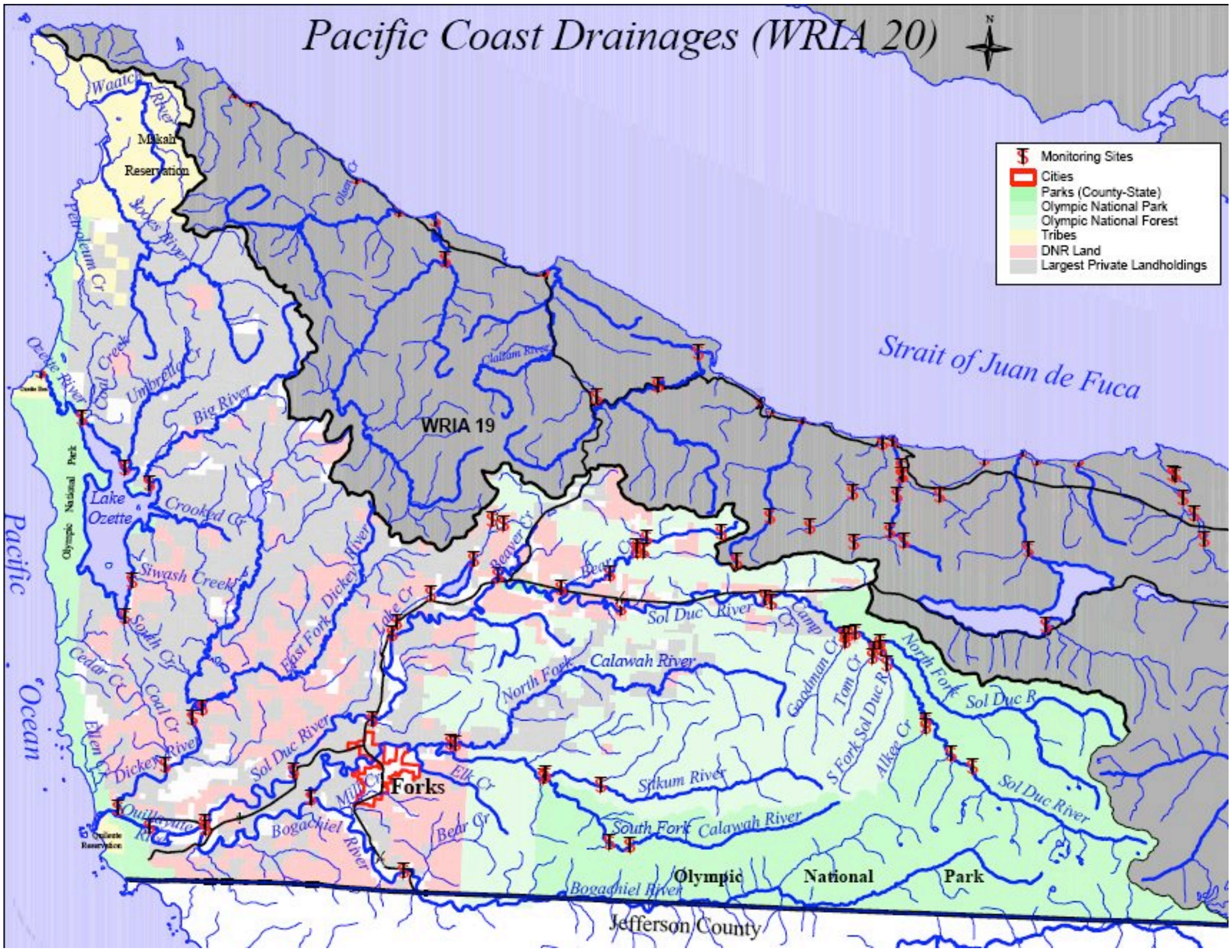


Figure 34. Pacific coast drainages and water quality sampling sites in Clallam County (Streamkeepers 2004).

The authors of the report rate water quality and aquatic habitats as:

Healthy: Ecologically intact; no known significant impacts to human health or salmonid populations or life stages.

Compromised: Showing signs of degradation; slight exceedance of human health-based water quality standards; impacts to one or more salmonid life-stages.

Impaired: Not likely to support self-sustaining salmon populations; exceedance of human health-based water quality standards.

Highly Impaired: Highly adverse to salmon and possibly other life forms; substantial exceedance of human health-based water quality standards.

Here we summarize conditions reported for freshwater bodies in or adjacent to the OLYM coastal strip (Lake Ozette and Ozette River, Dickey River and Quillayute River). Consistent with the report (Streamkeepers 2004) we use the term "impaired" as used by that report's authors, defined above. Note that the term is used differently by some other authors and agencies, including the NPS.

The Ozette River watershed is rated as impaired. Water quality conditions are rated as compromised with a confidence rating of moderate. Elevated temperature is the factor of concern. Note, however, that several sites including the Ozette River at rivermile 0 were rated as healthy. Overall habitat integrity was rated as impaired to highly impaired, with a confidence rating of high. Factors of concern include impacts resulting from past watershed alterations; loss of off-channel habitat; excessive sedimentation; poor riparian conditions; non-coniferous tress dominate, which will be unable to supply future large woody debris; and warm temperatures and low dissolved oxygen.

The Dickey River is rated as impaired. Water quality conditions are rated as compromised or impaired in the lower reaches, and as healthy in East Fork and Coal Creek tributary. Water temperature is the factor of concern. The confidence in these ratings is moderate. Overall habitat integrity is rated as impaired to highly impaired, with a confidence rating of moderate. Factors of concern include blockages for fish passage; riparian roads forming dikes, disconnecting habitat, and causing sedimentation; collapsing banks add sediment and degrade habitat; fine sediments are high, resulting in poor spawning habitat quality and quantity; lack of large woody debris in some reaches; warm temperatures; and wind-thrown trees resulting in degraded riparian corridors and a lack of buffers.

The mainstem of the Quillayute River is rated as impaired. Confidence in this rating is moderate. Factors of concern include high temperatures and low dissolved oxygen. Overall habitat integrity is rated as impaired to highly impaired, with a confidence rating of moderate. Factors of concern include riparian roads forming dikes, disconnecting habitat, and causing sedimentation; lack of large woody debris in the mainstem; warm temperatures; and estuarine habitat is altered, extremely limited and impacted by upstream problems.

Other Reports on Freshwater/Watershed Resources

The Washington State Conservation Commission (WSCC) published documents from their Salmon and Steelhead Habitat Limiting Factors Water Resource Inventory for different areas of Washington State (e.g., Smith 2000; Smith and Caldwell 2001). The Washington State Legislature requested these reports in 1998 as part of the state's salmon recovery program. The assessments are organized by WRIA (Water Resources Inventory Area). Two of these reports are relevant to OLYM, including those on WRIA Areas 20 (Soleduck-Hoh; Smith 2000) and 21 (Queets-Quinault; Smith and Caldwell 2001). The reports contain descriptions of general watershed conditions, information about the salmon and steelhead stock status in the various basins found in the WRIAs, and lists of habitat limiting factors in different basins, streams, rivers, and creeks. The limiting factors detailed include loss of access to spawning and rearing habitat, floodplain conditions, streambed sediment conditions, riparian conditions, water quality, water quantity, estuarine and nearshore habitat, lake habitat, and biological processes. Water quality factors addressed include temperature, dissolved oxygen, toxics that directly affect salmonid production, turbidity, and in some cases, fecal coliform problems. Data gaps and needs are also listed. Another source consulted for information on water resources in WRIA 20 was Hook (2004), which expanded on the work of Smith (2000). The results of these reports are presented below by WRIA.

WRIA 20 – Soleduck-Hoh

WRIA 20 is comprised of five main basins: Wa'atch, Sooes, Ozette, Quillayute, and Hoh, with some sub-basins.

Wa'atch and Sooes Basins

In both the Wa'atch and Sooes basins there generally are insufficient data to assess habitat conditions (Smith 2000; Hook 2004). Some concerns for these basins include blockages with resulting riparian road floodplain impacts; in addition, high water temperatures have been detected in the Sooes River and Wa'atch River (Hook 2004), although specific data to assess the causes have not yet been found (Smith 2000; Hook 2004). Other exceedances have been found in the Sooes River (dissolved oxygen), Wa'atch River (dissolved oxygen, pH), and Educket River (dissolved oxygen, pH) (Hook 2004). The stock status of many species is depressed in streams of these two basins, which suggests a lack of marine-derived nutrients.

Ozette Basin

Issues of concern for the Ozette Basin include sedimentation, warm temperatures, LWD removal, toxins, and invasive species (Smith 2000).

Sediment is a major limiting factor and has degraded habitat for lake spawning sockeye salmon. Although the cause of these excess sediment inputs is not certain, Smith (2000) found high road densities in the basin. In addition to roads, mass wasting is believed to be a major cause of excess sediment (Dlugokenski *et al.* 1981 *in* Hook 2004). Tributaries to Lake Ozette, such as Big River and Umbrella Creek, deliver find sediment, which can cause visibility and turbidity problems (Hook 2004).

High temperatures, above the preferred range of salmonids, have been detected on the upper Ozette River in the summer (Meyer and Brenkman 2001 *in* Hook 2004). High temperatures have also been detected in Lake Ozette, although these are probably "naturally high, in part due to the color of the water (tannins absorb infrared light very effectively) and to the low flows into the lake" (Crewson *et al.* 2004 *in* Hook 2004).

The removal of LWD is believed to have destabilized channel morphology in tributaries of the basin, leading to degraded spawning and rearing habitat (Haggerty 2004 draft *in* Hook 2004). LWD levels are rated "poor" on the lower Big River, parts of Siwash Creek, and parts of South Fork Crooked Creek, and "good" in Crooked Creek, North Fork Crooked Creek, parts of South Fork Crooked Creek, lower Siwash Creek, middle South Creek, and the middle reaches of Big River (Smith 2000). In addition, the Ozette River has been cleared of LWD, which Smith (2000) believes has contributed to reduced water level fluctuations in Lake Ozette. A spit formed near the Ozette River mouth between 1950 and 1997 "that became permanent enough to support the growth of beach rye and accumulated stable LWD," and which has contributed to changes in channel morphology (Figure 35; Smith 2000).

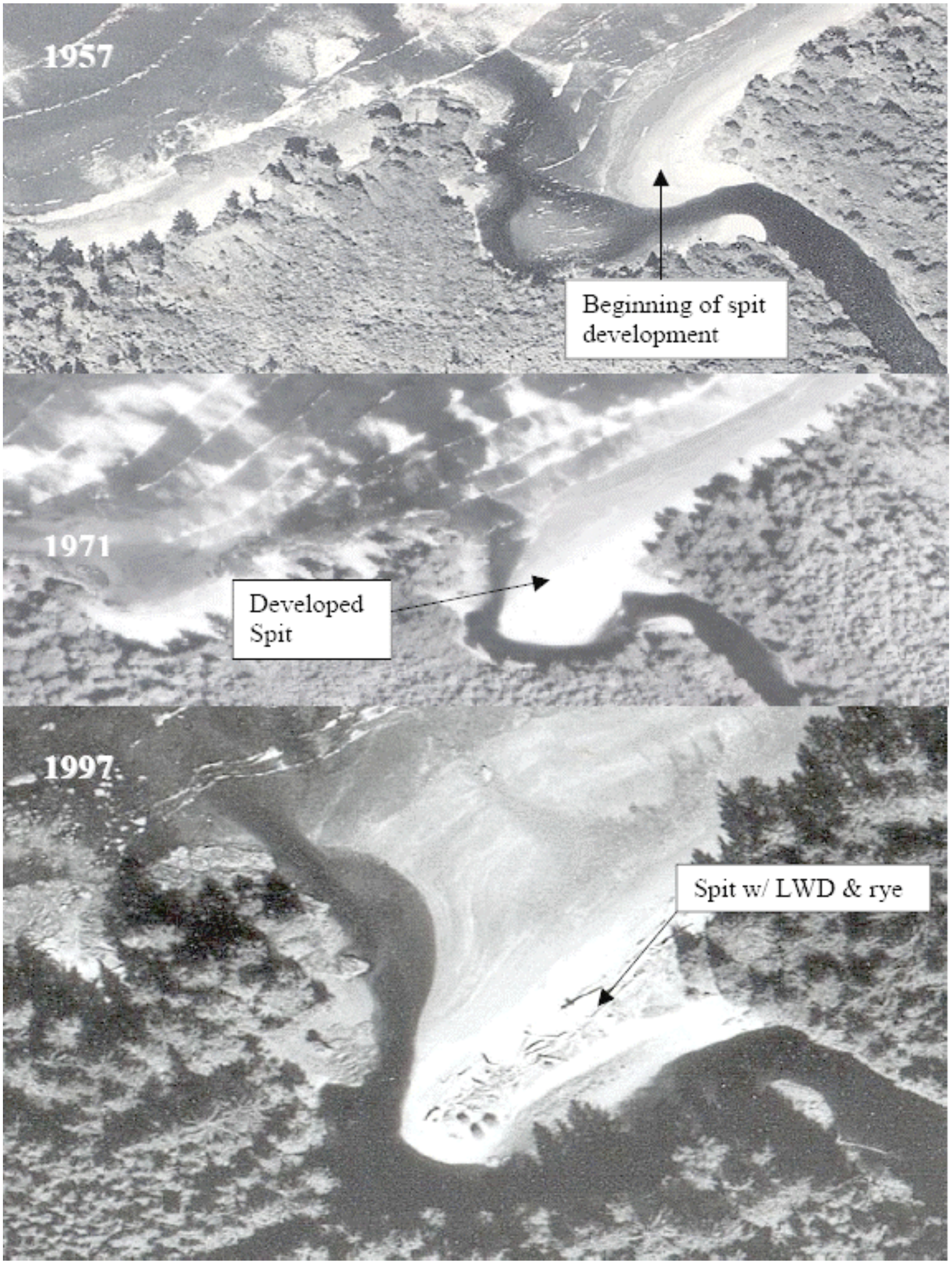


Figure 35. Channel changes to the Ozette River, 1957-1997 (Smith 2000).

WDOE manages the Washington State Toxics Monitoring Program (WSTMP), which evaluates fish tissue and surface water samples for toxins in freshwater environments within Washington State. Lake Ozette falls within the purview of this program and is one of the locations for which sampling has occurred. The 2002, 2003 and 2005 WSTMP data do not include information for Lake Ozette. However, the 2004 data set does include Lake Ozette sample results (Table 8) (WSTMP 2006).

Table 8. Summary of WSTMP fish tissue sampling and analyses at Lake Ozette, 2001-2004 (WSTMP 2006).
** Items marked with an asterisk indicate target analytes for which data exist elsewhere. An asterisk does not mean that the analyte is not present or that analyte levels have not been recorded.*

				----------------- Target Analytes -----------------					
Species	**Sample Year**	**# Fish Used**	**Skin Status**	**OCPest PCB PBDE**	**3PCB & 3DDT**	**Lipids**	**Hg**	**PCDD PCDF**	**PCB congeners**
Cutthroat trout	2004	3	on	Yes	*	Yes	Yes	-	-
Largemouth bass	2004	10	on	Yes	*	Yes	Yes	-	-
Northern pikeminnow	2004	10	on	Yes	*	Yes	Yes	Yes	Yes
Yellow perch	2004	10	on	Yes	*	Yes	Yes	-	-

Data for four edible fish species from Lake Ozette (cutthroat trout, largemouth bass, northern pikeminnow, and yellow perch) analyzed by the WSTMP (2006) indicate the presence of over 30 target analytes, including organochlorine pesticides, PCBs (polychlorinated biphenyls), PBDEs (polybrominated diphenyl ethers) and DDT (dichloro-diphenyl-trichloroethane*)*, ranging in concentration from 0.11 μg/kg to 11.2 μg/kg of wet fish muscle tissue. The WSTMP report notes that data for PCBs and DDTs found in fish tissue samples from Lake Ozette are “not verified, validated, or assessed for usability”; consequently, we make no further interpretation of these data.

Invasives species, such as Reed canarygrass, have been found on the shores of Lake Ozette, and along the banks of tributaries that drain into the lake, including Umbrella Creek, Big River, and Siwash Creek (Smith 2000).

Quillayute Basin
The Quillayute is the largest basin in WRIA 20 and issues of concern include sedimentation, warm temperatures, LWD removal, and degraded riparian habitat. The Quillayute Basin contains four sub-basins: the Dickey, Soleduck, Bogachiel, and Calawah, all of which drain into the Quillayute estuary (Smith 2000). This estuary, the largest in the WRIA, has been altered through dredging, armoring, and diking, and estuarine habitat has therefore been extremely limited. Dredging, which has occurred since 1949, has increased substrate instability and created poor spawning habitat by increasing water flow speeds (Smith 2000). The habitat most affected includes surf smelt spawning grounds and kelp and eelgrass habitat, which are important resources for salmonids. Increased sedimentation and water flows have become a concern for the estuary, and the most likely causes include problems upstream like incised channels, reduced LWD levels, and a lack of hydrologic maturity (Smith 2000). Figure 36 below shows changes in the channel near the Quillayute River mouth over time.

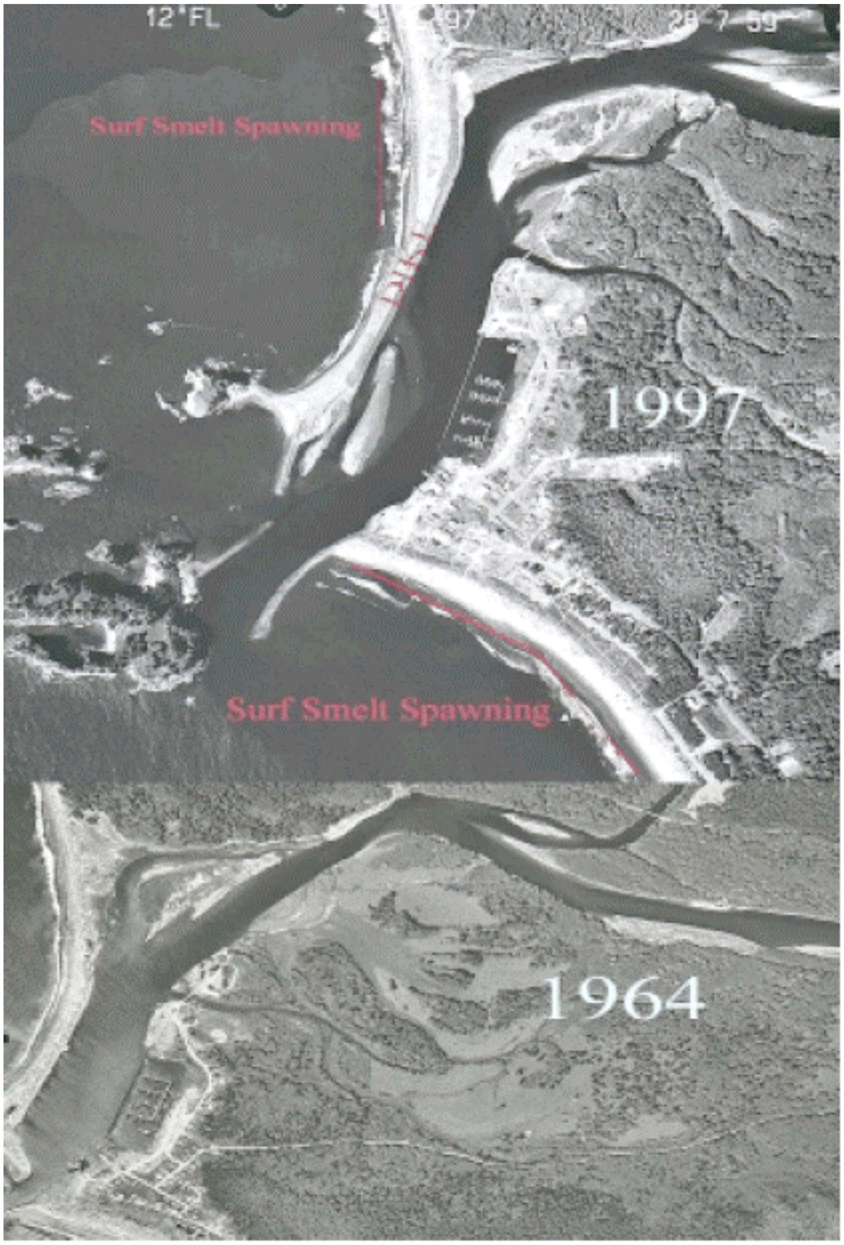


Figure 36. Channel changes near the mouth of the Quillayute River, 1964-1997 (Smith 2000).

Dickey Sub-basin

The Dickey sub-basin contains three major tributaries (East, West, and Middle Dickey) and is dominated by low gradient habitat (Smith 2000). Major problems include sedimentation, blockages and culverts, low water flows in the summer, and warm water temperatures. Sedimentation and blockages have altered wetlands and reduced riparian vegetation (Smith 2000). Low water flow in the summer is thought to limit salmon and steelhead production. Warm water temperatures are believed to contribute to an increased number and distribution of squawfish, known predators of salmon (Smith 2000), and temperature is considered the most outstanding problem in the Dickey sub-basin (Hook 2004).

Soleduck Sub-basin

The Soleduck sub-basin lies partly in OLYM and partly in timber-managed, agricultural, and residential development areas. In the regions outside of OLYM, problems include excess sedimentation due to high road densities; the high levels of fine sediments have reduced spawning habitat (Smith 2000; Hook 2004). Smith (2000) also found poor riparian conditions and poor hydrologic maturity outside of OLYM. Warm water temperatures have been detected in the summer (Smith 2000; Hook 2004), and the sub-basin contains adequate amounts of LWD in general (Smith 2000; Hook 2004).

Bogachiel Sub-basin

Like the Soleduck, this sub-basin lies partly in OLYM and partly in timber-managed and farming regions. This sub-basin has the “largest number of data gaps compared to other watersheds of the Quillayute in which watershed analyses have been completed” (Hook 2004). The habitat conditions within OLYM, however, are considered excellent (Smith 2000). Downstream of OLYM boundaries, problems include poor riparian habitat, warm water temperatures, poor LWD conditions, and increased sedimentation. Warm water temperatures are a problem in the lower Bogachiel (Smith 2000) and in Maxfield Creek (Hook 2004), though these higher temperatures may be a natural state. The lack of LWD has “led to increased water velocity and sediment transport on the mainstem of the Bogachiel...[which] has increased channel incision and exposed unstable clay layers. This incision has released sediment into the river and has resulted in a level of fines greater than 17%” (Smith 2000).

Calawah Sub-basin

Excess sedimentation due to high road densities is thought to contribute to dewatering in Hyas Creek, the North Fork Sitkum River, and Rainbow Creek, as well as channel instability (Smith 2000). Poor levels of LWD and warm water temperatures have been detected in many areas of the South Fork Calawah (Smith 2000).

Hoh Basin

A large portion of this basin lies within OLYM boundaries, but areas downstream of the park have many habitat problems, including debris flows, channel incision, sedimentation, access problems from culverts and cedar spalts, and reductions in hydrologic maturity (Smith 2000). In OLYM, LWD levels are adequate because old growth riparian areas still exist; outside of park boundaries, however, LWD levels are poor (Hook 2004). Cedar spalts are a major problem in the basin and can degrade water quality (Smith 2000). The spalts can lead to low dissolved oxygen levels, high pH levels, and high water temperatures (Hook 2004). Streams that have been impacted by cedar spalts include Winfield, Braden, Clear, Nolan, Red, Lost, Pins, Snell, Anderson, and Willoughby creeks (Smith 2000). Other problems outside park boundaries include mass wasting and road erosion, which are blamed for increased sediment loads in the basin (Smith 2000). These sedimentation problems are likely to influence the lowest reaches of mainstems (Smith 2000). Figure 37 below shows changes in the Hoh River mouth over time.

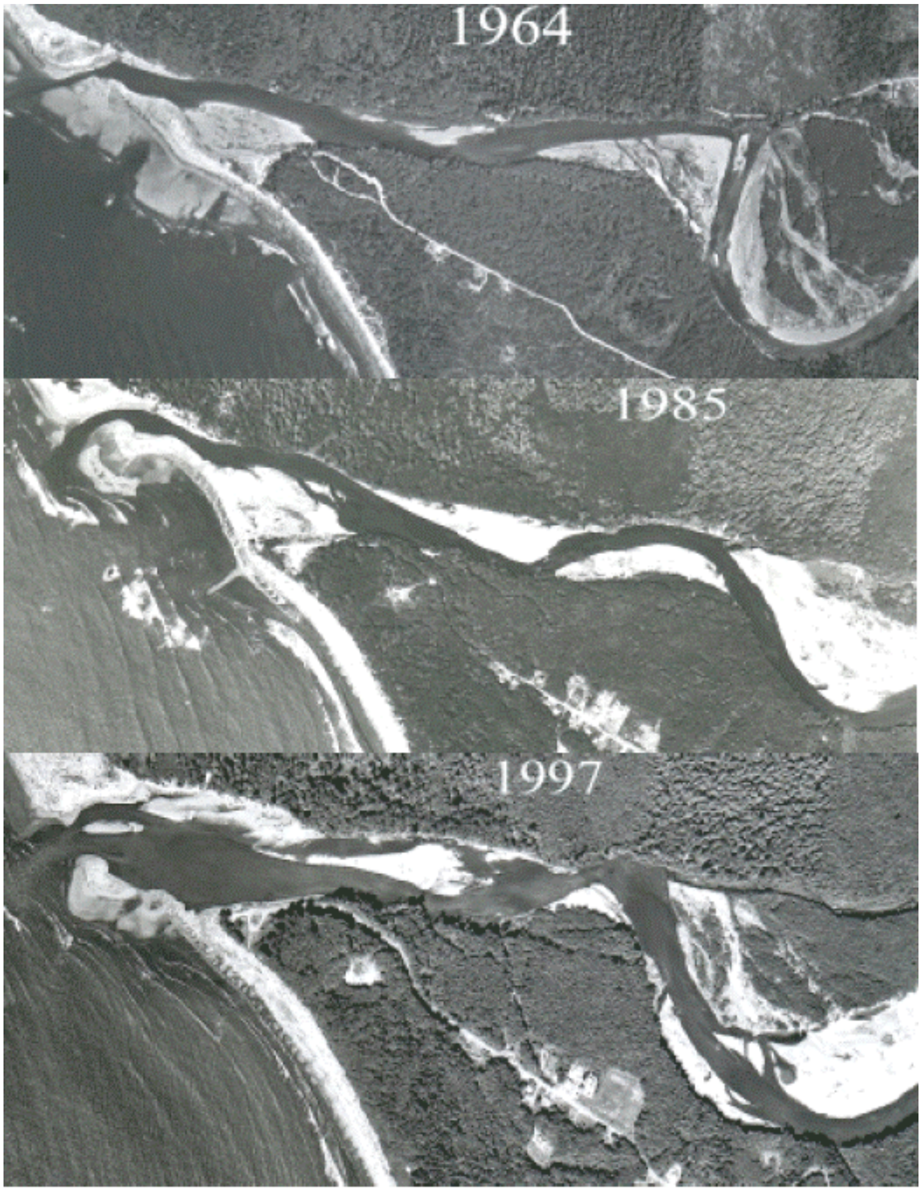


Figure 37. Channel changes in the lower Hoh River (Smith 2000).

The loss of fog drip is of particular concern in the Hoh Basin (Smith 2000), which is important because some studies “suggest that fog, as a meteorological factor, plays an important role in the water relations of the plants and in the hydrology of the forest. The results have important implications for ecologists, hydrologists, and forest managers interested in fog-inundated ecosystems and the plants which inhabit them” (Dawson 1998).

Independent salmon producing streams in WRIA 20

Smaller salmon and steelhead-producing streams are found in WRIA 20, including Goodman, Mosquito, Cedar, and Steamboat creeks. Smith (2000) found habitat data to be lacking overall for these streams, although some problems that have been documented include sedimentation (all streams), blockages from either culverts or spalts (Cedar and Steamboat creeks), and low levels of LWD (middle reaches of Goodman Creek).

Nearshore and Estuarine Environments in WRIA 20

Smith (2000) also reviewed nearshore and estuarine environments in WRIA 20. The nearshore is influenced by the Columbia River system; sediments are exported northward and are important for beach maintenance from the Hoh River south. Dams in the Columbia River system have decreased this sediment supply by approximately 24-50% (Smith 2000). In addition, "low levels of radionuclides and higher levels of polynuclear aromatic hydrocarbons have been found in sediments on the continental shelf between the Columbia River and Quinault Canyon (near the Hoh River mouth)...The source of these contaminants is the aluminum smelters on the lower Columbia River" (Smith 2000).

WRIA 21 – Queets/Quinault

Smith and Caldwell (2001) found an overall lack of detailed field information for WRIA 21, and listed data needs for floodplain and riparian conditions, fish habitat access, sedimentation, and water quality. Of relevance to OLYM is the Queets Basin, in which floodplain impacts (i.e., bank hardening, roads) are minimal, but loss of off-channel habitat is of concern in some water bodies, like the Clearwater, Salmon, and Sams Rivers, and in Matheny Creek. Excess sediment inputs were found within timber-managed areas, and especially in those areas with high road densities like the Clearwater sub-basin. High road densities were also found in Kalaloch Creek and the Raft River Watershed Administrative Unit (WAU), while there were "fair" densities in the Moclips River/Joe Creek and Copalis WAUs. Riparian conditions in the entire basin were generally rated "good" overall. High water temperatures were found in the lower Queets, lower Sams, lower Matheny, Salmon River, lower Clearwater, and the Raft and Moclips rivers. The Queets Basin was rated "poor" with regards to hydrologic maturity for Matheny Creek, lower Queets, the entire Clearwater sub-basin, and in the Raft River and Moclips River/Joe Creek WAUs; "good" ratings were attained by the Kalaloch Creek and Copalis River WAUs.

Nearshore and Estuarine Environments in WRIA 21

The estuarine habitat in WRIA 21 is generally rated "good," except for some areas of armoring along the banks of lower Joe Creek. The nearshore habitat is rated "good" as it mostly lies within the Copalis Rock National Wildlife Sanctuary. The decline in giant kelp has been a concern, but the cause has not yet been determined (Smith and Caldwell 2001).

Watershed Habitat Conditions in WRIAs 20 and 21

The condition of habitats within WRIA 20 compares unfavorably with most other WRIAs in the region, with a lower proportion of habitat in good condition, and a higher proportion in poor condition (Figure 38; Smith 2005). WRIA 21 is in better condition than WRIA 20, with a higher proportion of habitat in good condition, and a smaller proportion in poor condition (Smith 2005). Data gaps are substantial in both WRIA 20 and 21.

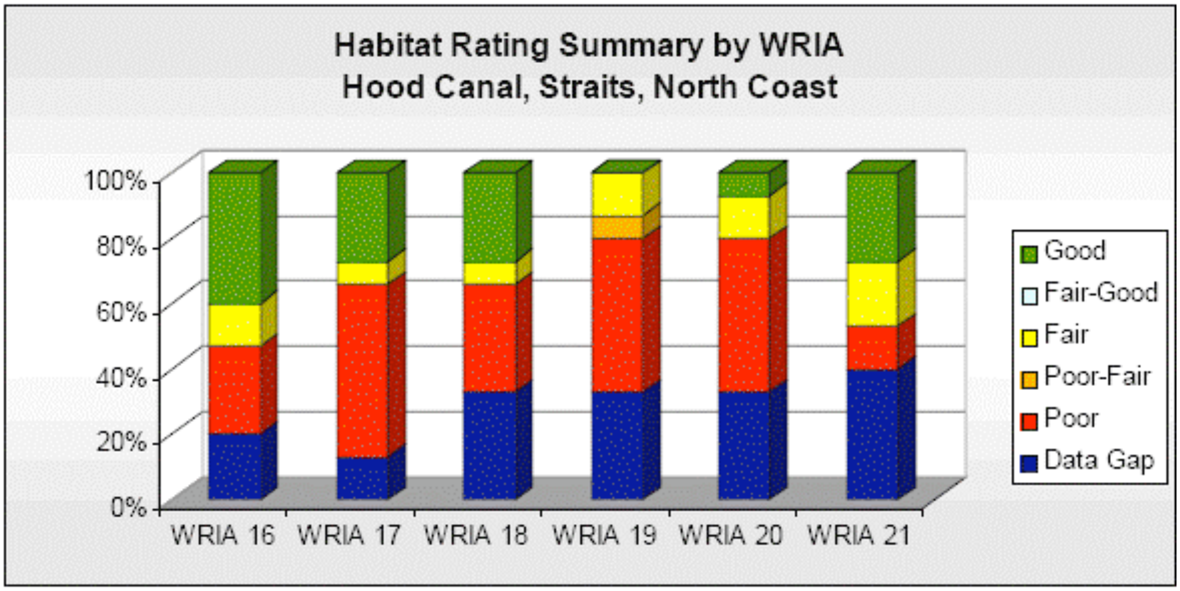


Figure 38. Summary of habitat conditions in WRIAs 16-21 (WRIA 16=West Hood Canal, 17=Quilcene, 18=Dungeness/Elwha, 19=Hoko, 20=North Coast, and 21=Queets/Quinault) (Smith 2005).

Summaries of watershed conditions in WRIAs 20 and 21, based on data presented in Smith (2000) and Smith and Caldwell (2001), are shown in Tables 9 and 10, respectively.

Table 9. Summary of watershed conditions in WRIA 20. DG = data gap. Table created from data reported in Smith (2000). Empty cells indicate no data.

WRIA 20 Stream Name	**Access**	**Floodplain**	**Sediment Quantity**	**Sediment Road Density**	**Sediment Quality, Fines**	**Channel Stability**
Wa'atch Basin	Poor					
• Wa'atch River		Fair				
Sooes Basin	Fair					
• Sooes River						
Ozette Basin	Fair					
• Ozette River						
• Ozette Lake					Poor	
• Siwash Creek					Poor	
Quillayute Basin						
Dickey Sub-basin	Poor					
• Coal Creek		Fair				

Soleduck Sub-basin						
• Soleduck River		Fair		Fair		Fair
• Goodman Creek				Poor	Fair	
Bogachiel Sub-basin						
• Bogachiel River		Poor lower; Good upper	Poor lower; Good upper		Poor lower	Poor lower
Hoh Basin						
• Hoh River		Poor	Poor in middle Hoh			Poor
• Braden Creek			Poor	Good	Fair	
• Nolan Creek	Poor	Fair	Poor	Fair		

WRIA 20 Stream Name	**Instream LWD**	**Riparian**	**Pools**	**Water Quality**	**Flows**	**Biological Processes**
Wa'atch Basin						Poor
• Wa'atch River				Poor		
Sooes Basin						Poor
• Sooes River				Poor		
Ozette Basin						Poor
• Ozette River	Fair	Good		Poor		
• Ozette Lake				Fair		Poor
• Siwash Creek	Poor				Poor	
Quillayute Basin						Good
Dickey Sub-basin				Poor	Poor	
• Coal Creek				Poor		
Soleduck Sub-basin					Poor lower - mid	
• Soleduck River		Poor-Fair; Good headwaters	Good	Poor lower and middle mainstem		
• Goodman Creek	Fair	Good	Good	Poor	Poor	
Bogachiel Sub-basin						
• Bogachiel River	Poor lower; Good upper	Poor lower; Good upper		Poor in lower		
Hoh Basin						Poor
• Hoh River	Poor lower; Good upper	Poor lower; Good upper				
• Braden Creek	Poor	Poor	Good	Poor	Poor	
• Nolan Creek	Poor	Poor	Fair	Poor	Poor	

Table 10. Summary of watershed conditions in WRIA 21. DG = data gap. Table created from data reported in Smith and Caldwell (2001). Empty cells indicate no data.

WRIA 21 Stream Name	Fish passage	Floodplain conditions	Sediment: gravel quantity	Sediment: gravel quality	Channel Stability
Quinault Basin					
Quinault estuary		Good (DG)			
Lower Quinault sub-basin		Fair (DG)	Fair (DG)		
Queets Basin					
Lower Queets		Good (DG)	Fair (DG)		
Kalaloch			Poor (DG)		

WRIA 21 Stream Name	Instream LWD (quantity)	Riparian	Pools	Water Quality	Biological Processes
Quinault basin					Fair
Quinault estuary	Fair (DG)				
Lower Quinault sub-basin		Fair-good along mainstem	Good in mainstem	Poor	
Queets basin					Good
Lower Queets				Poor (DG)	
Kalaloch		Fair (DG)	Poor (DG)	Good (DG)	

Effects of Logging Practices on Habitat and Coastal Water Quality

Logging practices (timber harvesting and road construction and maintenance) can affect the quantity and quality of aquatic and riparian habitat, and affect water quality (Hashim and Bresler 2005). Timber harvesting can result in a deficiency of LWD available to streams. LWD is important because it “forms pools, provides cover, supplies spawning gravels, and creates channel complexity” all of which are important to fish survival (Hashim and Bresler 2005). Harvesting also reduces the amount of shade available for streams; these reductions can adversely affect water temperatures. In a 1991 study in the Hoh Basin, mean daily temperatures in logged areas were 10.9% higher than in unlogged areas (Hatten 1991 *in* Hook 2004). Sediment loads from road surface runoff and mass wasting processes (e.g., debris avalanches, debris flow, and debris torrents) can cause damage by altering spawning habitat, eroding stream banks, and changing channel morphology (e.g., “causing a stream to widen and become shallower and susceptible to higher temperatures”) (Hashim and Bresler 2005).

Road density, a logging indicator, has been the focus of some studies. Tallis (2006) analyzed the density of logging roads across Olympic Peninsula watersheds with regard to water quality. A landscape-scale comparative analysis was applied to determine whether coastal logging practices or the presence of riparian buffer zones are associated with differences in nutrient and carbon concentrations in rivers and estuaries at a scale relevant to terrestrial and marine conservation. Fourteen watersheds that drain the north and west coasts of the Olympic Peninsula were studied, five of which drain the west coast from La Push to the Quinault Indian Reservation. Tallis (2006) was primarily interested in the ability of road density to describe variation in river chemistry beyond that described by watershed characteristics that are independent of land use.

Tallis (2006) found that rivers that drained from high road density watersheds had about 79 times more nitrate than rivers draining from low road density watersheds during the summer. In rivers downstream of high road density, phosphate was about seven times higher in the summer and ten times higher in the winter, and dissolved organic carbon was approximately eleven times higher in the summer.

Tallis (2006) also found a difference in the form of nitrogen exported in Olympic Peninsula rivers. A nonlinear response in the form of nitrogen moving downstream was detected, switching from organic nitrogen (low road density watersheds) to nitrate (high road density watersheds); approximately 85% of the Olympic Peninsula's coastal watersheds exhibit such a shift. The nitrate levels from rivers draining heavily logged watersheds are much higher than those draining less disturbed areas and these differences seem to persist for some distance into the ocean during the summer. This may indicate that logging drives increased summer primary production in the region.

Other studies show that small coastal rivers, characteristic of the U.S. Pacific Northwest, can significantly alter coastal biogeochemical cycles and influence ecosystem structure (Wetz *et al*. 2006). Physical structure and biogeochemistry is specifically altered on short timescales (days to weeks) following heavy precipitation and discharge events that are common during the winter in the Pacific Northwest. The input of riverine "freshwater leads to buoyant surface waters, increased stratification, and elevated macronutrient and Fe concentrations in coastal surface waters" (Wetz *et al.* 2006). Rivers carry terrestrial organic matter to the ocean that can either supplement the coastal food web (and potentially alter the system's metabolism), or be a sink for carbon by being transported to the deep ocean. Based on river discharge data, Wetz *et al.* (2006) believe that the riverine input is not unique to their study sites in Oregon but is instead representative of most of the northern California Current.

Coastal Environmental Monitoring and Assessment Program (EMAP)
In 1999, 44 coastal estuaries in Washington State were sampled as part of the EPA's Coastal EMAP (Wilson and Partridge 2007). Kalaloch Creek at the mouth was the only site sampled within OLYM. Because the creek is shallow and inaccessible by boat, only a partial set of the EMAP indicators were sampled there. For reporting purposes, statistical results from Kalaloch Creek were in many instances combined with three other 'walk-in' stations (Raft River, Quinault River, and Conner Creek) outside OLYM that were similarly inaccessible (Figure 39).

Figure 39. Washington state coastal EMAP stations. Stations indicated by filled boxes were sampled in 1999 (Wilson and Partridge 2007).

The quantitative results for indicators measured in Kalaloch Creek are given in Tables 11-22. The raw data for Kalaloch Creek and all other sites are available in the national EMAP database. In aggregate, the results from the four ‘walk-in’ stations are reproduced in Figures 40-77 in a format that allows visual comparison with other stations sampled by Coastal EMAP in 1999. These stations extend from the Columbia River to Makah Bay and the Strait of Juan de Fuca, and consequently reflect the range of spatial variation in water quality parameters in the vicinity of OLYM.

Other abbreviations used in the following tables and figures include:
CSL: Washington State Sediment Cleanup Screening Level
ERL: NOAA Effects Range Low
ERM: NOAA Effects Range Median
SQS: Washington State Sediment Quality Standard
TSS: Total Suspended Solids

Table 11. Light extinction and PAR (Photosynthetically Active Radiation) (Wilson and Partridge 2007).

Light-extinction coefficient	Surface Depth (m)	Light-Extinct. Coeff. K (1/m)			
	0.5	2.34			
Surface photosynthetically-active radiation (PAR)	Surface Depth (m)	Surface Submerged PAR (µmol/m2/s)	Surface Terrestrial PAR (µmol/m2/s)	Surface SubPAR as % of TerPAR (%)	Surface Light-Extinct. Coeff. k (1/m)
	0.5	232	1266	18.3	3.40

Table 12. Surface TSS, chlorophyll-*a*, phaeopigments, dissolved nutrients, N:P ratio (Wilson and Partridge 2007).

TSS (mg/L)	Chl-a (µg/L)	Phaeo (µg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
4.0	0.9	1.3	9.77	0.00	12.58	4.21	876.43	1.60	0.14	11.76

Table 13. Sediment lithology (Wilson and Partridge 2007).

Silt-Clay Content (%)	Total Organic Carbon (%)
0.00	0.14

Table 14. Sediment metals concentrations (µg/g dry weight) (Wilson and Partridge 2007).

Al	Sb	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Ag	Sn	Zn
14000	0.24	3.48	0.075	22	6.6	16300	3.89	287	0.0084	7.9	0.12	0.81	29.2

Table 15. Sediment individual LPAH concentrations (Wilson and Partridge 2007).

1-Methyl Naphthalene	1-Methyl phenanthrene	2,3,5-Trimethyl naphtha-lene	2,6-Dimethyl naphtha-lene	2-Methyl Naphtha-lene	Acenaph-thene	Acenaphthy-lene
4.4	3.7	2.1	5.2	11	0.64	1.1

Anthracene	Biphenyl	Dibenzothio-phene	Fluorene	Naphthalene	Phenanthr-ene	Retene
69	4.7	1.1	8.4	4.3	37	10

Table 16. Sediment individual HPAH concentrations (Wilson and Partridge 2007).

Benz(a) anthracene	Benzo(a) pyrene	Benzo(b) fluoranthene	Benzo[e] pyrene	Benzo(k) fluoranthene
4.5	6.4	7.4	5.2	7.4

Chrysene	Fluoranthene	Indeno (1,2,3-c,d) pyrene	Perylene	Pyrene
48	4.5	8	9.1	4.2

Table 17. Sediment individual LPAH concentrations - TOC-normalized (Wilson and Partridge 2007).

TOC (%)	2-Methylnaph-thalene (ppm org. C)	Acenaphthene (ppm org. C)	Acenaphth-ylene (ppm org. C)	Anthracene (ppm org. C)	Fluorene (ppm org. C)	Naphtha-lene (ppm org. C)	Phenan-threne (ppm org. C)
0.14	7.86	0.46	0.79	49.29	6.00	3.07	26.43

Table 18. Sediment individual HPAH concentrations - TOC-normalized (Wilson and Partridge 2007).

TOC (%)	Benz(a) anthracene (ppm org. C)	Benzo(a) pyrene (ppm org. C)	Benzo(g,h,i) perylene (ppm org. C)	Chrysene (ppm org. C)
0.14	3.21	4.57	5.29*	34.29

Dibenz(a,h) anthracene (ppm org. C)	Fluoranthene (ppm org. C)	Indeno (1,2,3-c,d) pyrene (ppm org. C)	Pyrene (ppm org. C)	Total Benzofluoranthenes (ppm org. C)
1.14*	3.21	5,71	3.00	10.57

* All concentrations were non-detects; therefore, the highest reporting limit (RL) was used as the concentration, per Washington State Department of Ecology (1995).

Table 19. Sediment total PAH concentrations (Wilson and Partridge 2007).

EMAP Total LPAH (ng/g)	EMAP Total HPAH (ng/g)	EMAP Total PAH (ng/g)	TOC (%)	SQS/CSL Total LPAH (ppm org. C)
115.64	90.4	206.04	0.14	86.03

SQS/CSL Total HPAH (ppm org. C)	ERL/ERM Total LPAH (ng/g)	ERL/ERM Total HPAH (ng/g)	ERL/ERM Total PAH (ng/g)
71	131.44	67.6	199.04

Table 20. Sediment total and individual DDT concentrations (ng/g dry weight) (Wilson and Partridge 2007).

Total DDT	4,4'-DDD	4,4'-DDE
Non-detect	Non-detect	Non-detect

Table 21. Sediment chlorinated pesticide concentrations (ng/g dry weight) (Wilson and Partridge 2007).

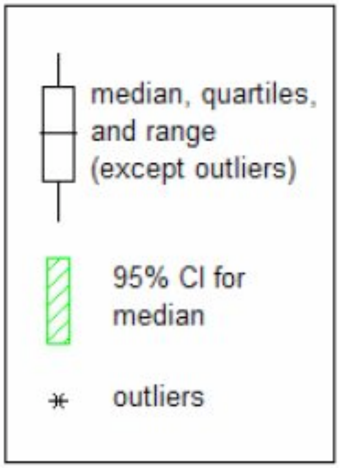
Hexachlorobenzene (Method SW 8081)	Hexachlorobenzene (Method SW 8270)
Non-detect	Non-detect

Table 22. Sediment toxicity test results (Wilson and Partridge 2007).

Amphipod Survival Test (*Ampelisca abdita*) Control-Corrected Survival (%)	Sea Urchin Fertilization Test (*Arbacia punctulata*) Control-Corrected Fertilization (%)	Sea Urchin Embryo Development Test (*Arbacia punctulata*) Normal Development (%)
101.1	102.6	98.1

Data from the Coastal EMAP program from 1999 indicate that, in comparison to other stations along the coast, the Walk-In Stations (including Kalaloch Creek) are characterized by relatively low light (photosynthetically active radiation [PAR])(Figure 40), and by low concentrations of dissolved nitrite (Figure 46), nitrate (Figure 47), and inorganic nitrogen (Figure 48). Concentrations of aluminum (Figure 51), antimony (Figure 52), arsenic (Figure 53), cadmium (Figure 54), copper (Figure 55), iron (Figure 56), lead (Figure 57), manganese (Figure 58), mercury (Figure 59), nickel (Figure 60), silver (Figure 62), tin (Figure 63), zinc (Figure 64), and DDT (Figure 65) in sediments also are relatively low. Relative concentrations of chlorophyll-*a* (Figure 43) and HPAHs (High molecular weight PAH) (Figures 69, 71, and 73) and silt-clay content (Figure 49) are low to intermediate. Light extinction coefficients are intermediate (Figure 41). Levels of PCBs (polychlorinated biphenyls), total PAHs (polycyclic aromatic hydrocarbon) (Figures 67 and 74), LPAHs (Low molecular weight PAH) (Figures 68, 70, and 72) are relatively high, but variable. Bioassays of amphipod survival (Figure 75) and sea urchin fertilization success (Figure 76) are high. Concentrations of suspended solids (Figure 42), phaeopigments (Figure 44), ammonium (Figure 45), total organic carbon content (Figure 50), and sediment selenium (Figure 61), and bioassays of sea urchin development (Figure 77) are relatively high with a large amount of variation. This variation likely results from spatial variation among pooled sites. Collectively, these results suggest that water quality at the stations is relatively good, as indicated by low levels of nitrogen-nutrients, low levels of most metals in sediments, and high levels of amphipod survival and urchin fertilization success in bioassays. Relatively high but variable levels PCBs, LPAHs, and sediment selenium could be cause for further investigation to identify the sources of the variation and the levels for individual streams.

Legend for Figures 40-77:



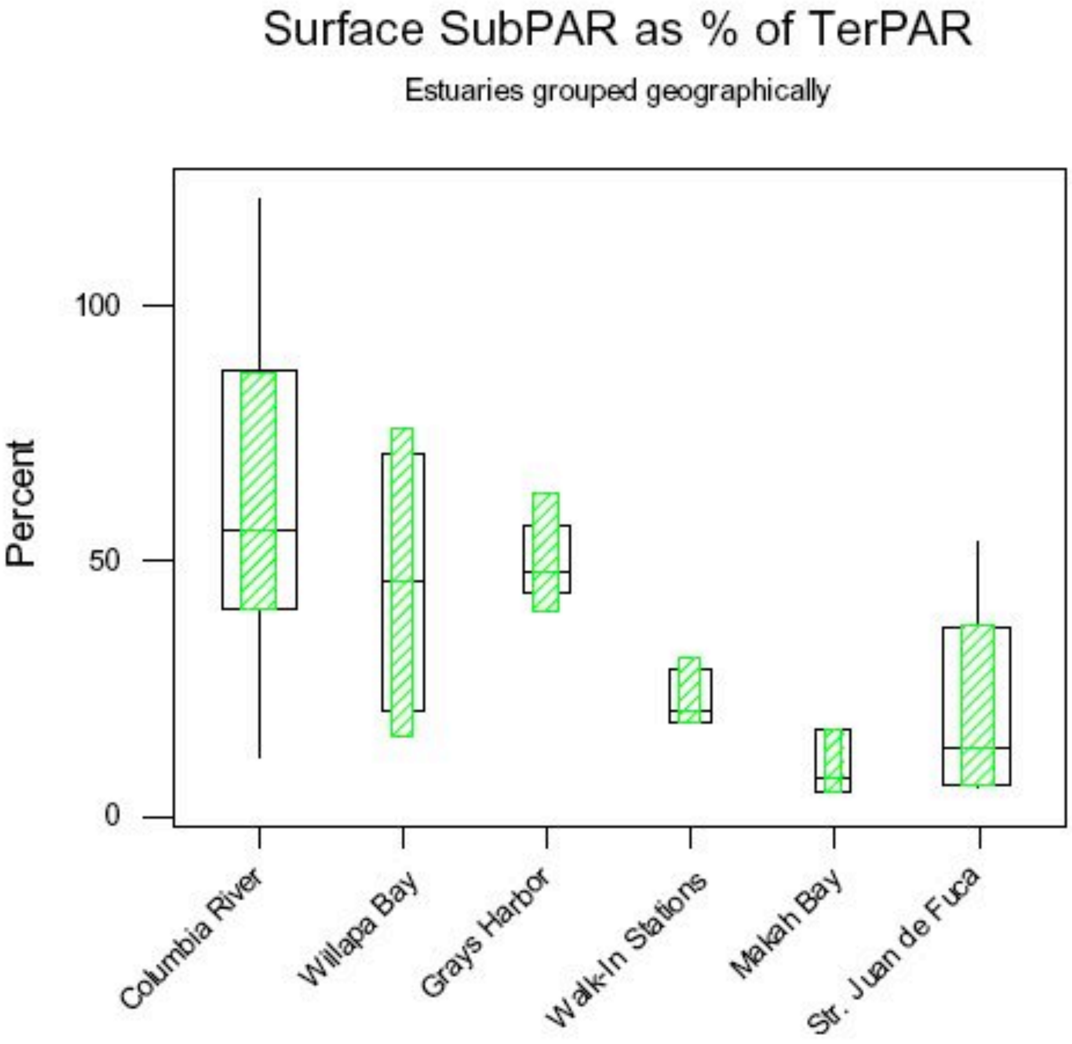


Figure 40. Surface SubPAR as % of TerPAR (Wilson and Partridge 2007).

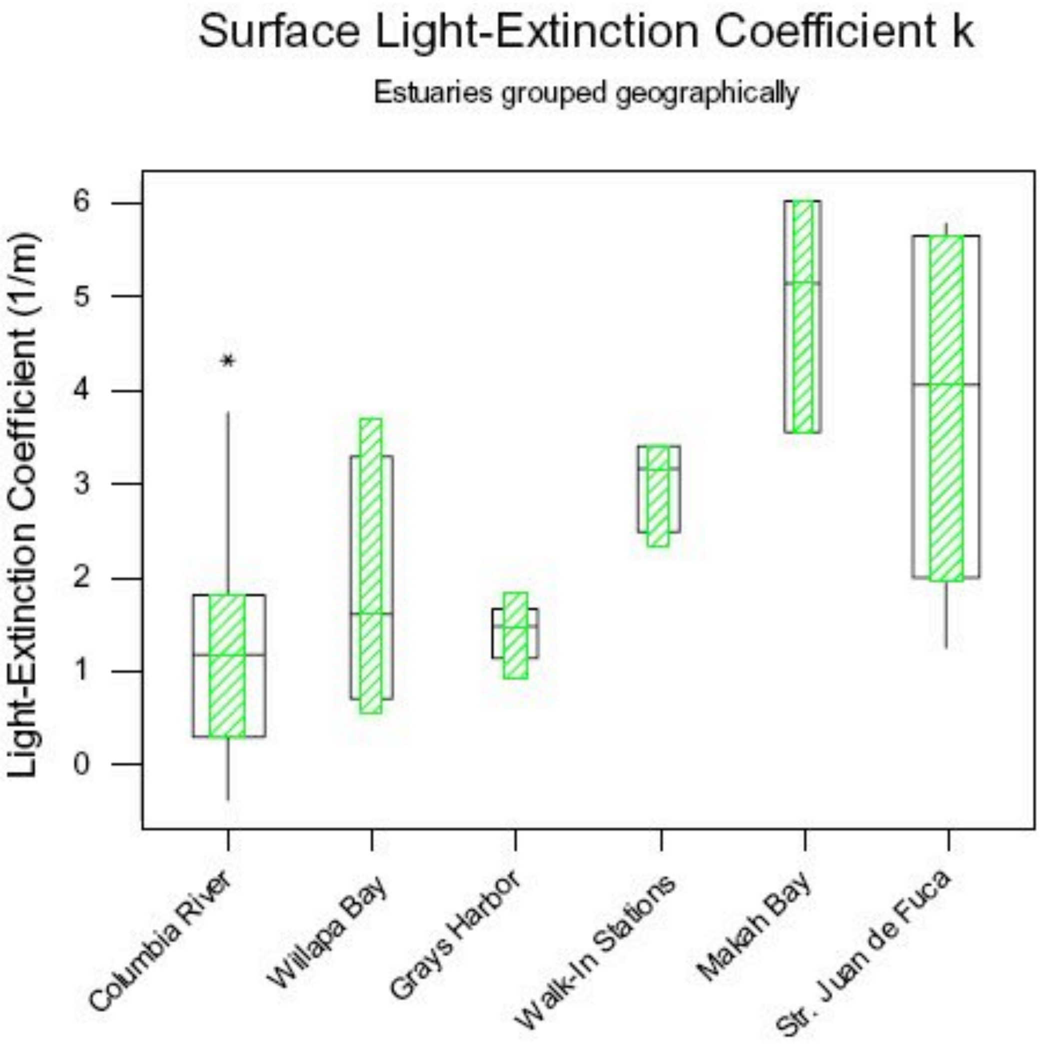


Figure 41. Surface Light-Extinction Coefficient k (Wilson and Partridge 2007).

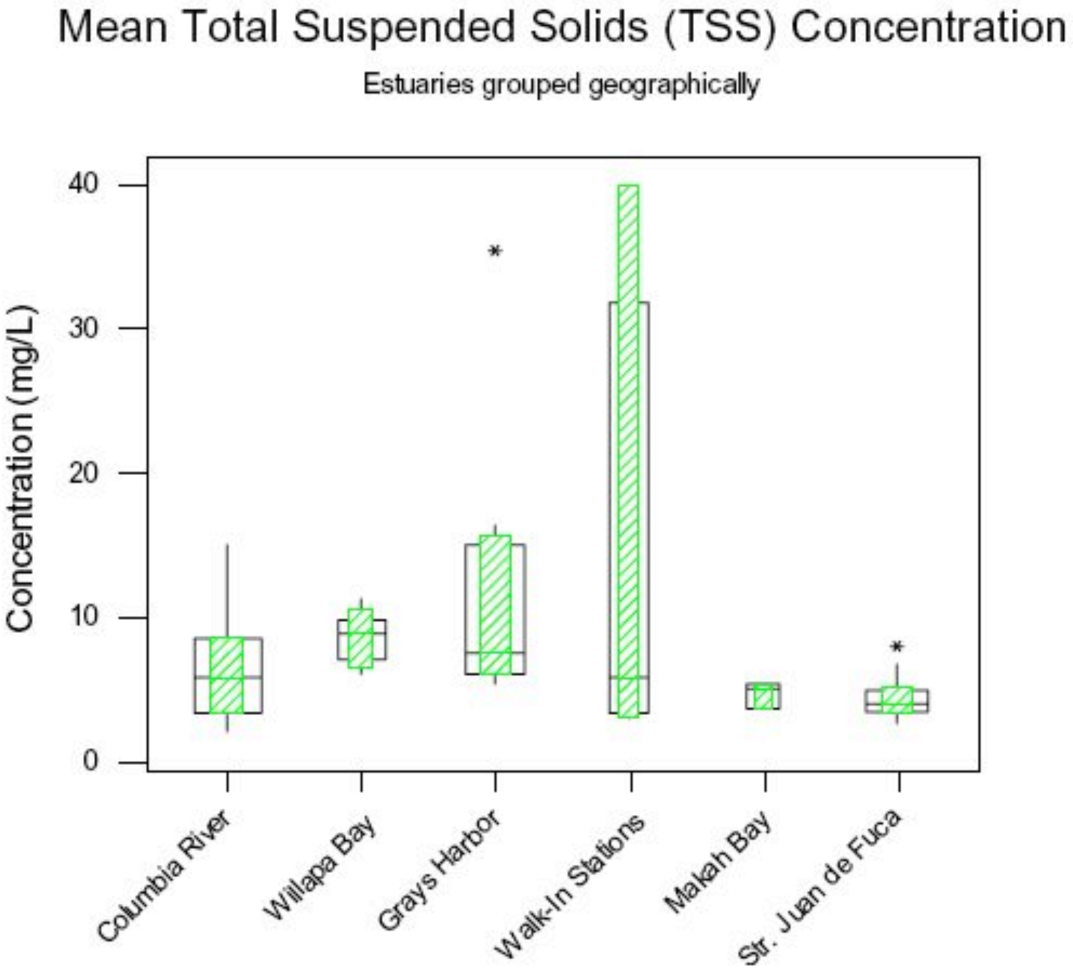


Figure 42. Mean Total Suspended Solids (TSS) Concentration (Wilson and Partridge 2007).

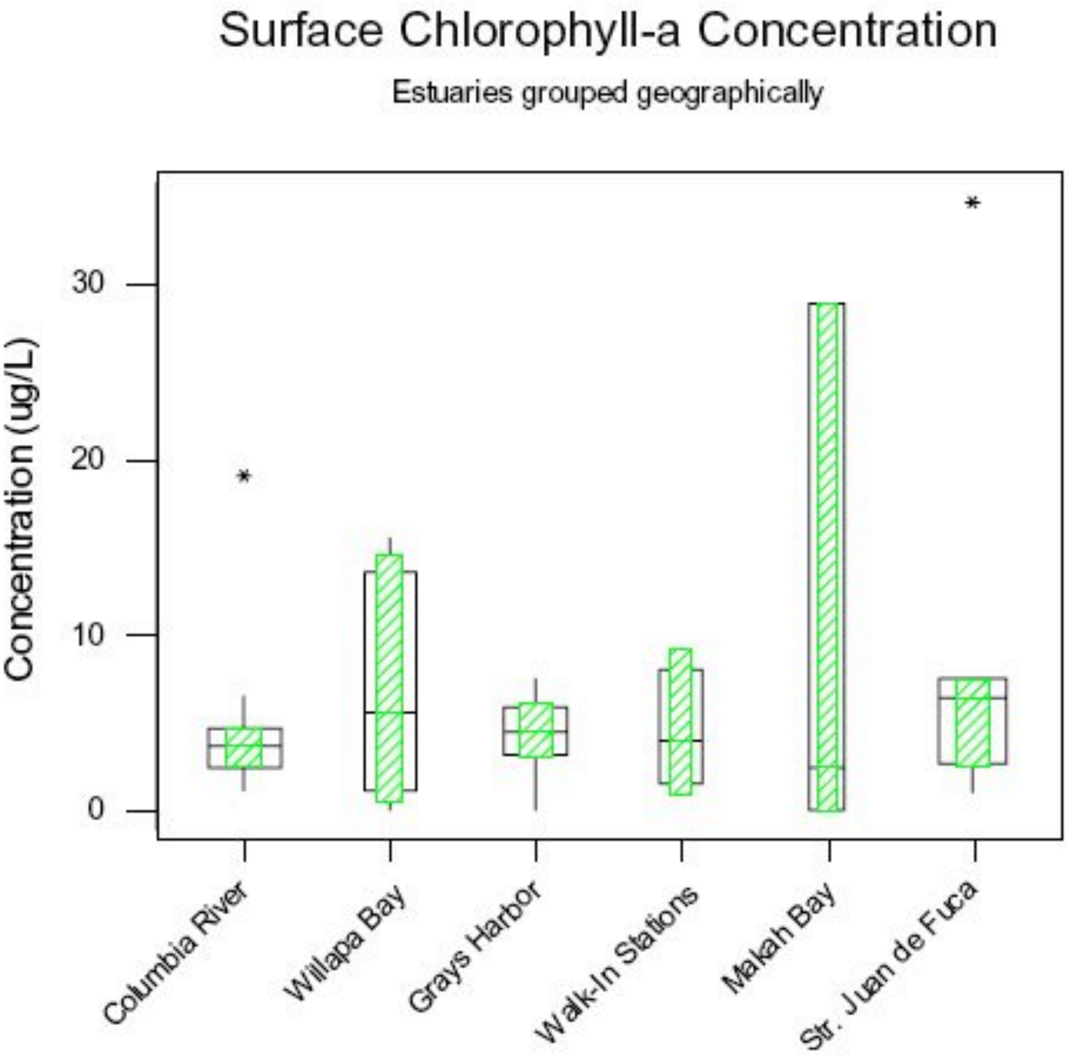


Figure 43. Surface Chlorophyll-a Concentration (Wilson and Partridge 2007).

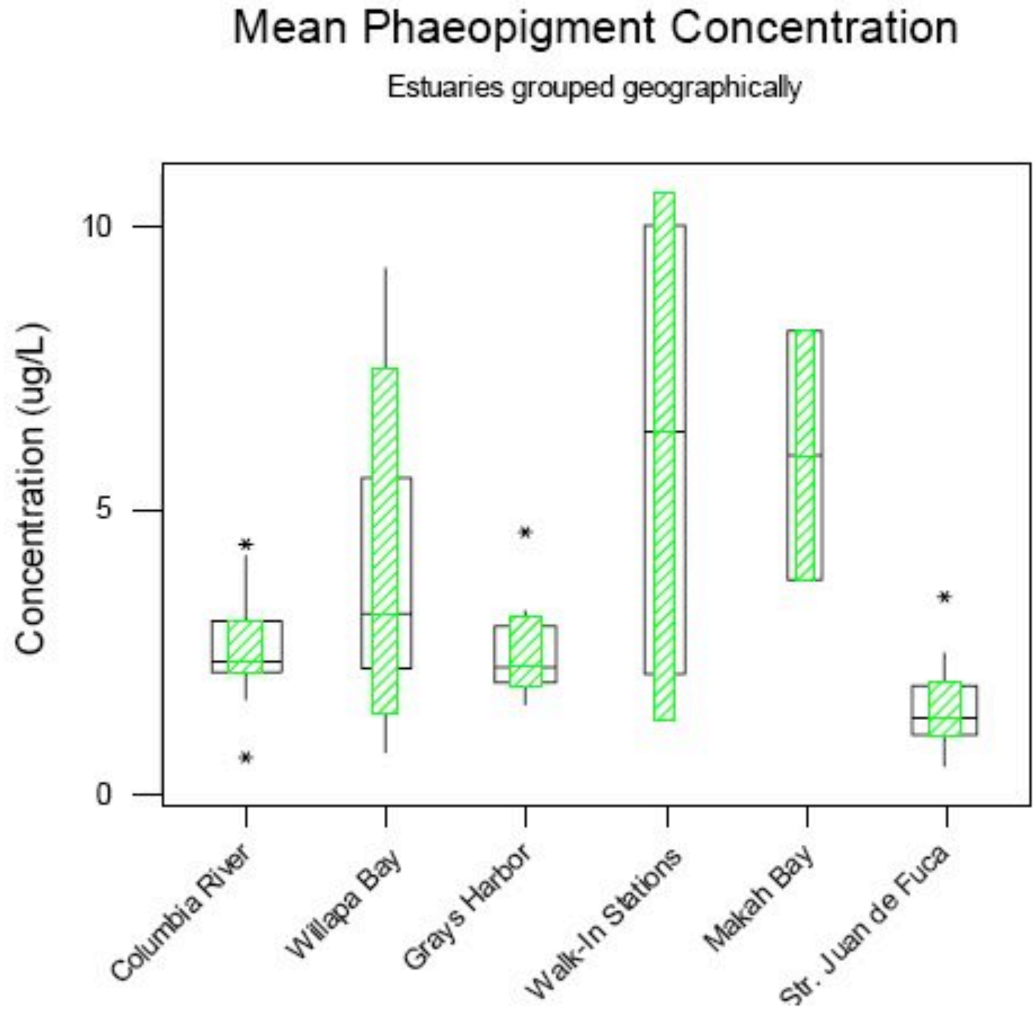


Figure 44. Mean Phaeopigment Concentration (Wilson and Partridge 2007).

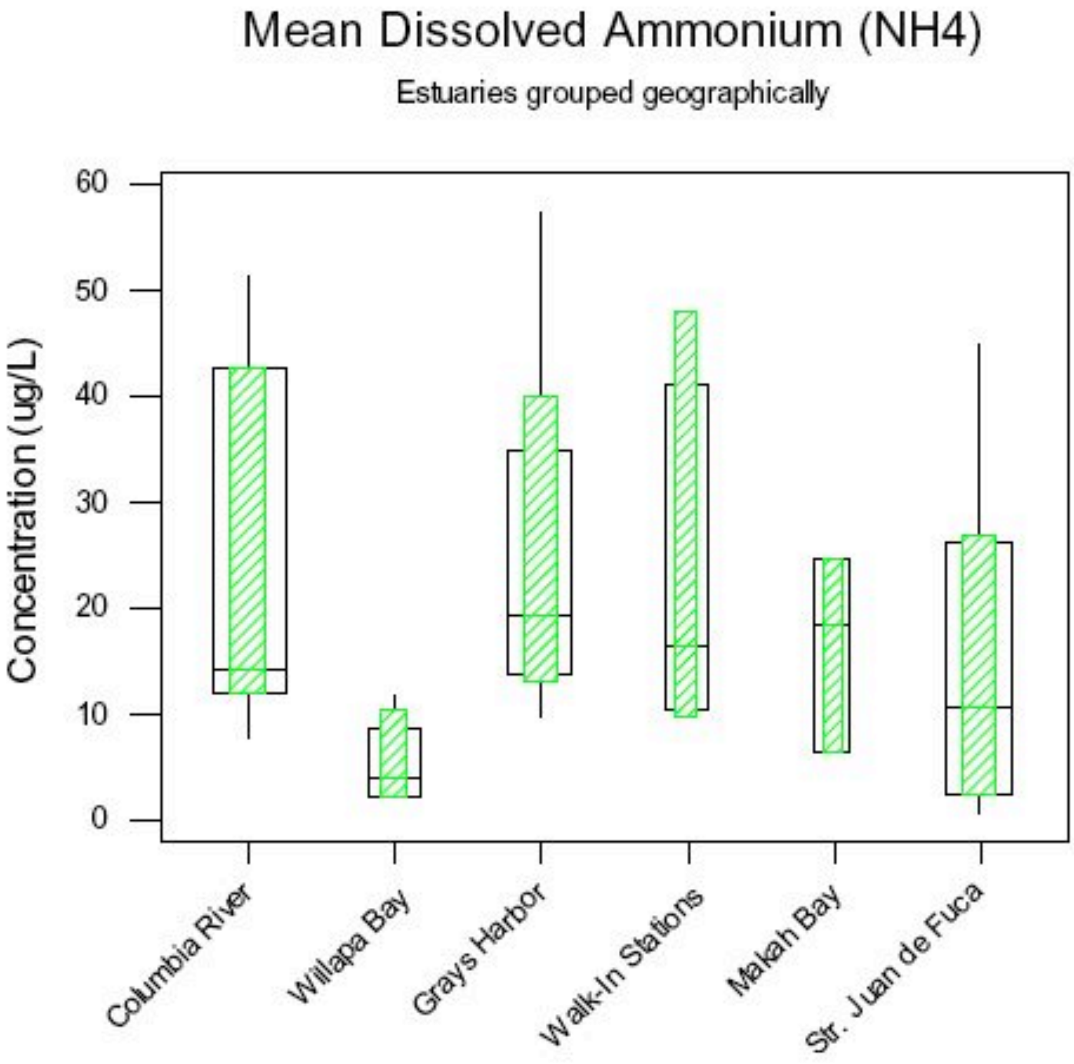


Figure 45. Mean Dissolved Ammonium (NH4) (Wilson and Partridge 2007).

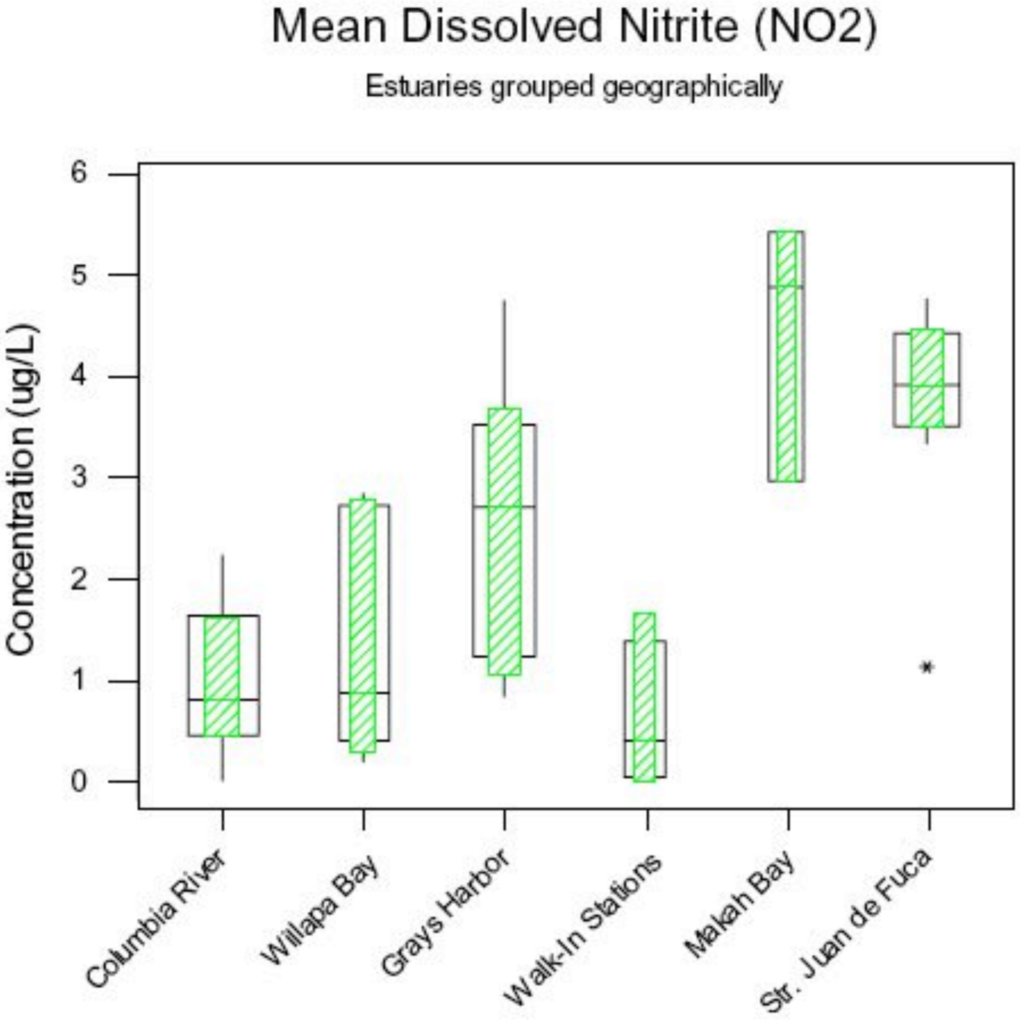


Figure 46. Mean Dissolved Nitrite (NO2) (Wilson and Partridge 2007).

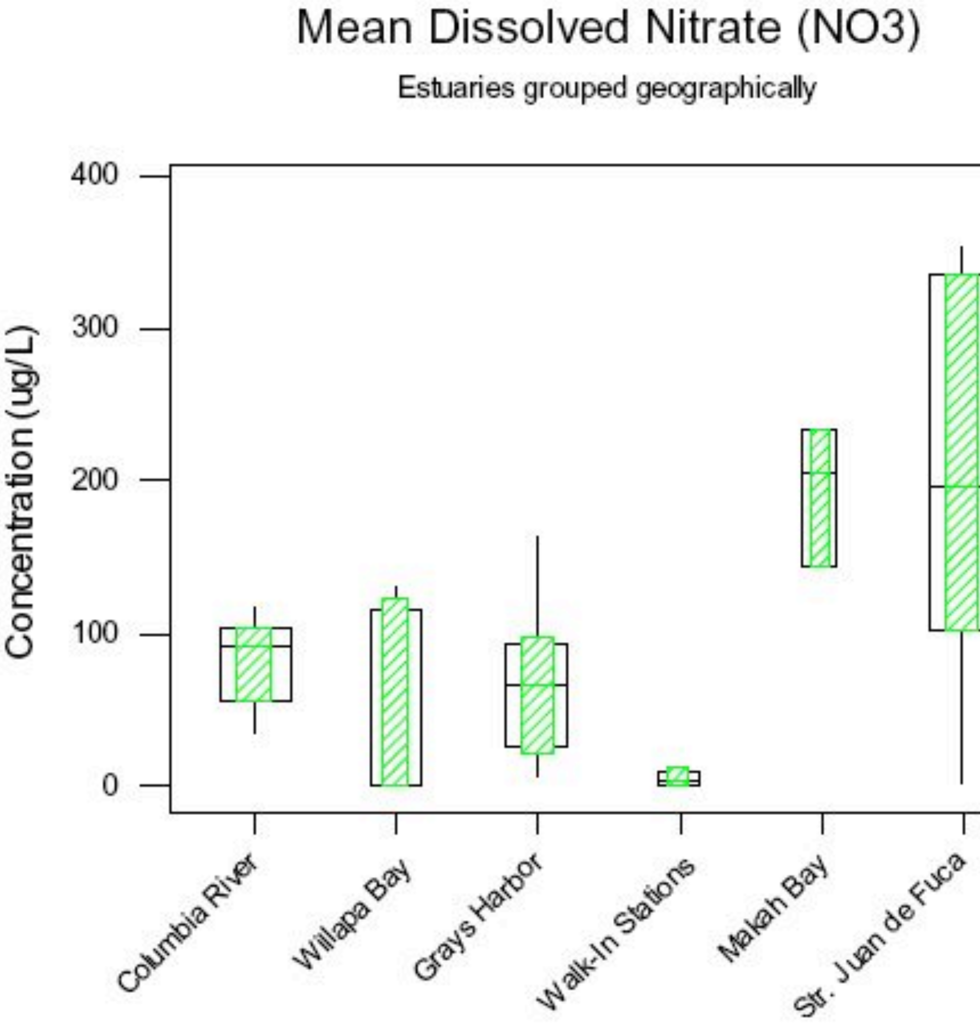


Figure 47. Mean Dissolved Nitrate (NO3) (Wilson and Partridge 2007).

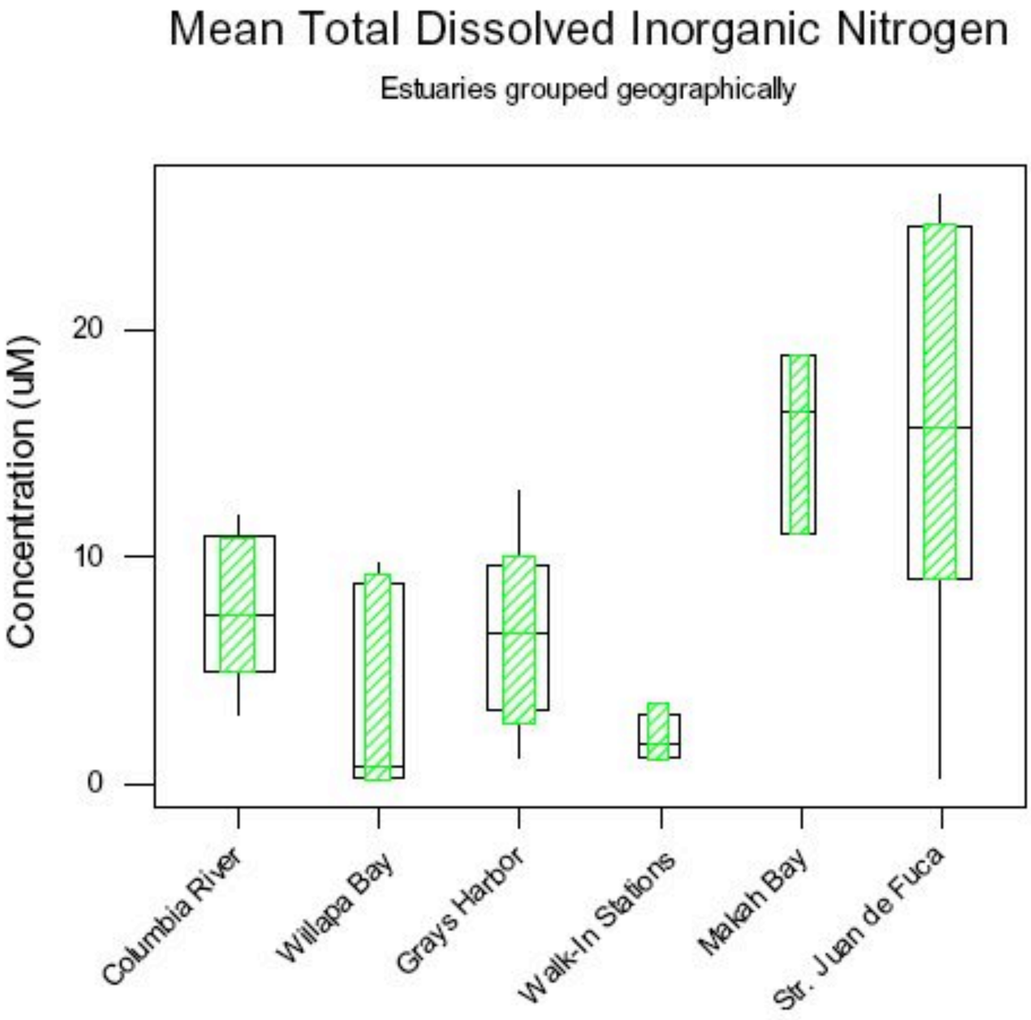


Figure 48. Mean Total Dissolved Inorganic Nitrogen (Wilson and Partridge 2007).

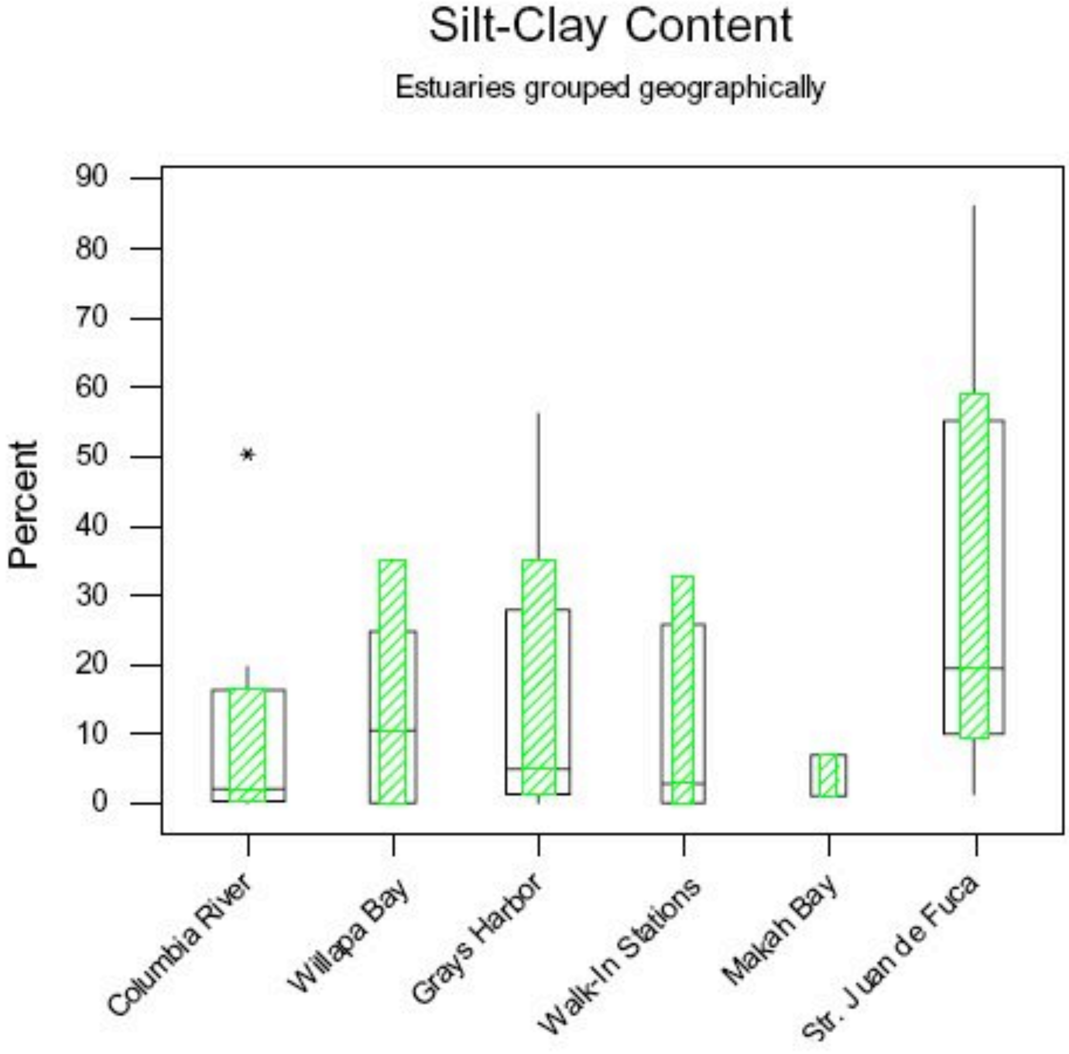


Figure 49. Silt-Clay Content (Wilson and Partridge 2007).

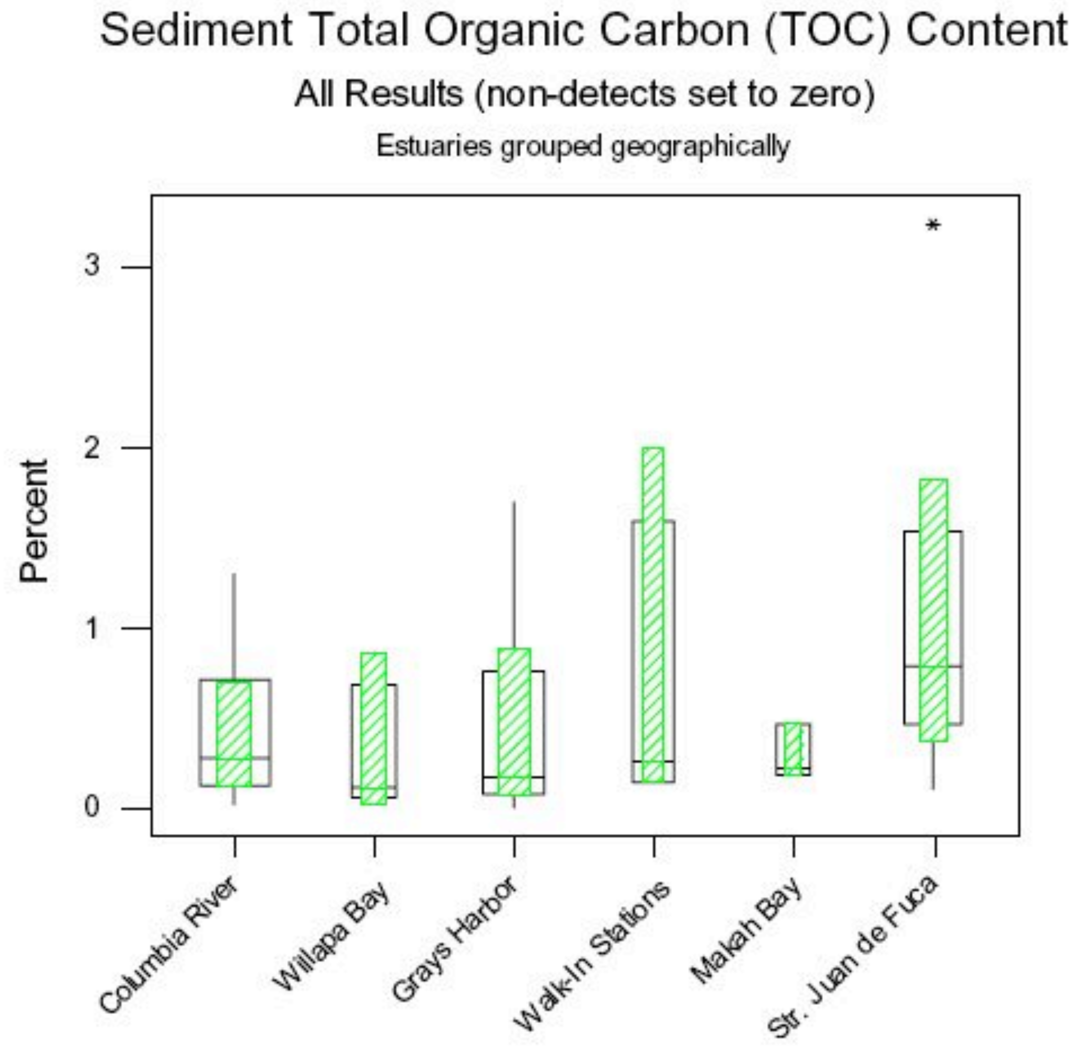


Figure 50. Sediment Total Organic Carbon (TOC) Content (Wilson and Partridge 2007).

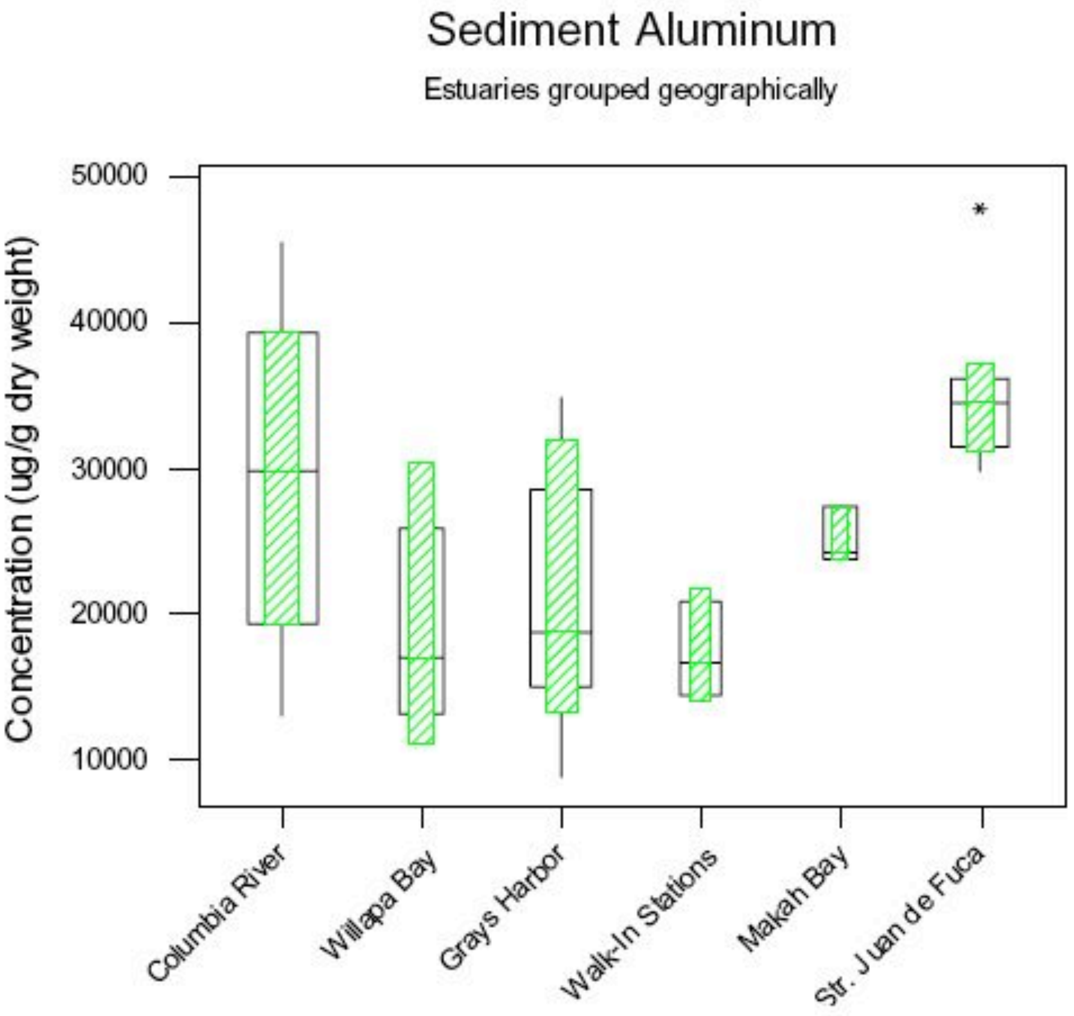


Figure 51. Sediment Aluminum (Wilson and Partridge 2007).

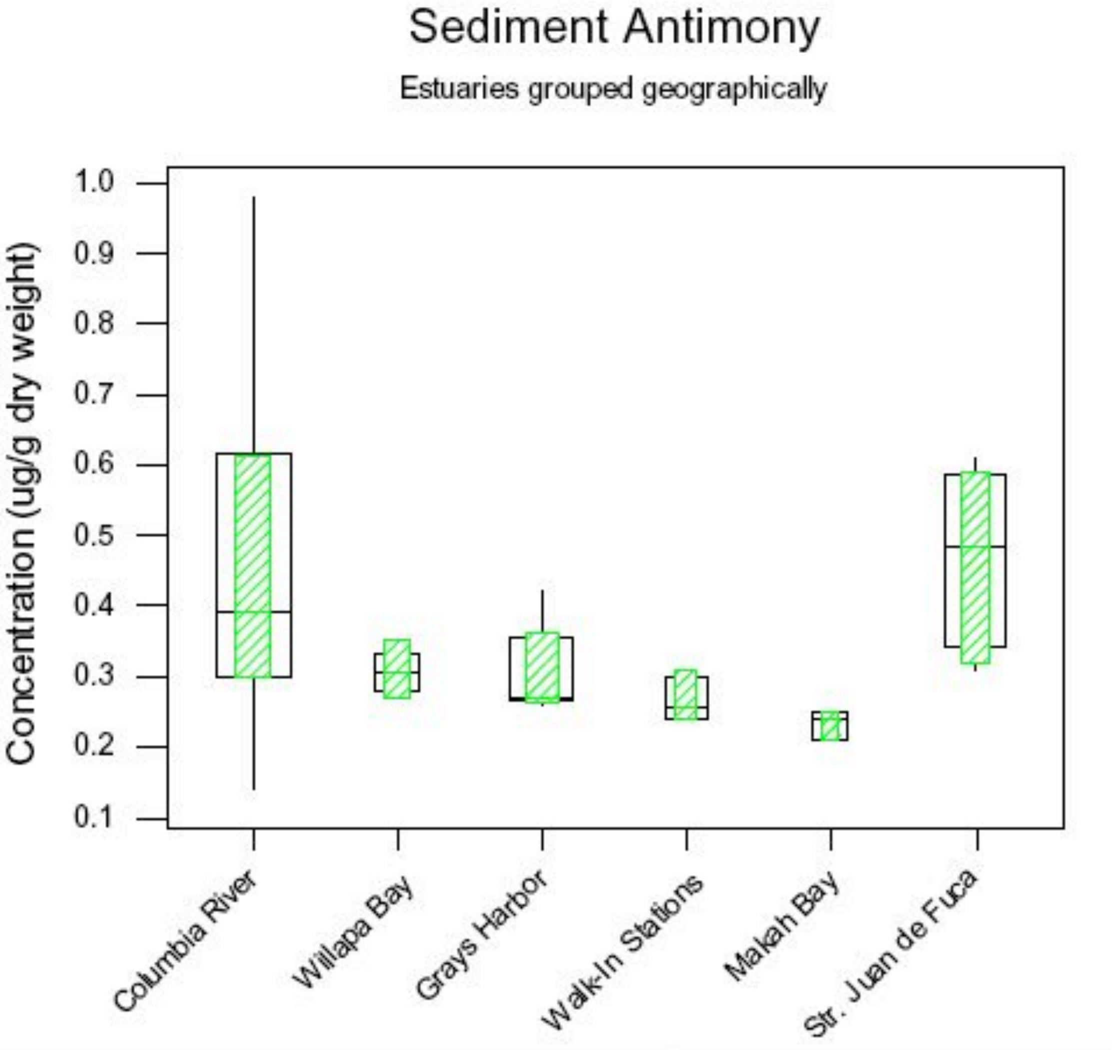


Figure 52. Sediment Antimony (Wilson and Partridge 2007).

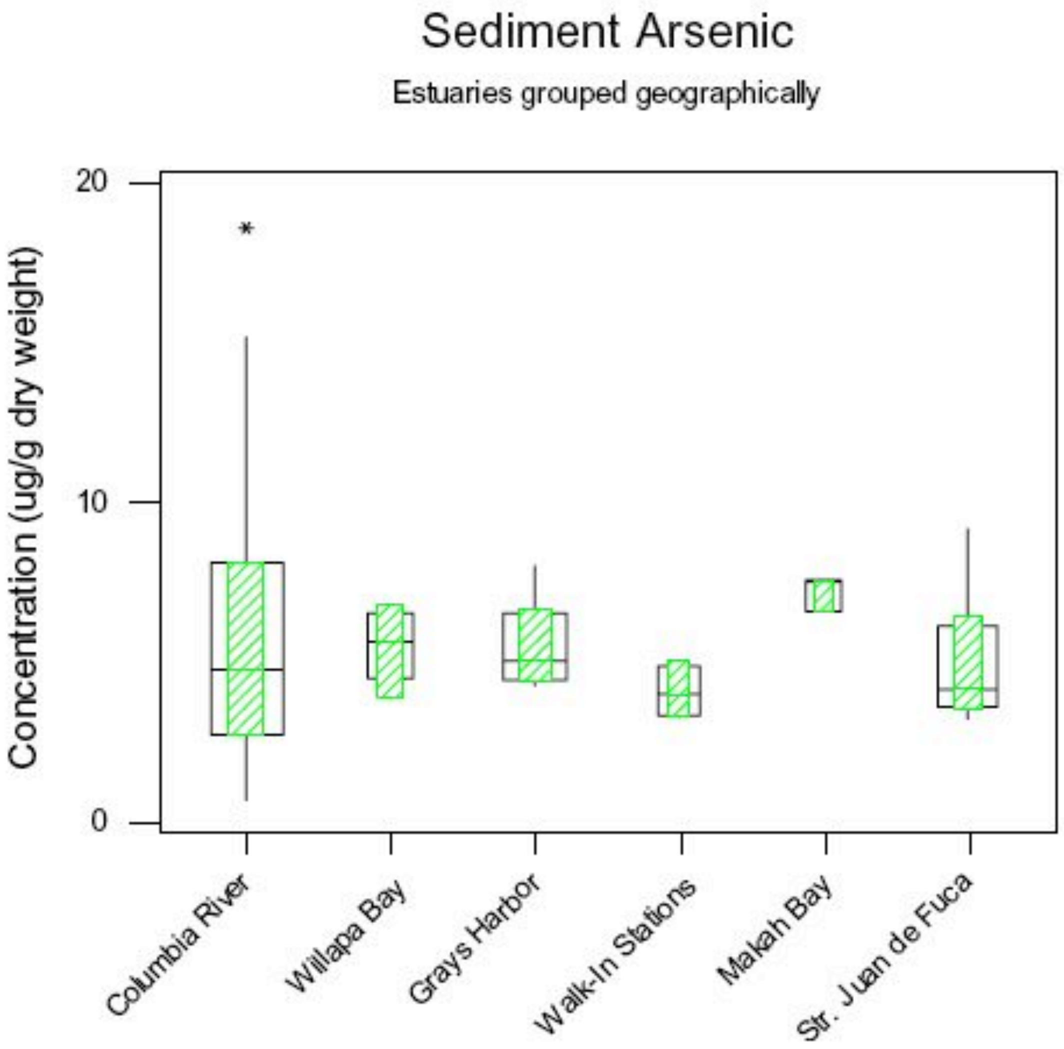


Figure 53. Sediment Arsenic (Wilson and Partridge 2007).

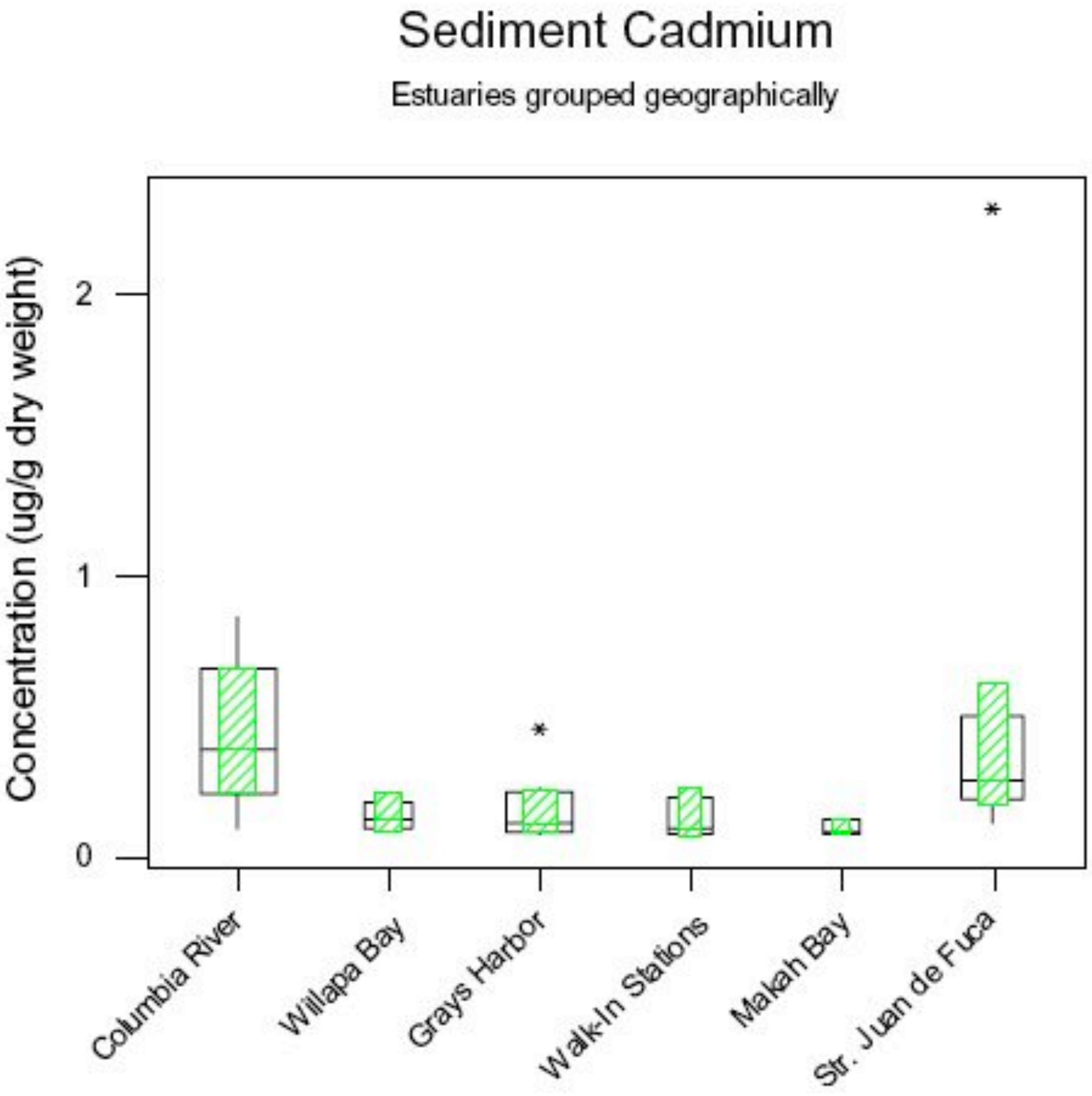


Figure 54. Sediment Cadmium (Wilson and Partridge 2007).

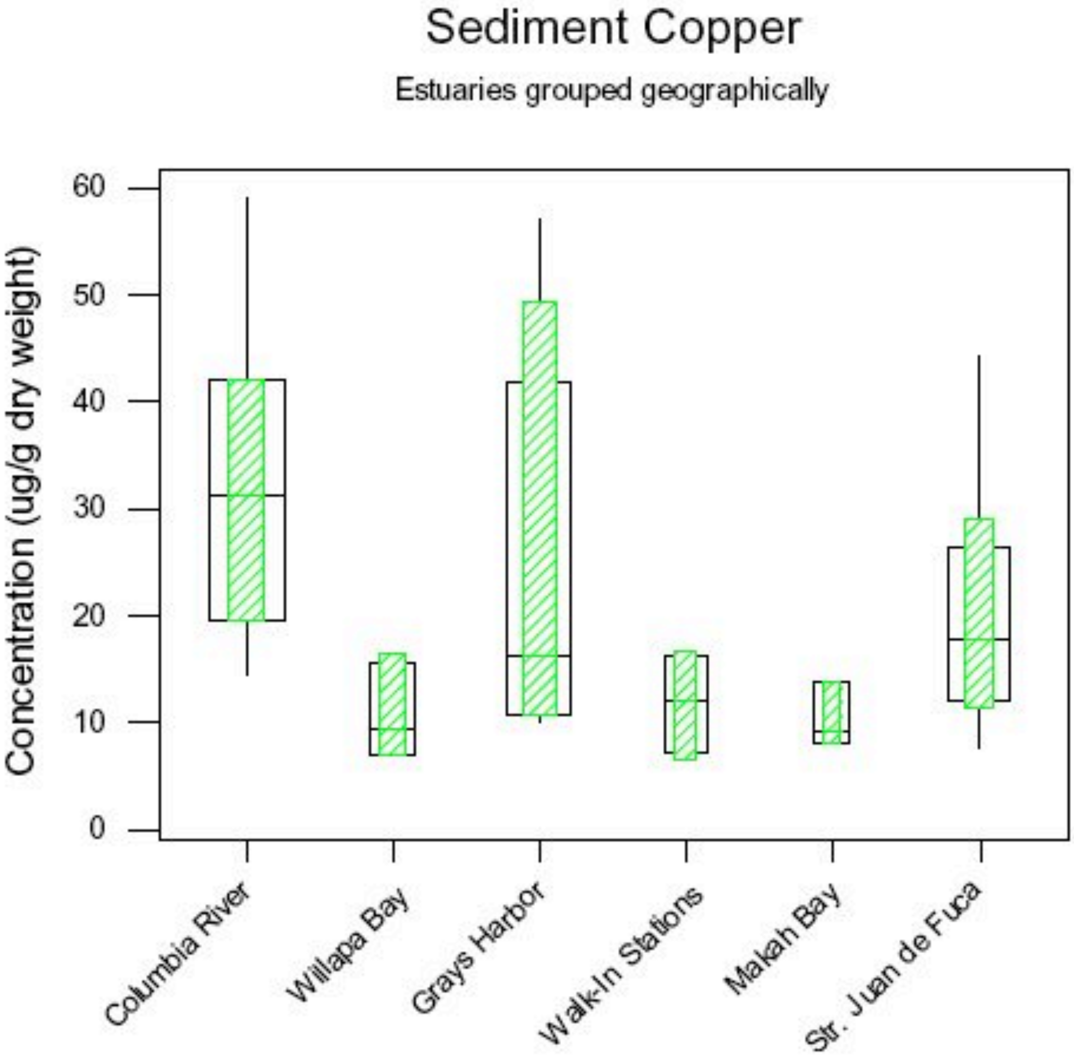


Figure 55. Sediment Copper (Wilson and Partridge 2007).

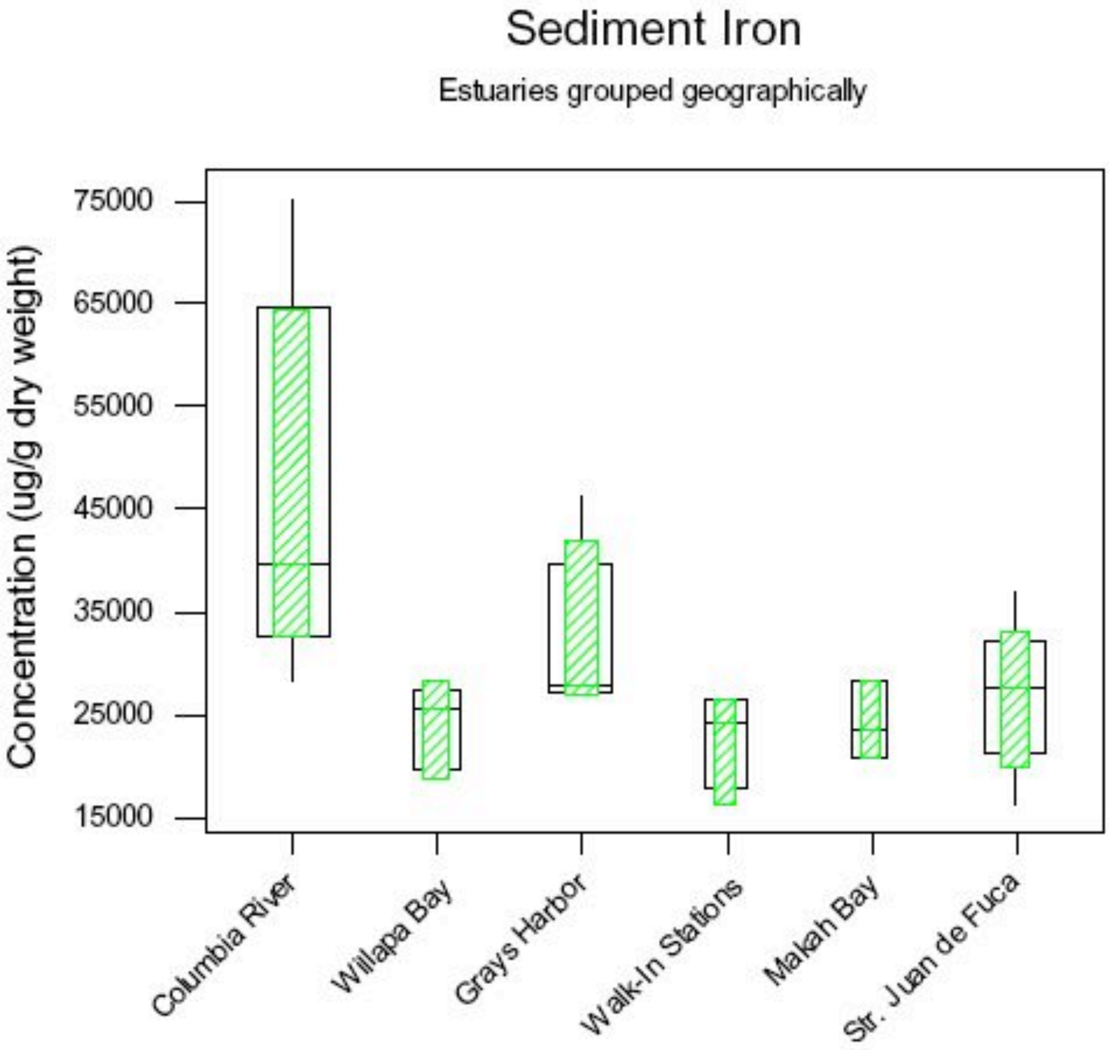


Figure 56. Sediment Iron (Wilson and Partridge 2007).

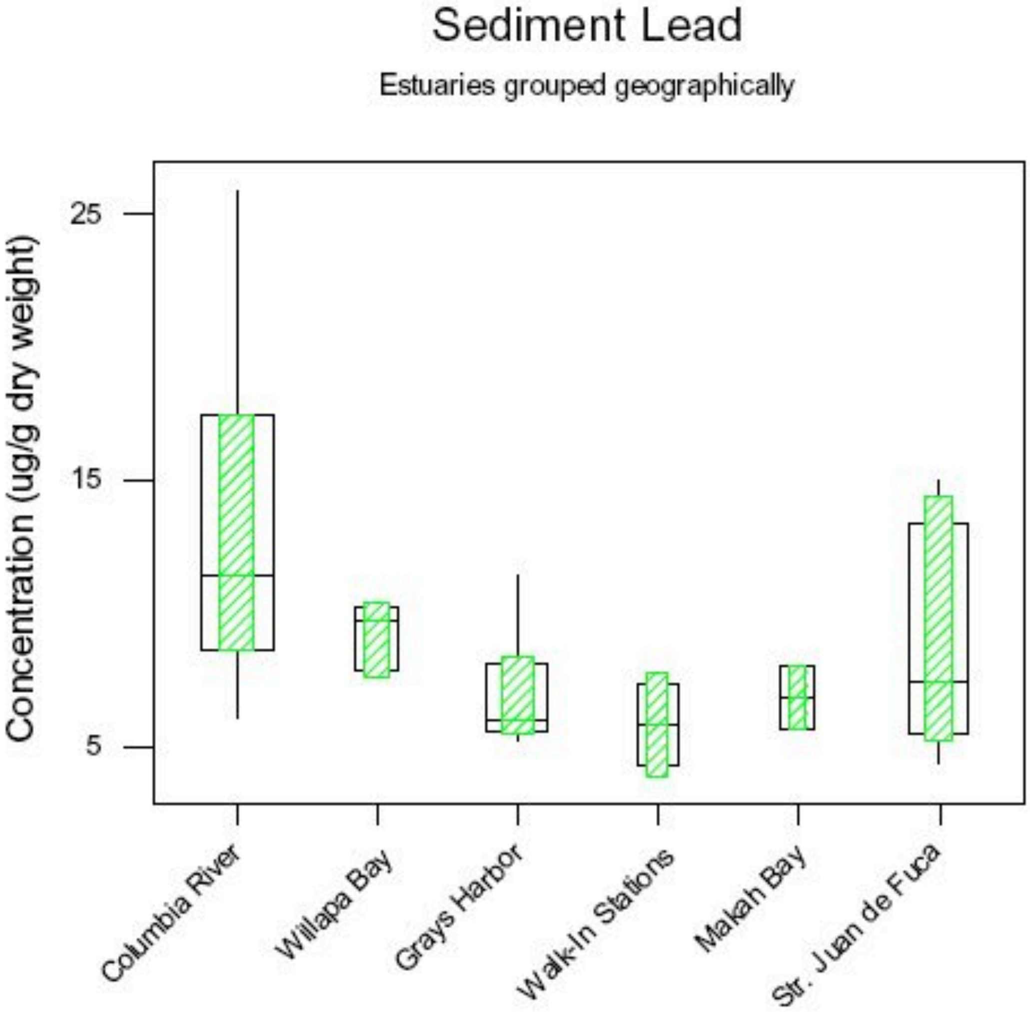


Figure 57. Sediment Lead (Wilson and Partridge 2007).

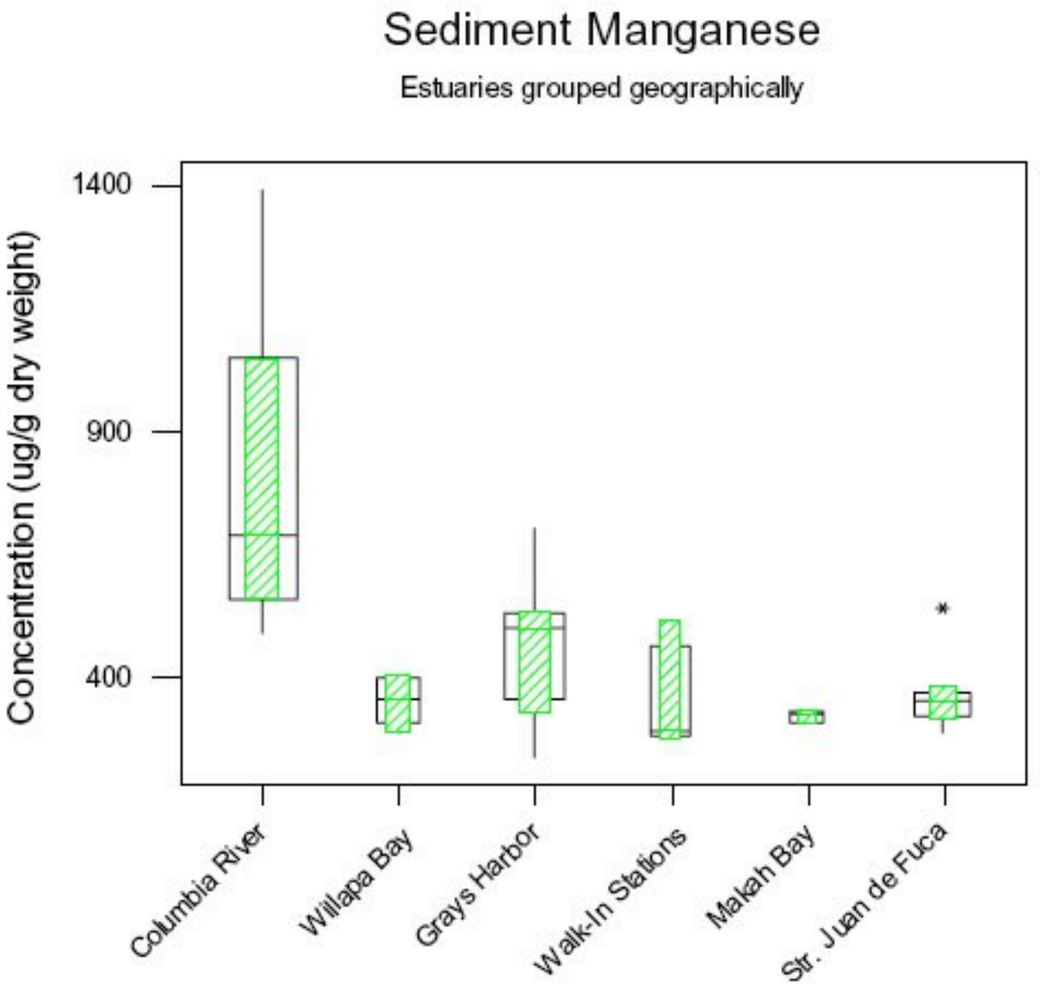


Figure 58. Sediment Manganese (Wilson and Partridge 2007).

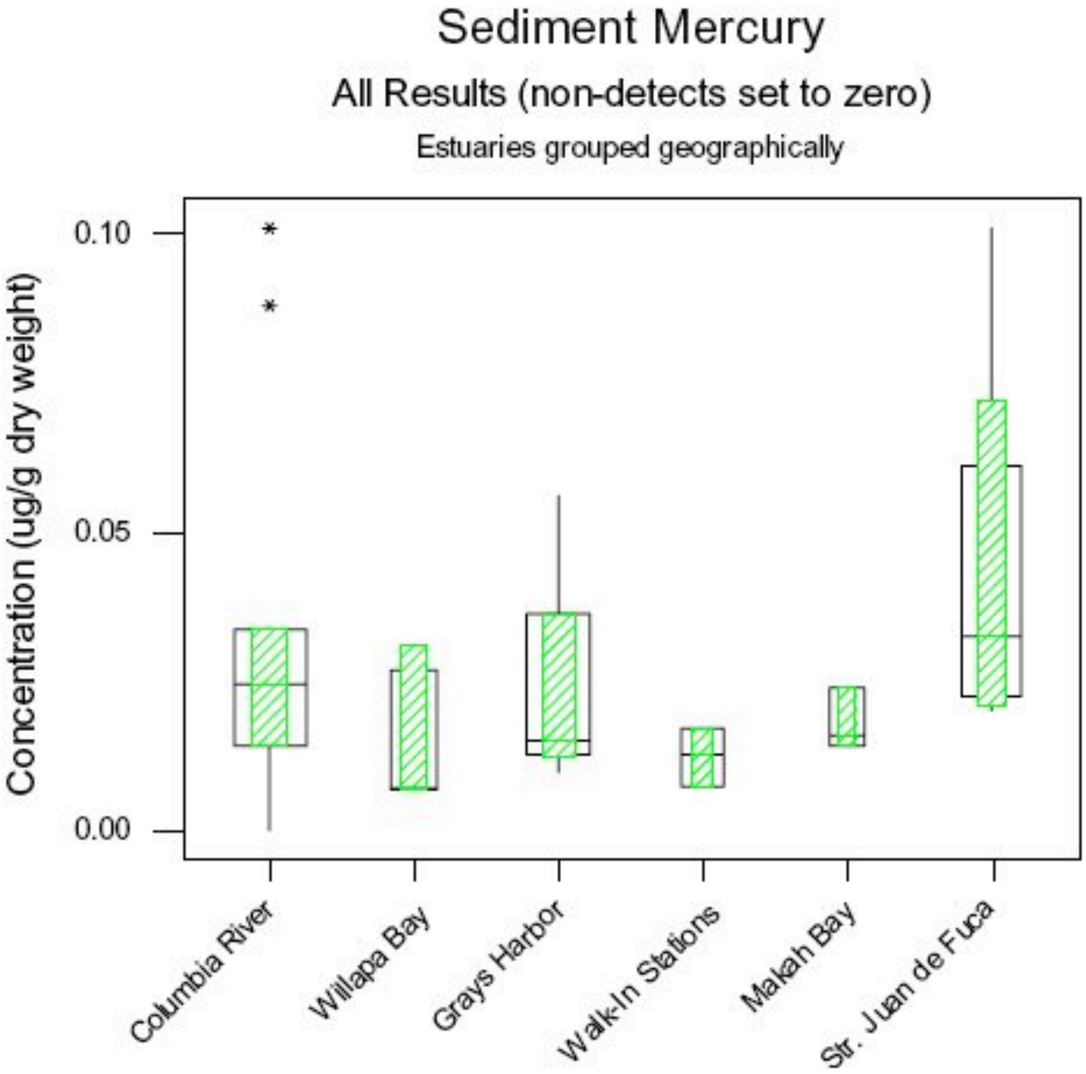


Figure 59. Sediment Mercury (Wilson and Partridge 2007).

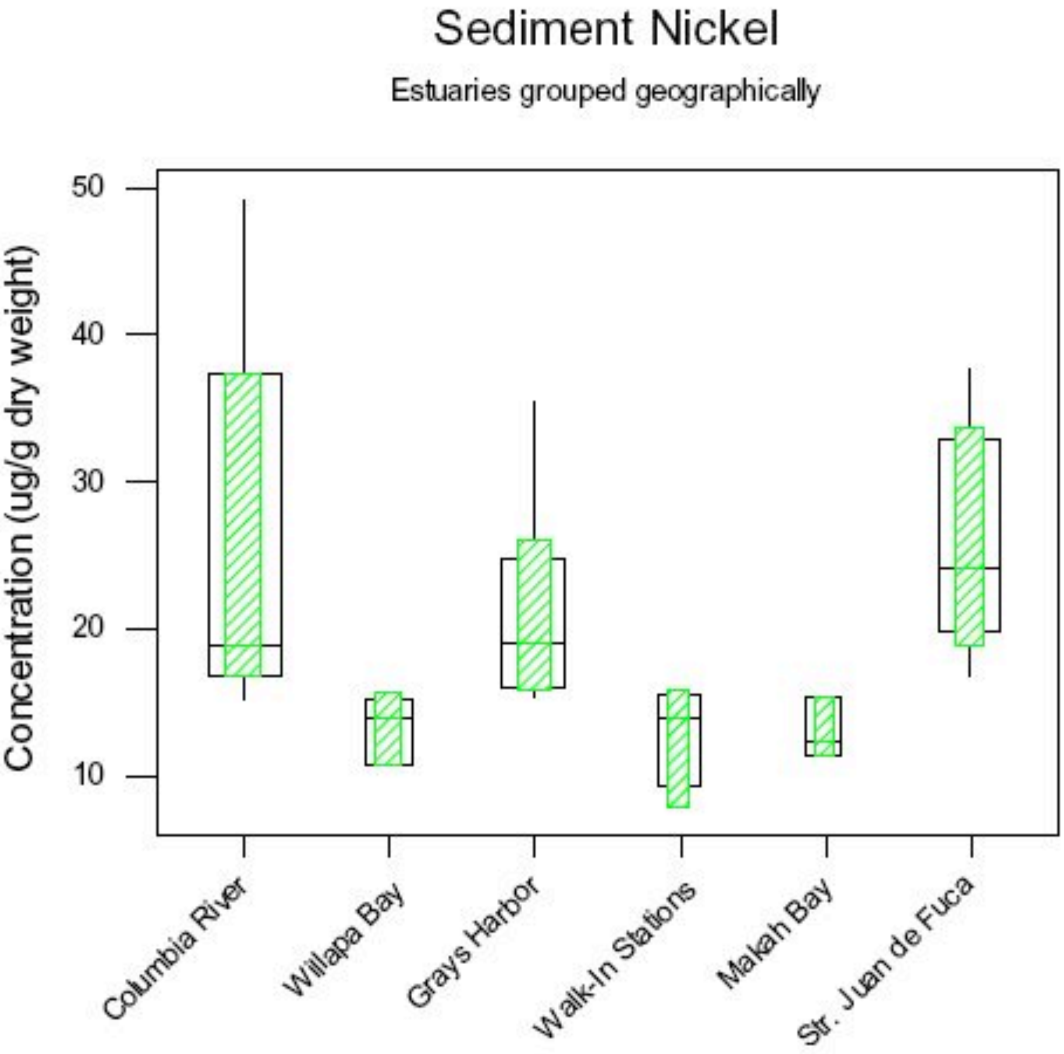


Figure 60. Sediment Nickel (Wilson and Partridge 2007).

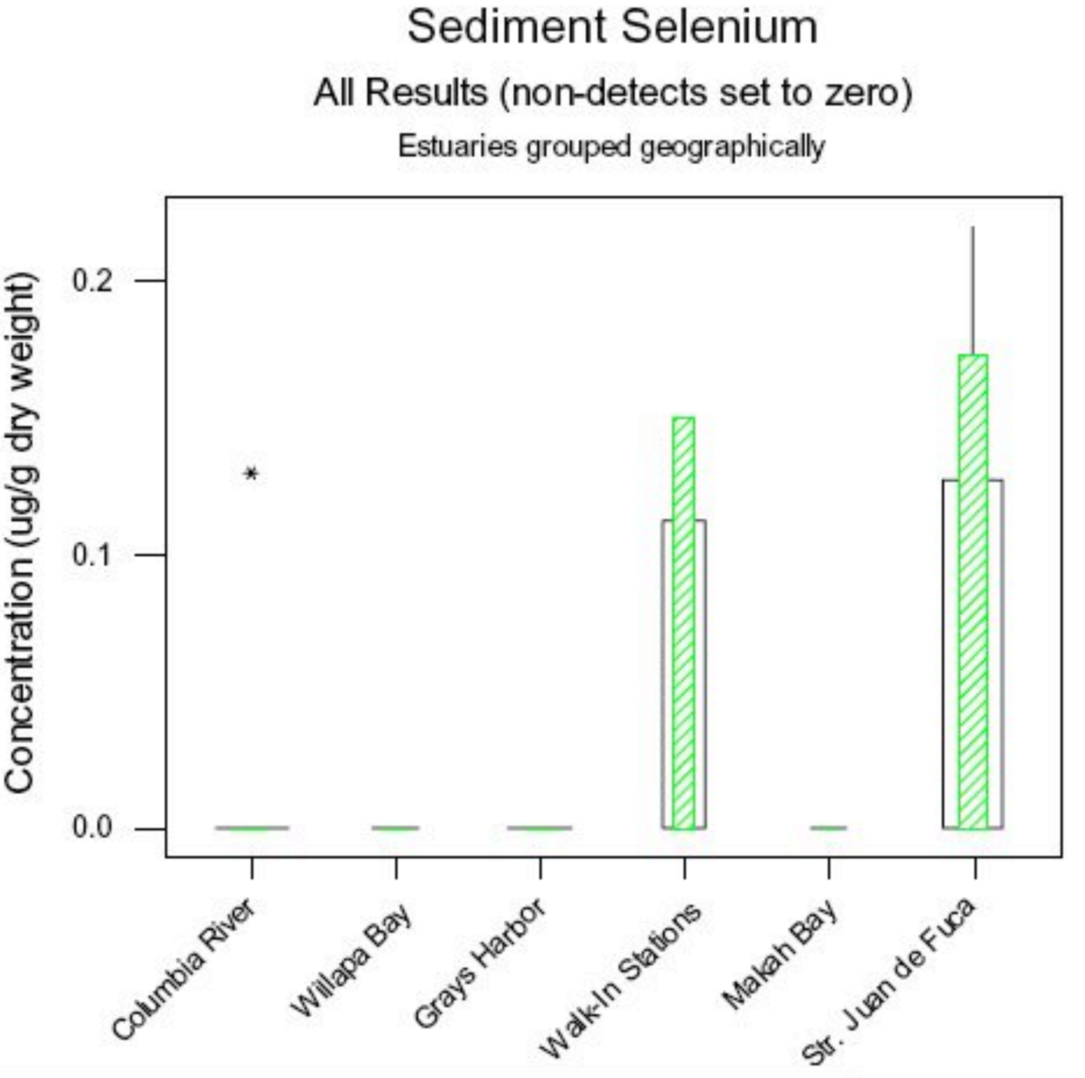


Figure 61. Sediment Selenium (Wilson and Partridge 2007).

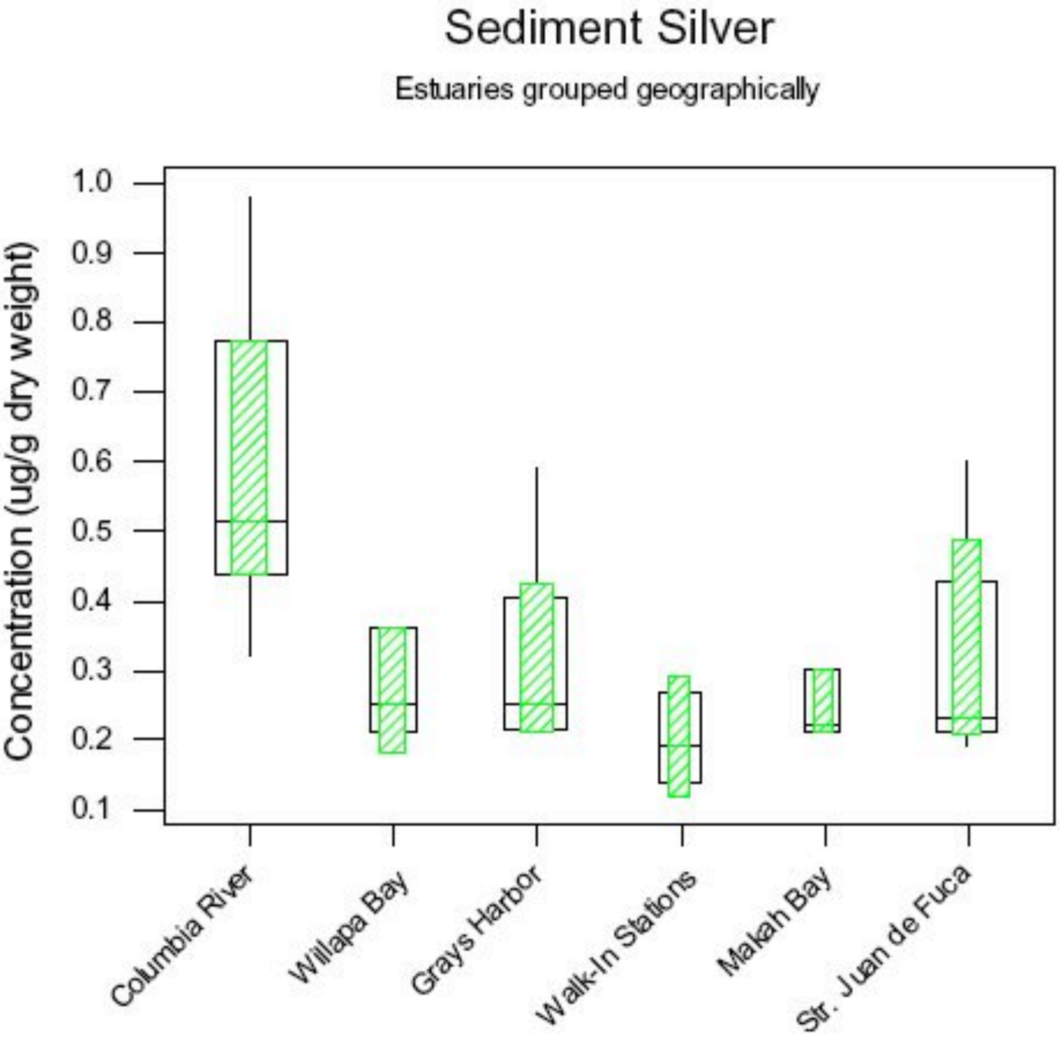


Figure 62. Sediment Silver (Wilson and Partridge 2007).

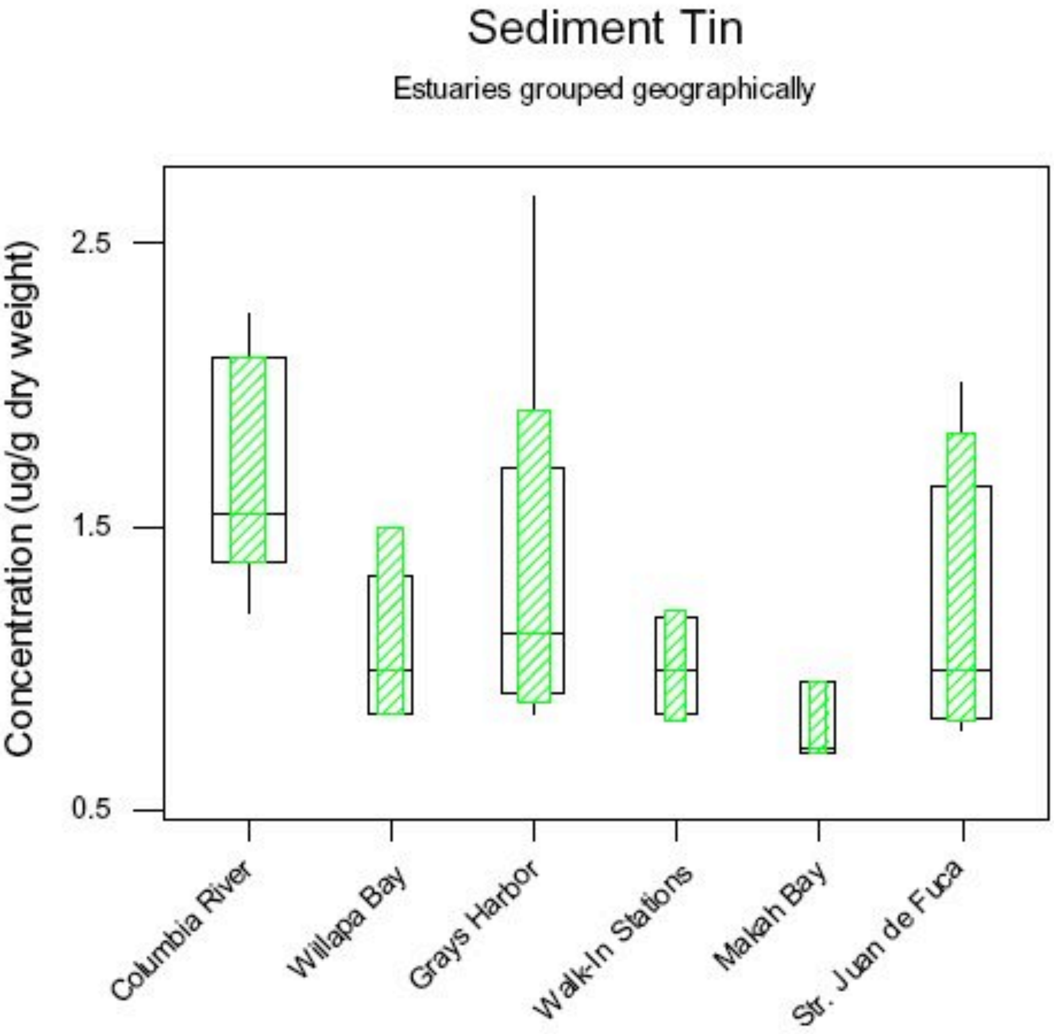


Figure 63. Sediment Tin (Wilson and Partridge 2007).

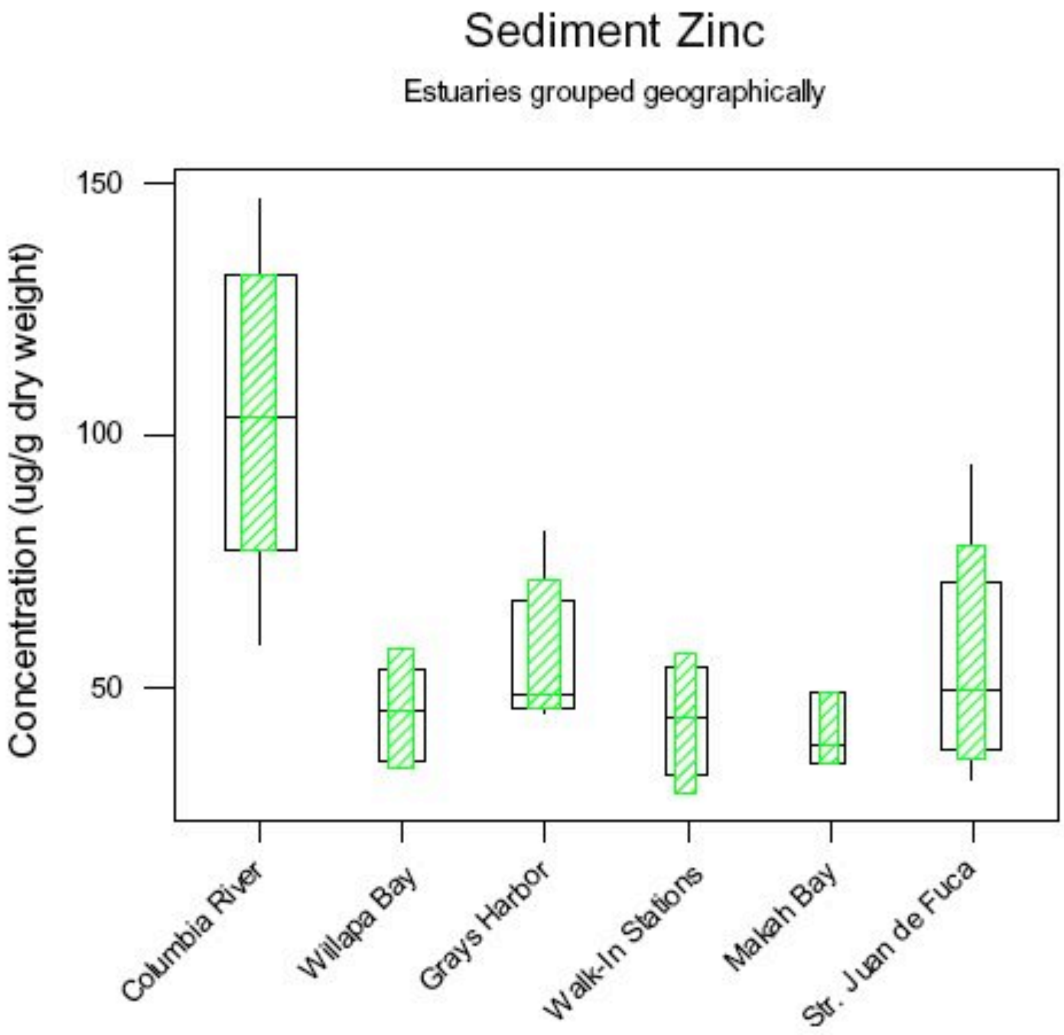


Figure 64. Sediment Zinc (Wilson and Partridge 2007).

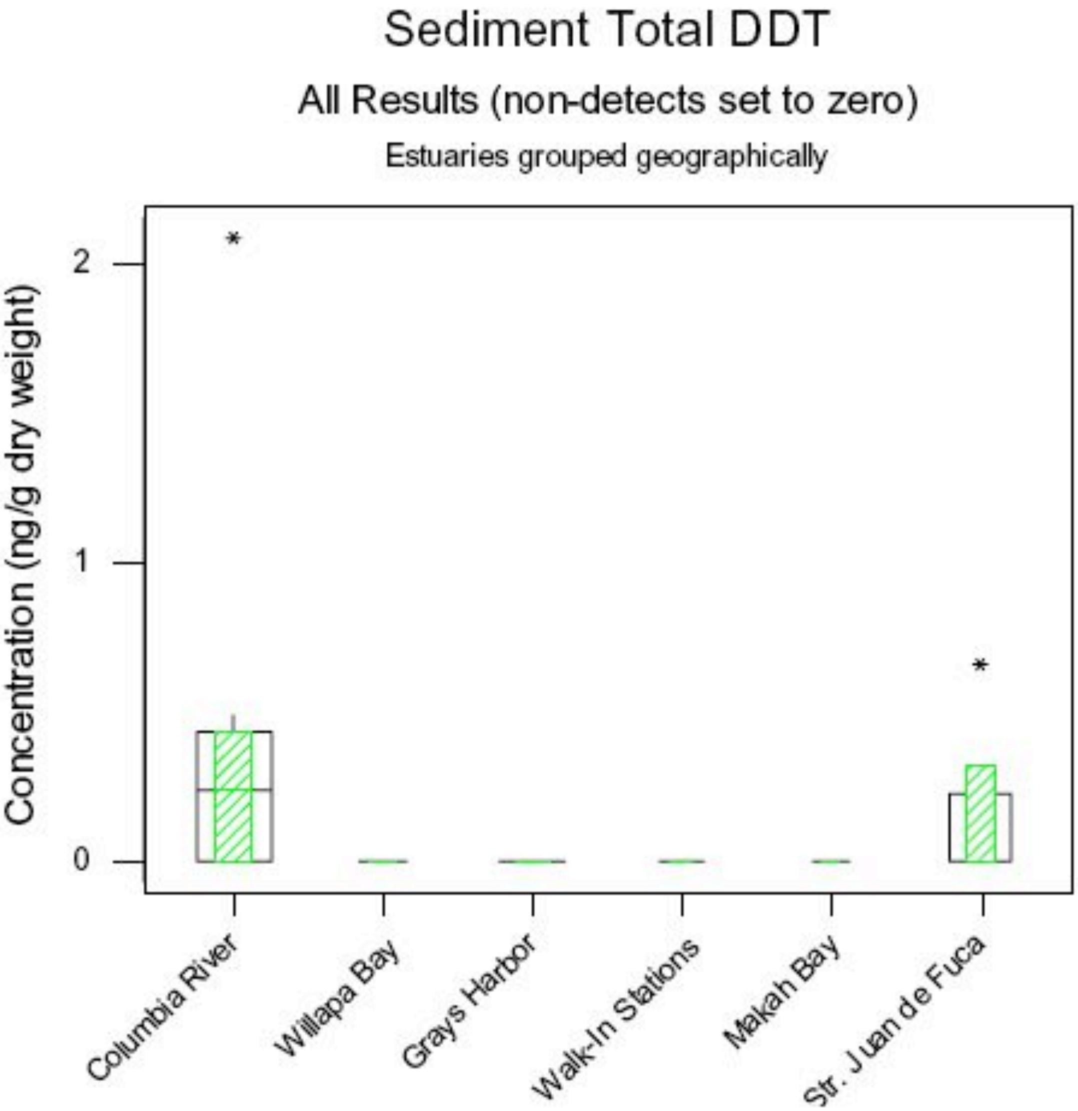


Figure 65. Sediment Total DDT (Wilson and Partridge 2007).

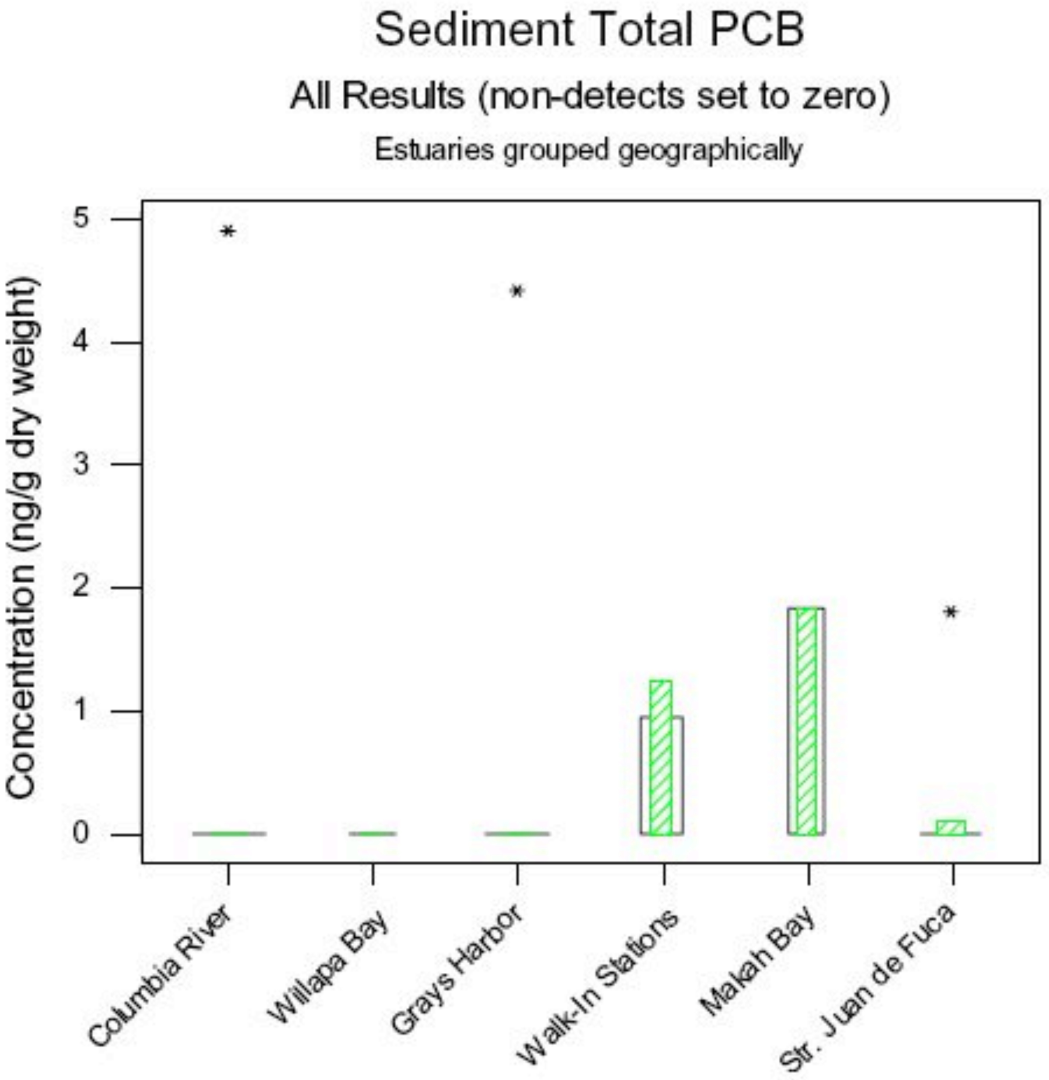


Figure 66. Sediment Total PCB (Wilson and Partridge 2007).

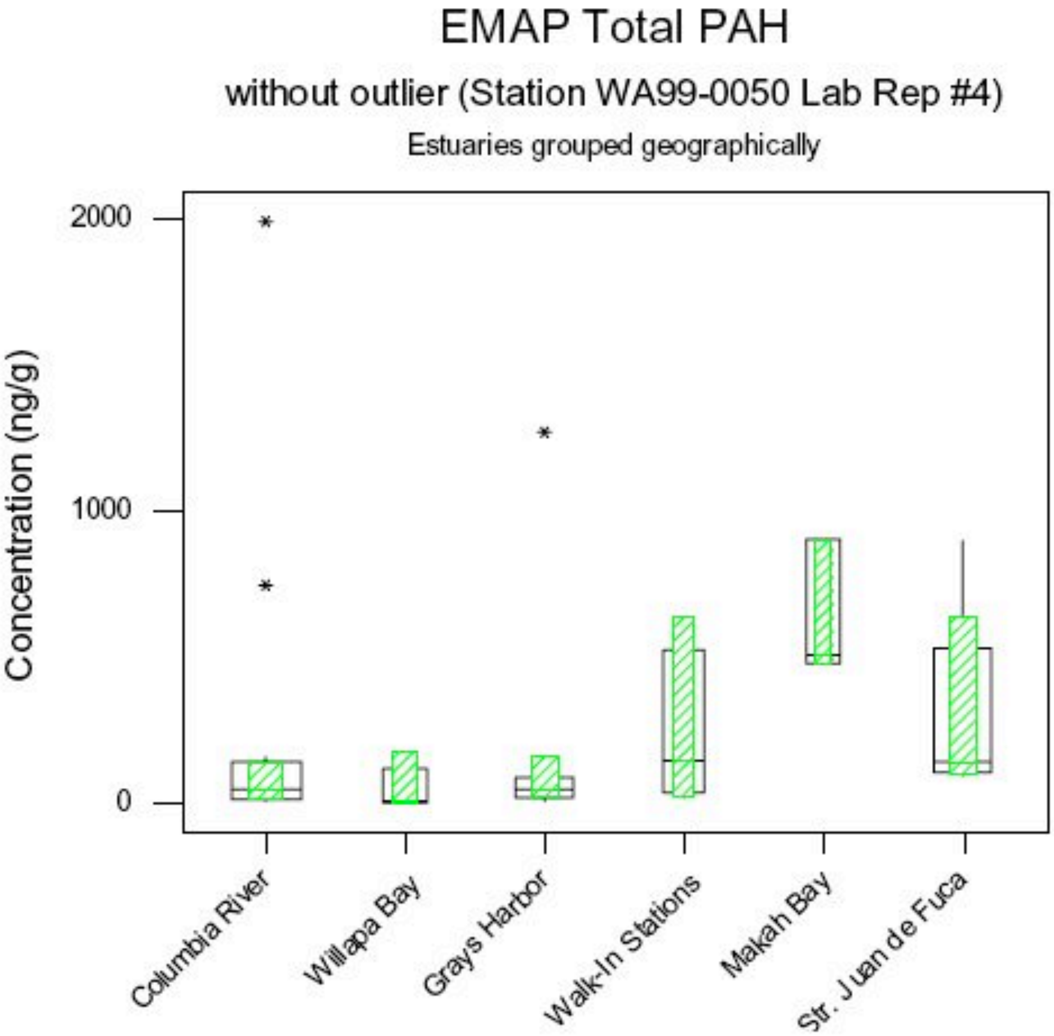


Figure 67. EMAP Total PAH (Wilson and Partridge 2007).

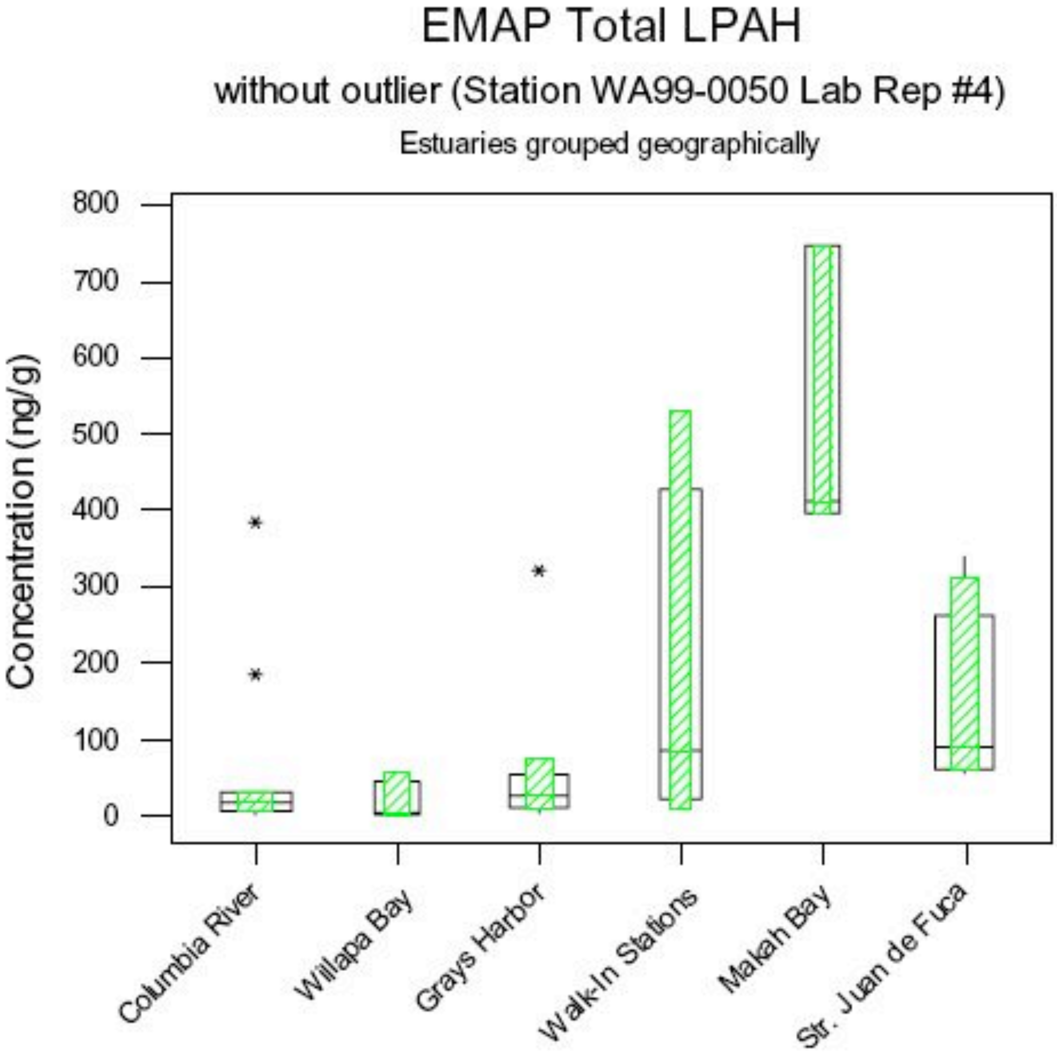


Figure 68. EMAP Total LPAH (Wilson and Partridge 2007).

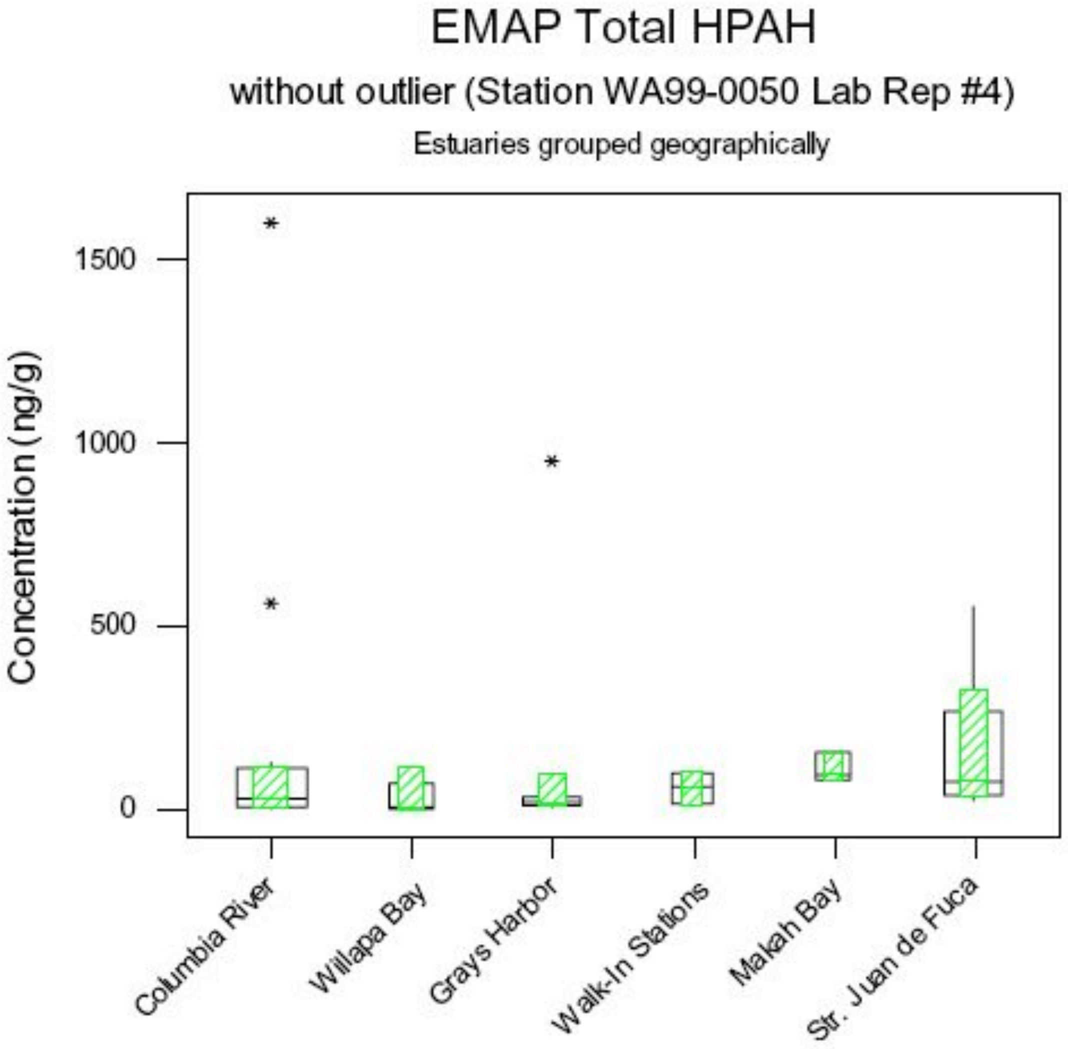


Figure 69. EMAP Total HPAH (Wilson and Partridge 2007).

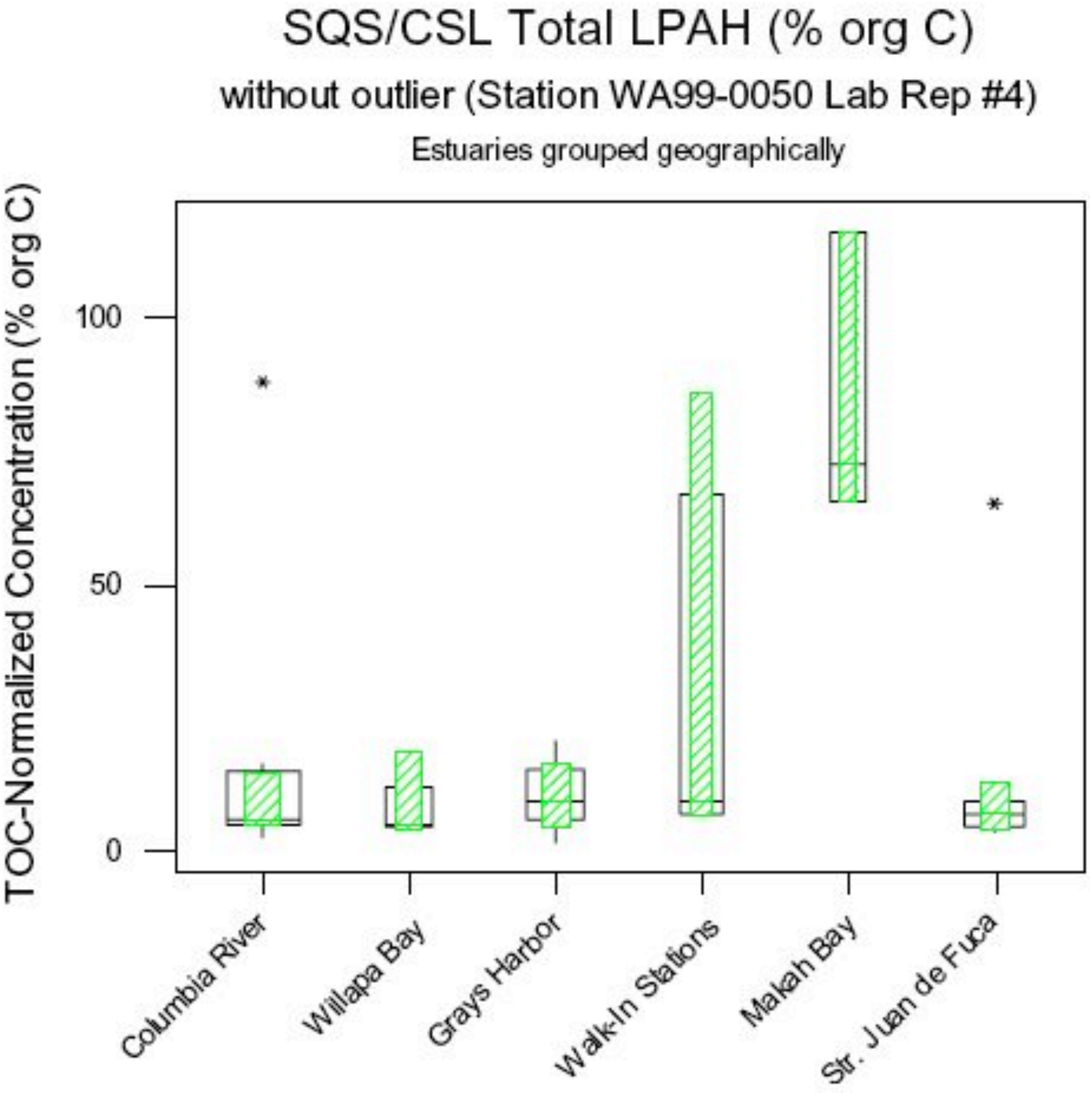


Figure 70. SQS/CSL Total LPAH (% org C) (Wilson and Partridge 2007).

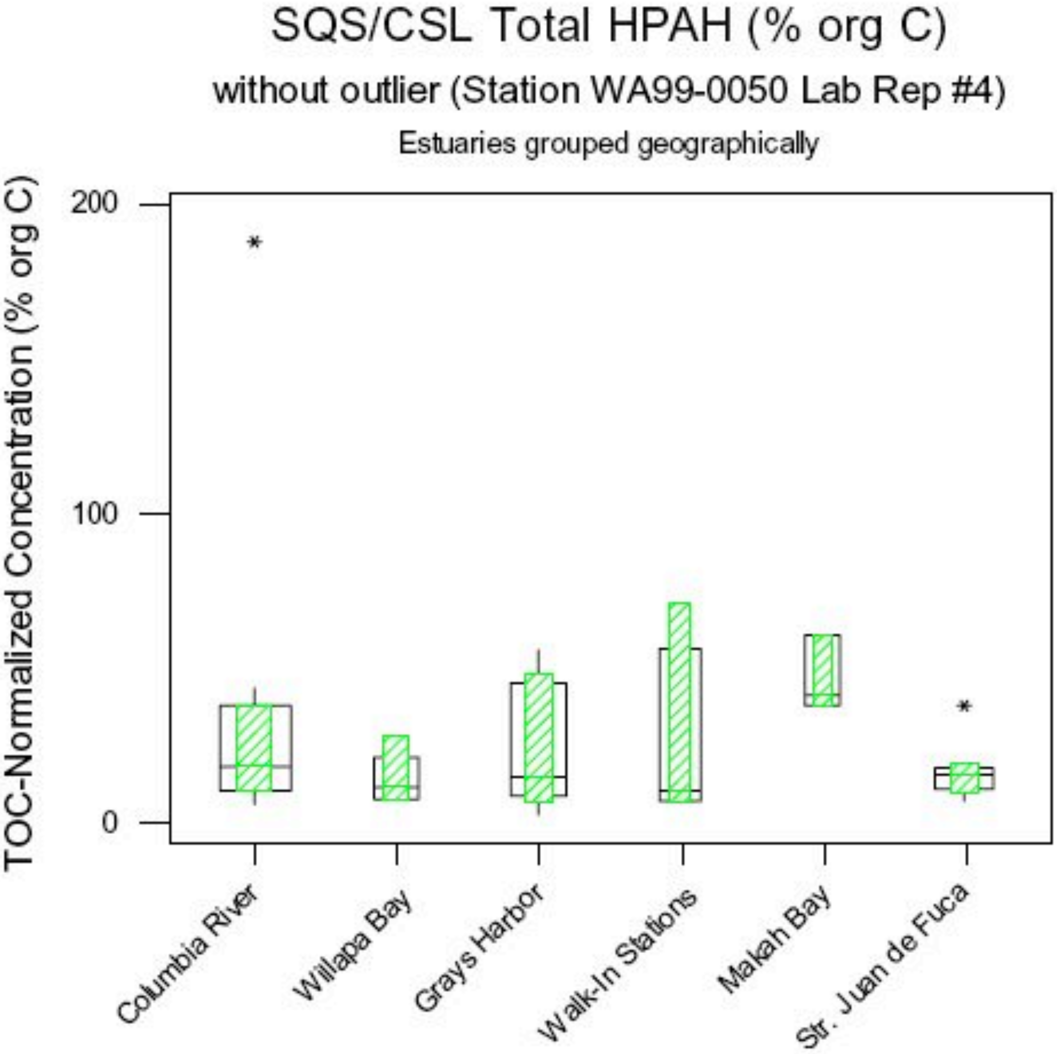


Figure 71. SQS/CSL Total HPAH (% org C) (Wilson and Partridge 2007).

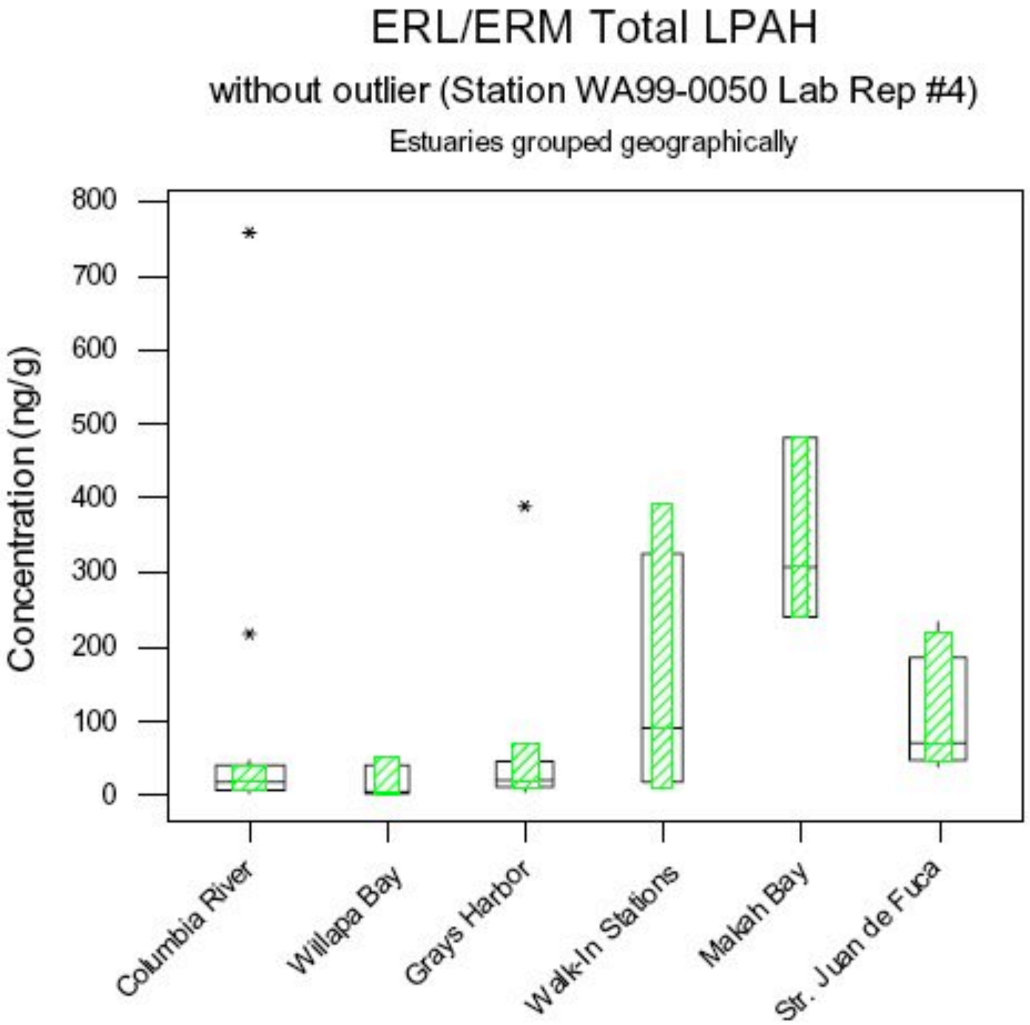


Figure 72. ERL/ERM Total LPAH (Wilson and Partridge 2007).

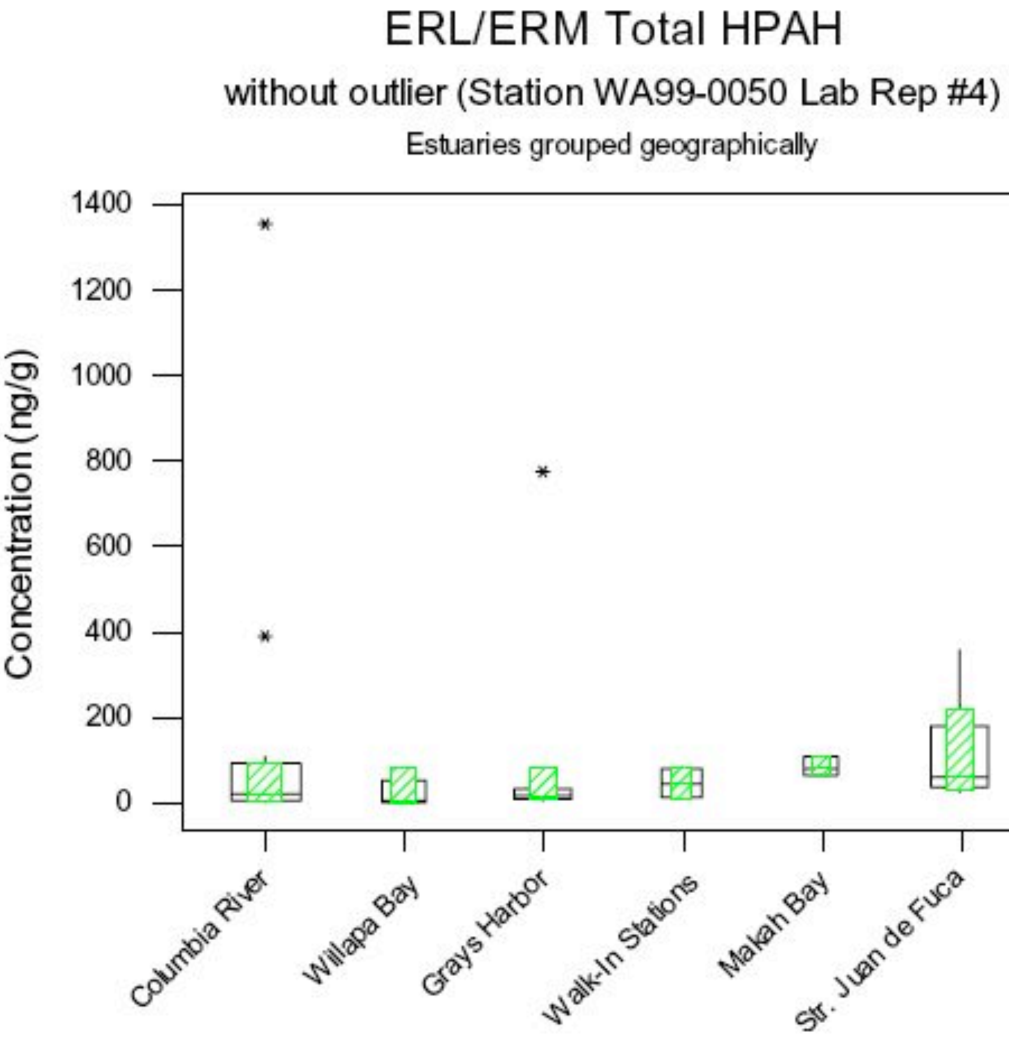


Figure 73. ERL/ERM Total HPAH (Wilson and Partridge 2007).

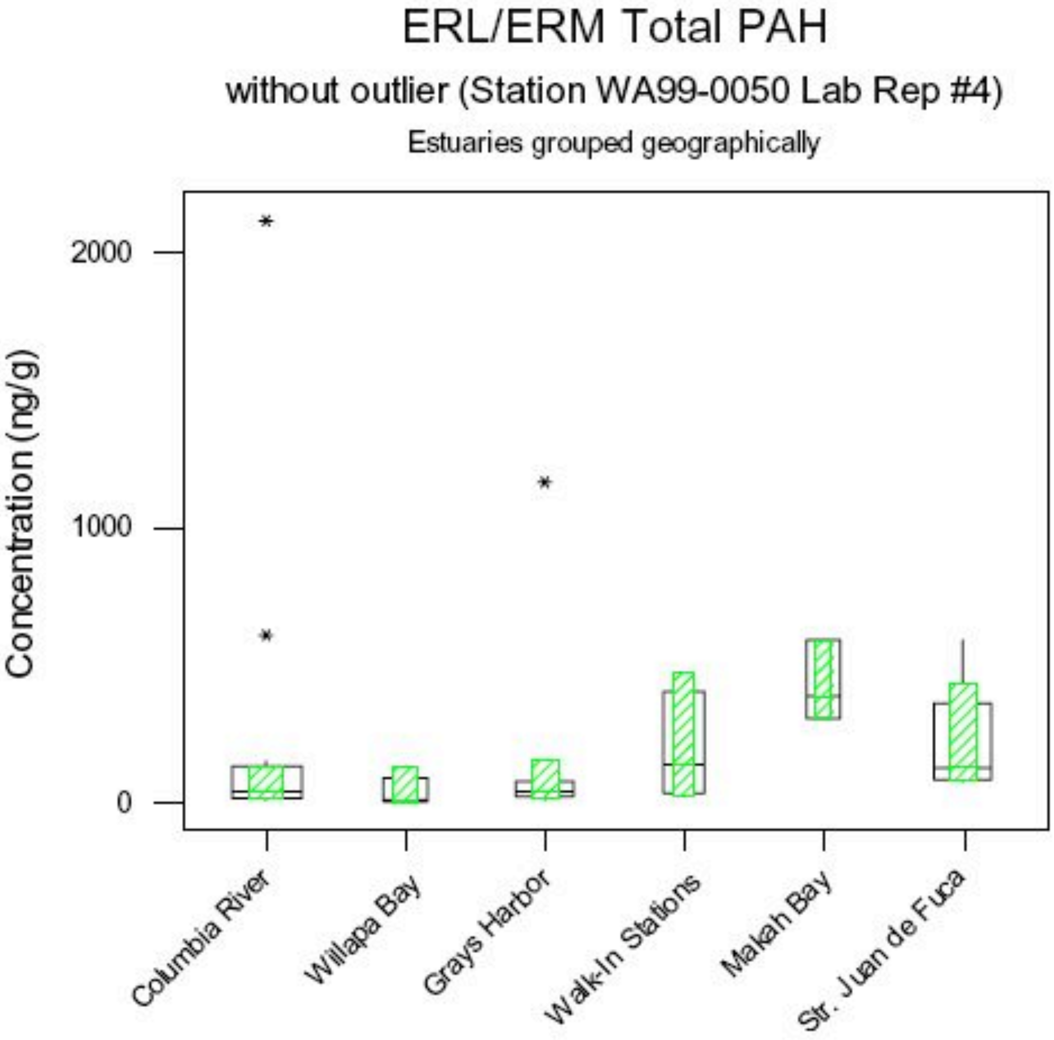


Figure 74. ERL/ERM Total PAH (Wilson and Partridge 2007).

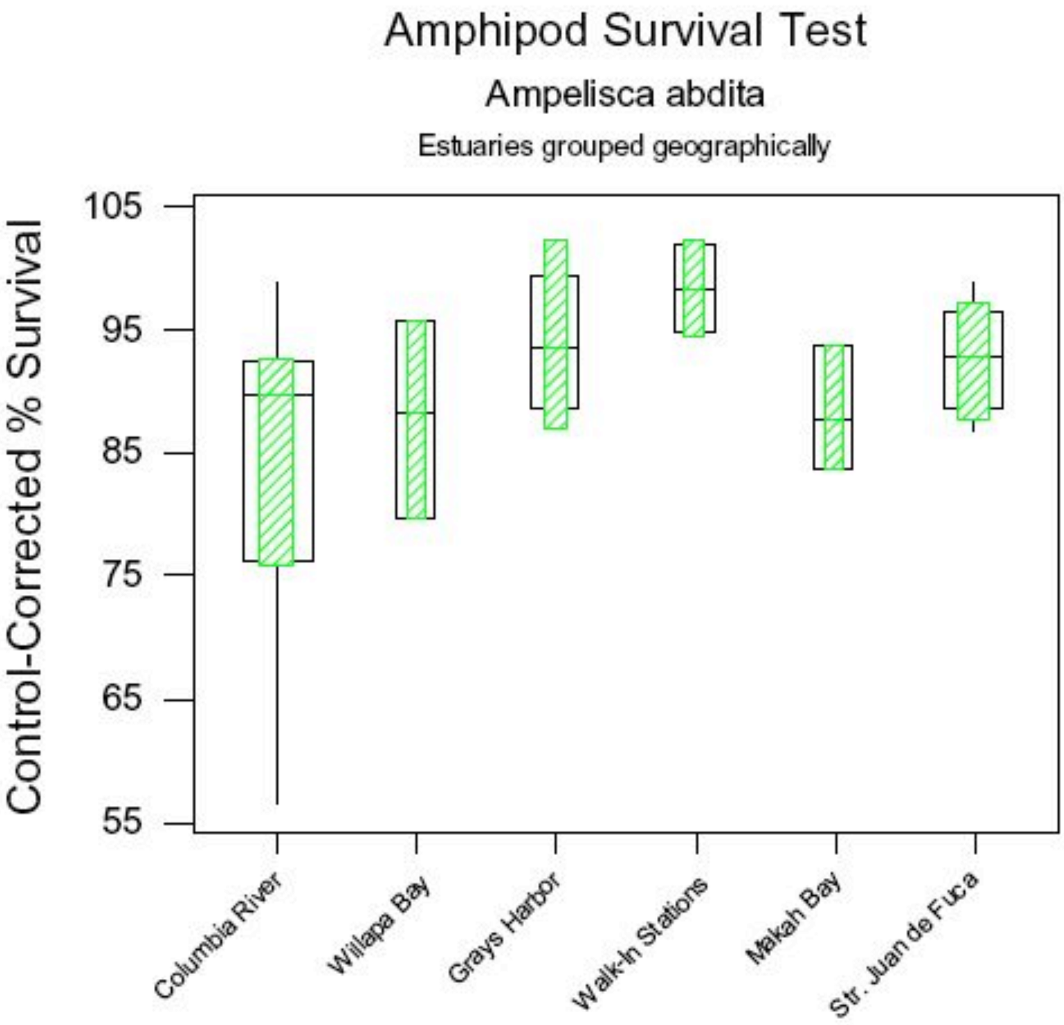


Figure 75. Amphipod Survival Test (*Ampelisca abdita*) (Wilson and Partridge 2007).

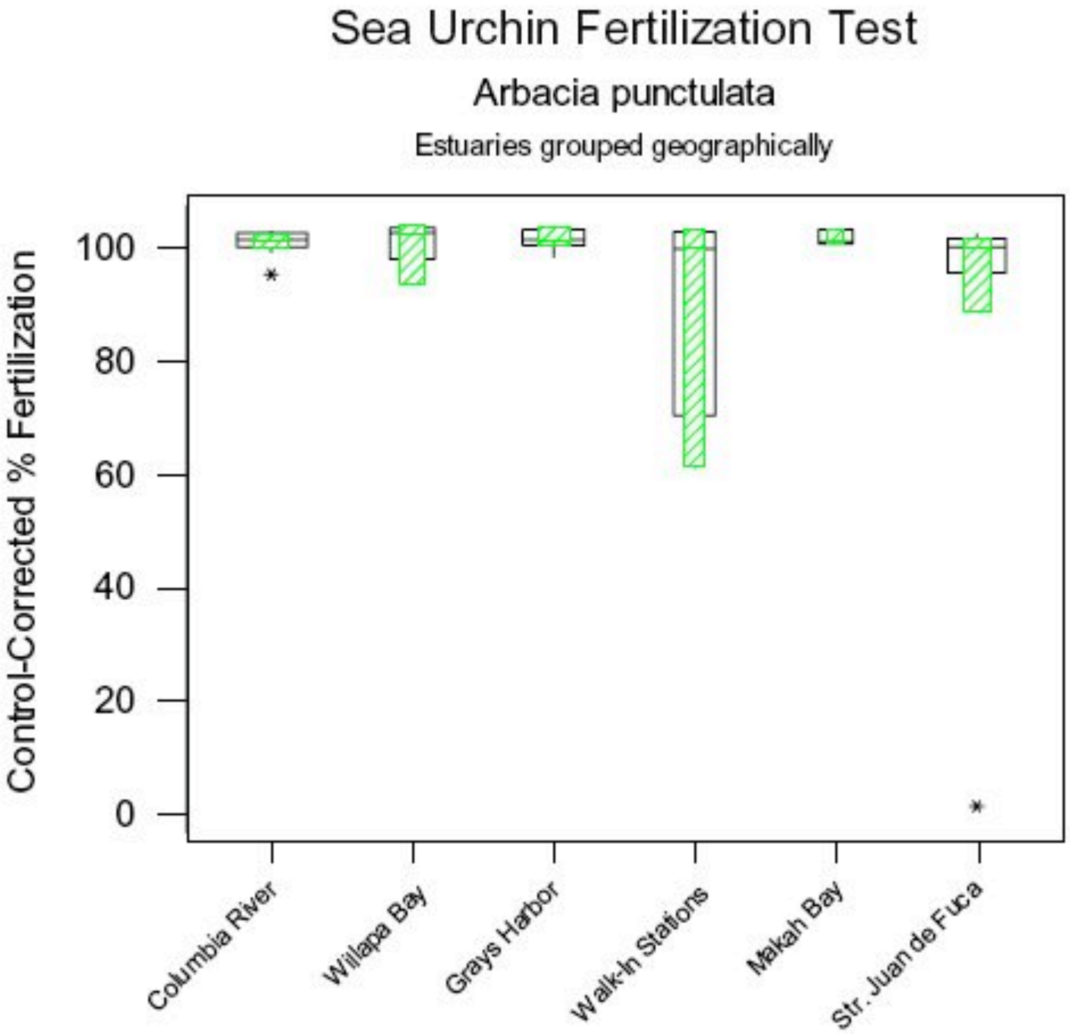


Figure 76. Sea Urchin Fertilization Test (*Arbacia punctulata*) (Wilson and Partridge 2007).

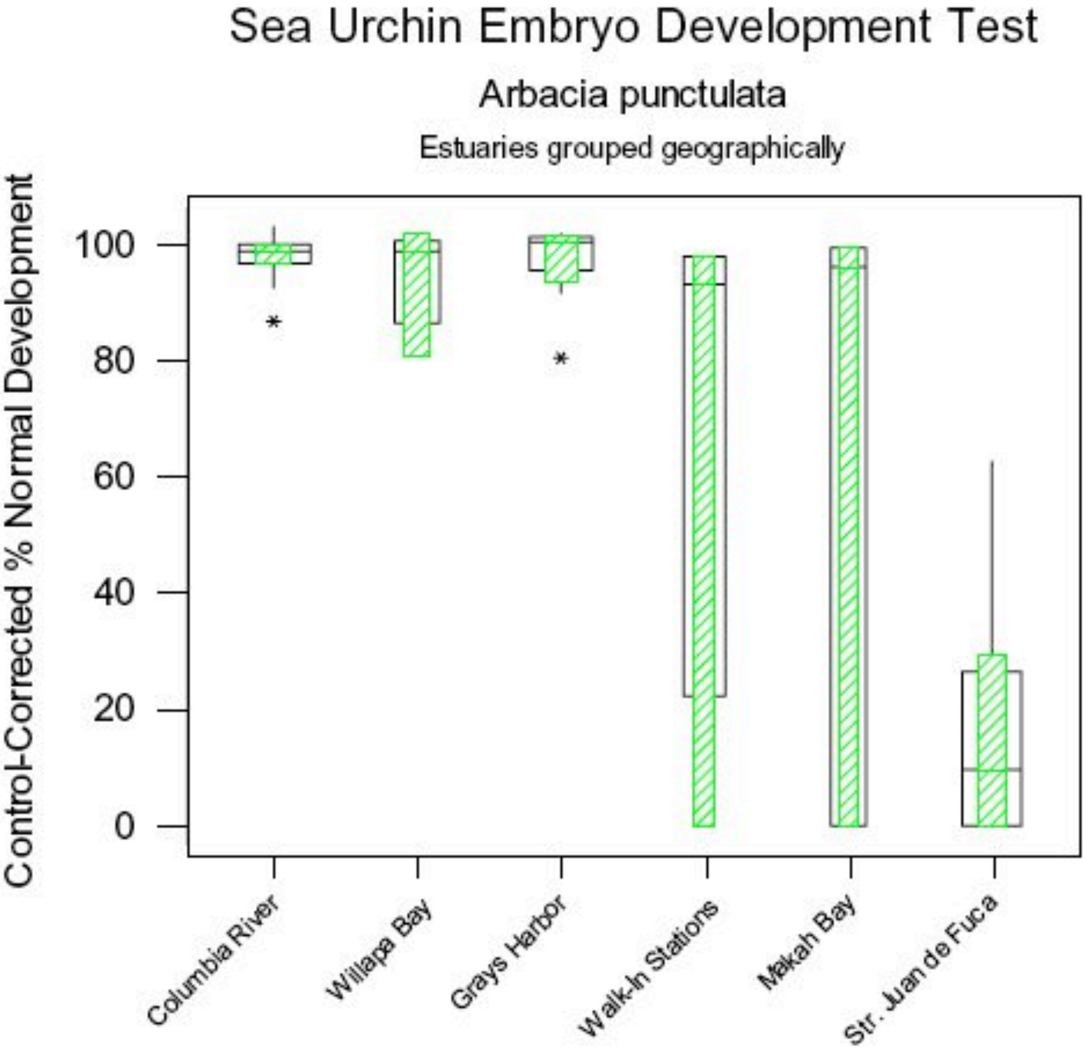


Figure 77. Sea Urchin Embryo Development Test (*Arbacia punctulata*) (Wilson and Partridge 2007).

B.1.d. Data Gaps and Information Inconsistencies

Our research has revealed a number of data gaps and information inconsistencies regarding water quality monitoring and data collection in vicinity of the OLYM coastal region, as illustrated by the following:

- WDOE conducts water quality monitoring on an annual or rotating basis at locations throughout Washington's marine waters. However, the only locations monitored are in Puget Sound, Grays Harbor, and Willapa Bay. Therefore, no WDOE data are available that describe conditions within or adjacent to OLYM (WDOE

2006d). In 2006, some locations within Grays Harbor were listed as "threatened" due to elevated bacteria levels. The distance from the mouth of Grays Harbor to the southern border of the OLYM coastal strip is approximately 45 miles, but the prevailing current is southerly, suggesting that conditions in Grays Harbor are unlikely to strongly affect OLYM, except under unusual oceanographic conditions.

- The EPA program BEACON (Beach Advisory and Closing On-line Notification) program provides a public database concerning the status of state beaches. Each beach contains information regarding contacts, monitoring and notification, general beach characteristics, advisories and closings, and location data (BEACON 2006). The website shows that no water quality or advisory data has been made available for OLYM beaches.

- According to *Testing the Waters: A Guide to Water Quality at Vacation Beaches*, a report published by the Natural Resources Defense Council (NRDC) in July 2005, Washington State "regularly monitors less than half of [its] beaches," and the OLYM beaches are listed as "not monitored" (NRDC 2006).

- The Hoh Tribe collects stream gauge, water quality, and temperature information, but the data were not available when queried.

B.2. Water Quality Degradation

WDOE's 303(d) water quality assessment for 2004 includes WRIAs 20 and 21 (WDOE 2006i). Tables 6 and 7 display Category 5 listings and details for both WRIAs, although most waterbodies lie outside OLYM boundaries. The Soleduck River was listed for exceeding pH standards within the boundaries of OLYM, at a station immediately downstream from a natural geothermal hotspring and hotspring resort. It is not known whether this exceedance results from natural geothermal processes or from impacts associated with the resort.

According to Streamkeepers (2004), the Ozette River watershed, the Dickey River, and the Quillayute River all show signs of degradation associated with high water temperatures, low dissolved oxygen, sedimentation, channel modification, and loss of salmon spawning habitat.

Only two of the beaches monitored through the BEACH program are near or adjacent to OLYM boundaries; three beaches are to the north in the Makah reservation, and two are in La Push on the Quileute reservation. Sites that exceeded EPA closure criteria in 2005 for the presence of *Enterococcus* (104 colonies/100mL H_2O) include one instance at

Neah Bay on November 10th, and two instances at La Push #1 on November 1st and November 8th (Table 23). Many of the beaches on the outer Pacific coast are not monitored at all and there is insufficient state funding to test beaches throughout the state as a whole.

Table 23. Summary of bacterial levels at five sites, from data collected by the BEACH program. Shaded boxes indicate exceedances (WDOE 2006a).

Date	# of *Enterococcus* colonies/ 100mL $H_2$0				
	Sooes Beach	Hobuck Beach	Neah Bay	La Push #1	La Push #2
11/10/2005	<10	26	312	N/A	N/A
11/8/2005	N/A	N/A	N/A	219	10
11/2/2005	35	10	35	N/A	N/A
11/1/2005	N/A	N/A	N/A	155	52

Surfrider's Blue Water Task Force program has monitored more extensively than the BEACH program within the OLYM coastal strip, including sampling at Shi Shi Beach, Rialto Beach, La Push, Second Beach, and Kalaloch (Surfrider BWTF 2006). The majority of these samples are collected by volunteers, and the testing intervals are sporadic and vary by site. Results of testing from 2003-2005 include only one instance of moderate to high levels of *Enterococcus* at both Shi Shi Beach and Second Beach.

The WDOH biotoxin monitoring program monitors levels of PSP and DA in shellfish tissue samples. Data from 1990-2005 has shown a total of 16 PSP exceedances in Clallam County, and five PSP exceedances in Jefferson County. Data from 1990-2005 also show 14 DA exceedances in Clallam County, and 181 DA exceedances in Jefferson County. Kalaloch has been known to have DA levels that are "typically higher than at other Washington coastal sites" (ORHAB 2006).

WDOH's Shellfish Growing Area Classification Program evaluates and monitors all commercially harvested shellfish growing areas in Washington State. A growing area's classification is determined by conducting a "sanitary survey," which evaluates the results of a shoreline survey conducted to identify and assess possible pollution sources, the results of fecal coliform monitoring performed by WDOH in that area and an assessment of how weather conditions, tides, currents, and other factors may affect the distribution of pollutants in the area. WDOH conducts a sanitary survey and reassesses the classification of a growing area periodically. The coastal strip immediately beneath OLYM within Grays Harbor County has been classified as "Approved" from 2000 – 2004 (WDOH 2006b). This indicates that the region does not pose potential or present threats to public health; areas within OLYM are not likely to be impacted because of the lack of development and the relative absence of pollution sources.

B.3. Sources of Pollutants

Coastal areas in the vicinity of OLYM are relatively sparsely populated in comparison with other areas of western Washington; consequently, sources of pollutants typically associated with urban, suburban, and industrial areas elsewhere in western Washington are largely absent. Potential sources of pollution in coastal regions of OLYM include non-point sources from the Quillayute, Hoh, Queets and Quinault rivers, runoff from roads and parking lots, and atmospheric deposition. Point sources of pollution consist of discharges from sewage treatment systems, discharges from recreational boating activities, and oil and fuel spills (Bowlby *et al.* 2001). Pesticides used in forest practice applications and biocides used to control bacterial growth (for example, in Sol Duc Hot Springs) are additional sources of pollutants.

Industrial facilities discharges in the vicinity of OLYM were identified by the NPS Water Resources Division (NPS 1999) and are summarized in Table 24. Volume of discharge and extent and nature of impact were not specified in the report (NPS 1999). Seven of 12 dischargers are federal or state agencies or entities. Seven of 12 discharge locations and three of twelve receiving waters are listed as Neah Bay. Given the local ocean circulation, discharges into Neah Bay are likely to be well-mixed into the receiving waters at the mouth of the Strait of Juan de Fuca, with some likelihood of seasonal entrainment in the Juan de Fuca eddy. The impact discharges into Neah Bay on shoreline ecosystems within OLYM is unknown but likely to be small except in the case of large, accidental discharges.

Table 24. Industrial discharges in the vicinity of OLYM (NPS 1999).

Station/Facility Name	**City**	**Receiving Water**
Defense, Air Force	Neah Bay	
Makah Indian Tribe	Neah Bay	Neah Bay
Quinault Ind Tribe Queets V	Clearwater	Queets River
Point Adams Packing Co.	Neah Bay	Neah Bay
Transportation, Coast Guard	La Push	
Transportation, Coast Guard	Neah Bay	
Makah Fisheries Community	Neah Bay	
Interior, Fish & Wildlife	Neah Bay	Sooes River
Bay Fish Co.	Neah Bay	Neah Bay HBR
WA Fish (Sol Duc Hatchery)	Sappho	
WA Game (Bogachiel Rear Pond)	Forks	

The NPS maintains facilities at Kalaloch. The OLYM Environmental Assessment on Kalaloch Contact Station indicates the following regarding available facilities in the coastal strip (NPS 2006e):

> Drinking water for the developed facilities comes from Kalaloch Creek through a water treatment facility operated by the OLYM. Waste water for the same area goes to a series of waste treatment lagoons to the south of the developed area. The sewage system was designed as a facultative lagoon with two primary cells and one secondary cell. The ponds (cells) are currently operated in series as one primary cell with aerators, one secondary cell, and a polishing cell. Treated water is then sprayed onto an adjacent field. The water treatment facility and the waste treatment facility are underutilized in their current configuration. No problems beyond normal maintenance have been noted with either of these facilities...

Facilities within and managed by OLYM include those in Ozette Campground, Mora Campground, and Kalaloch Campground (NPS 2006f). The Ozette Campground consists of 14 sites and three boat ramps. The Mora Campground includes 94 sites, restrooms, RV dump facilities, and the Dickey River Boat Ramp. The Kalaloch Campground consists of 170 sites, restrooms, and RV dump facilities. Kalaloch Lodge, the only concessioner on the coast, consists of 58 cabins and motel rooms, and also offers gasoline. In 2000, an accidental discharge from Kalaloch reportedly released fuel into Kalaloch Creek.

Although road density within OLYM is relatively low, Highway 101 carries a high volume of traffic through the park. Pollutants from the highway enter coastal water systems via runoff into rivers and by surface flow directly onto beaches.

Atmospheric transport and deposition of pollutants is increasingly recognized as a potential threat to Pacific Coast ecosystems. According to Wilkening *et al.* (2000),

"…two recent events have been particularly important in focusing researchers' attention on trans-Pacific pollutant transfer. In 1997, rapid transport of pollutants from Asia to the Olympic Peninsula of Washington State was observed... and in April 1998, satellite remote sensing showed aerosols being whisked across the Pacific to North America from a massive dust storm in western China... Observational data, computer simulations, and research on pollutant concentrations in various media such as snow, fish, or eagles have since provided additional evidence of a potential pan-Pacific air quality problem." Rising levels of nitrates and sulfates in pristine streams in OLYM may originate from atmospheric sources, and airborne pollutants from Asia have been cited as a potential source of contamination in lake fish and sediments in the Fraser River, British Columbia (Wilkening *et al.* 2000 and references therein).

Airborne contaminants in OLYM are monitored through the Western Airborne Contaminants Assessment Project (WACAP 2007). WACAP is implemented by the NPS Air Resources Division in cooperation with other federal agencies and participating universities. The objectives of the project are to determine whether contaminants are present in western national parks, and if so, to determine the spatial distribution of accumulation, identify compounds that pose threats to ecological systems, identify indicators that can be used to address contamination, and determine the sources of such contaminants. The project measures airborne pollutants in eight National Parks and Preserves in western states, taking samples from high-altitude snow and from watersheds. Pollutants of concern include semi-volatile organic compounds, including PCBs and DDT, mercury, and other metals that are produced by human industrial activity and transported atmospherically. Sampling in OLYM was scheduled to take place in 2005, with analysis and reporting scheduled for 2006-2007. Contaminants in seasonal snowpack samples were measured at several parks in 2003 (Hageman *et al*. 2006); however, samples were not collected from OLYM at that time due to a lack of snowpack.

Smith (2000) listed a number of potential and actual pollutant threats to water basins near OLYM. In the Queets Basin, a decrease in dissolved oxygen levels in the Quillayute boat basin 20 years ago was believed to be caused by the dumping of waste from boats, although whether this is a current problem is unknown. Generally, pollution threats from industrial and urban runoff are thought to be low, and pesticide use is low compared to levels in other areas along the Pacific coast.

C. Other Areas of Concern

Several additional potential threats to water resources within OLYM exist. Here we consider some of the more likely threats. Our treatment is not comprehensive but is intended to reflect the nature and range of threats that are known to occur or are anticipated along the coastline. These threats differ in their characteristic scales, level of risk, likelihood of occurrence, natural range of variation, and reversibility. They are not equally amenable to local or regional management, and some may not require or respond to management at the scale of OLYM. Fradkin (in Jenkins *et al*. 2003) identified seven stressors operating on marine intertidal systems in OLYM: nutrient enrichment, hydrologic manipulation, toxic contamination, exotic species, harvest, aquaculture, and climate change. We include consideration of these stressors in the subsections below.

C.1. Harmful Algal Blooms

Harmful algal blooms (HABs) are a potential threat to water quality on the Olympic Coast. HABs are known to cause deaths of both wild and farmed fish and shellfish, illness or death in other marine animals and birds, human illness or death "from toxic seafood or from toxin exposure through inhalation or water contact…and alteration of marine habitats and trophic structure" (Anderson *et al.* 2002). HABs in the vicinity of OLYM are most likely to be caused by phytoplankton that can cause paralytic shellfish poisoning (PSP) or amnesic shellfish poisoning (ASP), also known as domoic acid poisoning (DAP). The alert levels for DA and PSP are 2 ppm and 80 µg/100 g, respectively.

Physical characteristics such as tidal mixing and eddy formation can entrain phytoplankton along the coast and establish conditions conducive to HAB formation. High densities of bloom-forming algae, including *Pseudo-nitzschia*, have been reported from the Juan de Fuca eddy (Trainer *et al.* 2002). Waters from the Juan de Fuca eddy can be transported to shore by periods of southward flow and associated coastal upwelling followed by periods of northward flow and downwelling (ECOHAB 2007). Consequently, the transport of blooms of *Pseudo-nitzschia* from the Juan de Fuca eddy to coastal areas and the subsequent toxification of coastal shellfish are sensitive to the duration of upwelling events and the timing of fall storms (Trainer and Suddleson 2005).

DA was reported in tissues of razor clams and Dungeness crabs along the Washington coast in 1991 (Trainer *et al.* 2002). A subsequent razor clam toxification event occurred in the late summer and early autumn of 1998, during which record levels of DA were measured (Adams *et al.* 2000). Conditions associated with the 1998 DA event included relaxed strength of coastal upwelling, low rainfall, and a reversal of winds and currents, allowing transport and retention of *Pseudo-nitzschia* in coastal areas (Trainer *et al.* 2002). A subsequent bloom of *Psuedo-nitzschia* was reported off the coast of OLYM in late September 2004 (Figure 78). The bloom was estimated to be about 24 km off the coast, with a width of about 48 km. Trainer and Suddleson (2005) report seven *Psuedo-nitzschia* bloom events on the Washington coast between 1998 and 2004 (Table 25).

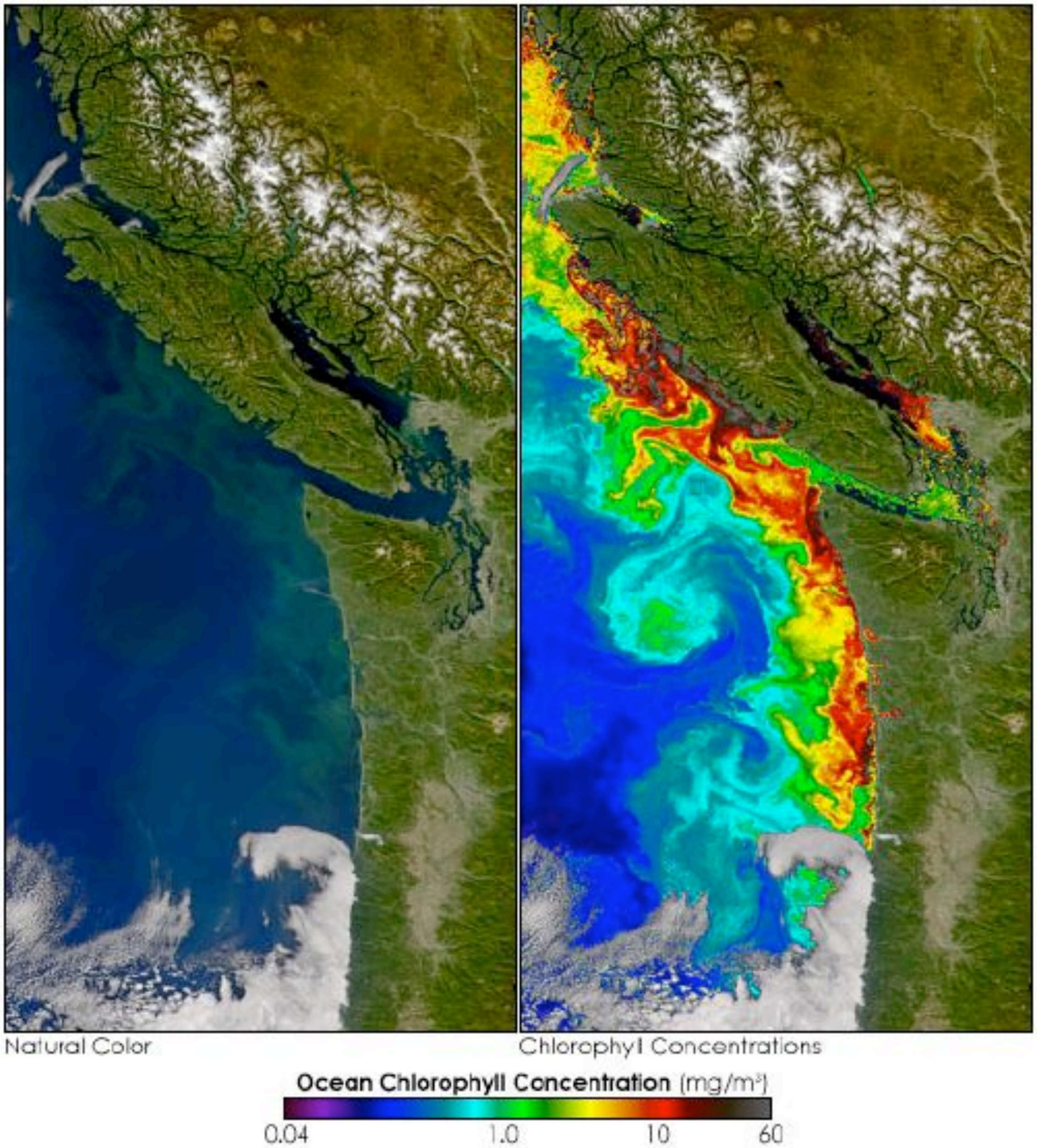


Figure 78. Satellite image of toxic algal bloom off the coasts of Washington and British Columbia, September 2004. Left: true color image. Right: false color image showing chlorophyll concentration and eddy structure. Image courtesy of NASA (visibleearth.nasa.gov/view_rec.php?id=19623).

Table 25. *Psuedo-nitzschia* bloom events on the Washington Coast, 1998-2004 (Trainer and Suddleson 2005).

Event	**Fisheries Closure**
Summer 1998	Coastwide
Spring 2001	Southern beaches (outside OLYM)
Summer 2001	None
Spring 2002	None
Summer 2002	Coastwide
Summer 2003	Kalaloch Beach only
Summer 2004	Kalaloch Beach only

Fisheries closures due to DA toxification events have affected local economies. For example, the closure of Washington State beaches to recreational and commercial shellfish harvest in 1991 resulted in an estimated $15-20 million loss in revenue to local communities (note that much of this loss was sustained by communities to the south of OLYM). In 1998, the fisheries closures resulted in substantial losses to the Quileute Tribe (ECOHAB 2007).

The ECOHAB Pacific Northwest program is a 5-year, multi-investigator, multi-disciplinary program to study the ecology, physiology, oceanography, and toxicology of *Pseudo-nitzschia* species along the Pacific Northwest coast (ECOHAB 2007). The long-term goal of the program is to develop an ability to forecast HABs caused by *Pseudo-nitzschia*. Objectives of the program are to determine oceanographic factors that promote the growth of *Psuedo-nitzschia* within the Juan de Fuca eddy; to understand the factors that lead to domoic acid production and release; and to determine oceanographic transport pathways (ECOHAB 2007). A combination of approaches (field, laboratory, oceanographic moorings, and oceanographic cruises) will be used to collect information.

WDOH monitors beaches for biotoxins through the Marine Biotoxin Bulletin (see Section B). However, WDOH does not release information regarding causes of shellfish harvest closures, so it is impossible to discern the number of closures that are due to HABs. ORHAB is a collaborative partnership between coastal Washington tribes, federal and state agencies, and businesses. The purpose of the partnership is to investigate the origin of toxic algal blooms, monitor bloom formation, evaluate conditions that lead to bloom formation, and explore methods to reduce their impacts. HAB monitoring within OLYM began at Kalaloch in 1992; DA levels there are often higher than at other Washington coastal sites, occasionally causing closure of the razor clam fishery. DA levels at Kalaloch reached over 300ppm in 1998. By 1999, DA levels returned to levels at or below 20 ppm (Figure 79) (ORHAB 2006).

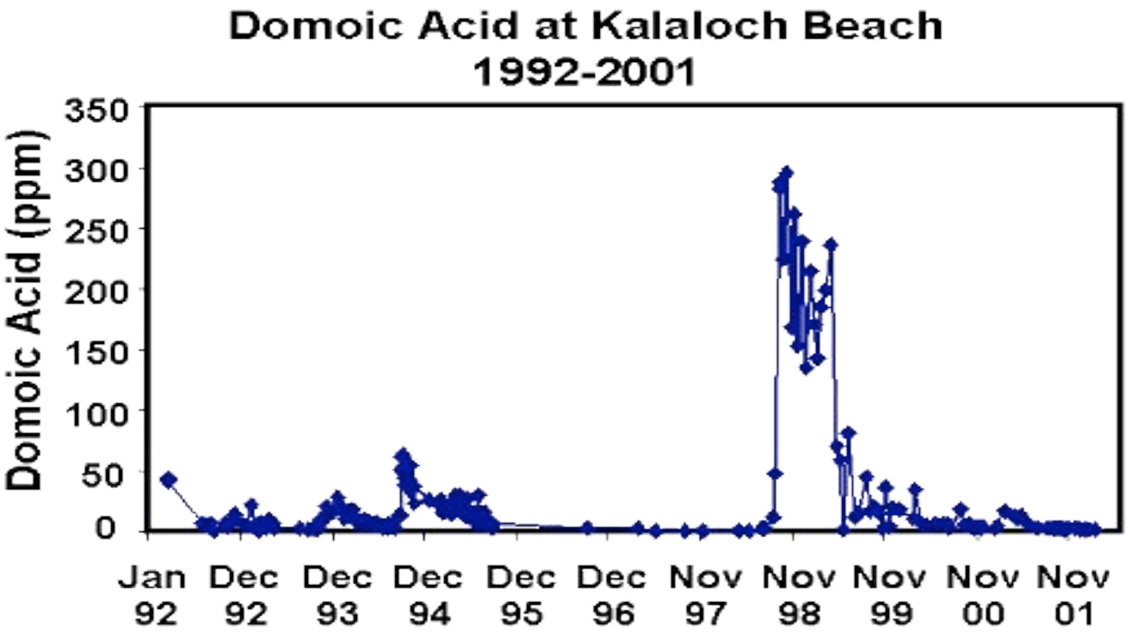


Figure 79. Domoic acid levels measured at Kalaloch Beach (ORHAB 2006).

WDFW also reports DA levels in razor clams. DA levels measured in razor clams from Kalaloch between September 1996 and February 2007 are shown in Figure 80.

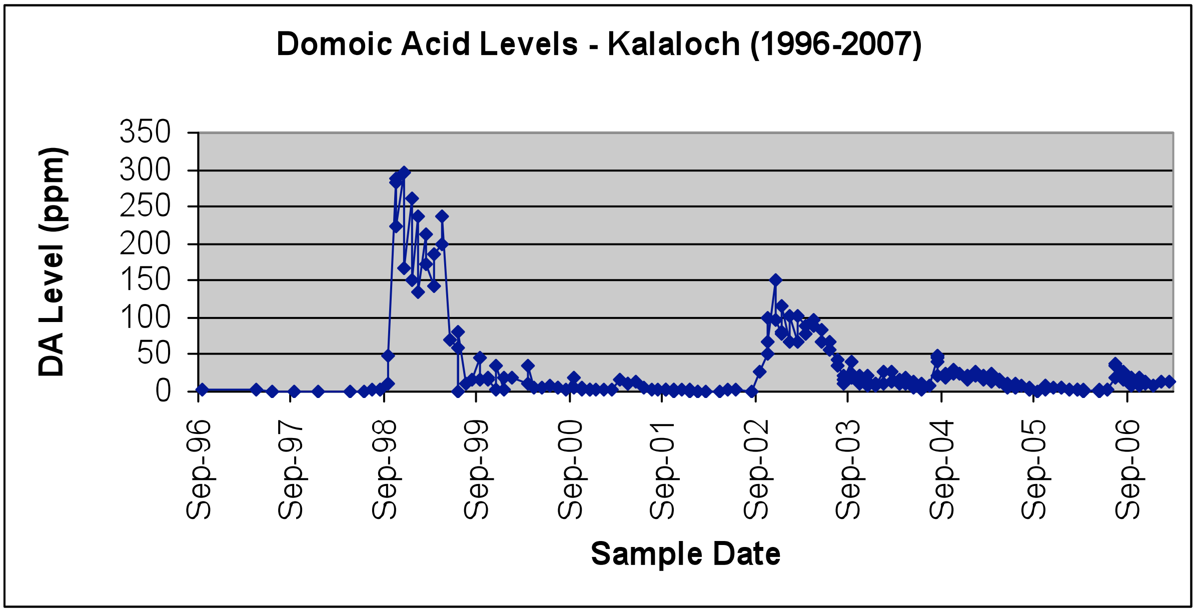


Figure 80. Domoic acid levels in razor clams measured at Kalaloch Beach,1996-2007 (WDFW 2006a).

C.2. Non-indigenous and Invasive Species

The proximity of the OLYM coastal strip to the busy shipping lanes of the Straits of Juan de Fuca may pose an invasive species threat to OLYM via the introduction of non-indigenous species by ballast water. However, many factors influence the dispersion of ballast water (Larson *et al.* 2003) as well as the establishment and spread of non-indigenous species. A group of scientists recently modelled the potential movements of organisms discharged in ballast water and found that "under normal conditions, organisms moved southward (summer) or northward (winter) in the Shelf Break Current and only under strong eastward or northward winds were they transported to the Washington or Vancouver Island shorelines" (Larson *et al.* 2003). However, the potential for introduction of non-indigenous invasive species remains, especially when ballast water is discharged inside the 1000 m isobath (Larson *et al.* 2003).

A rapid assessment survey for non-indigenous marine species was performed in intertidal and nearshore areas of OCNMS in 2001 and 2002 (deRivera *et al*. 2005). Twenty-three sites were surveyed over the two-year study period (Figure 81). Multiple habitats were sampled, including rock shelf, mud flat, boulder, cobble, sand, gravel, estuarine salt wedge, and marina. Preliminary analysis identified 11 non-indigenous and 13 cryptogenic species from among the samples (Appendix D). Cryptogenic species are defined as "a species that is not demonstrably native or introduced" (Carlton 1996). Non-indigenous species included one alga, two polychaete worms, one amphipod, one bryozoan, four bivalves, and two ascidians. Cryptogenic species included eight polychaete worms, one amphipod, one copepod, two isopods, and one ascidian.

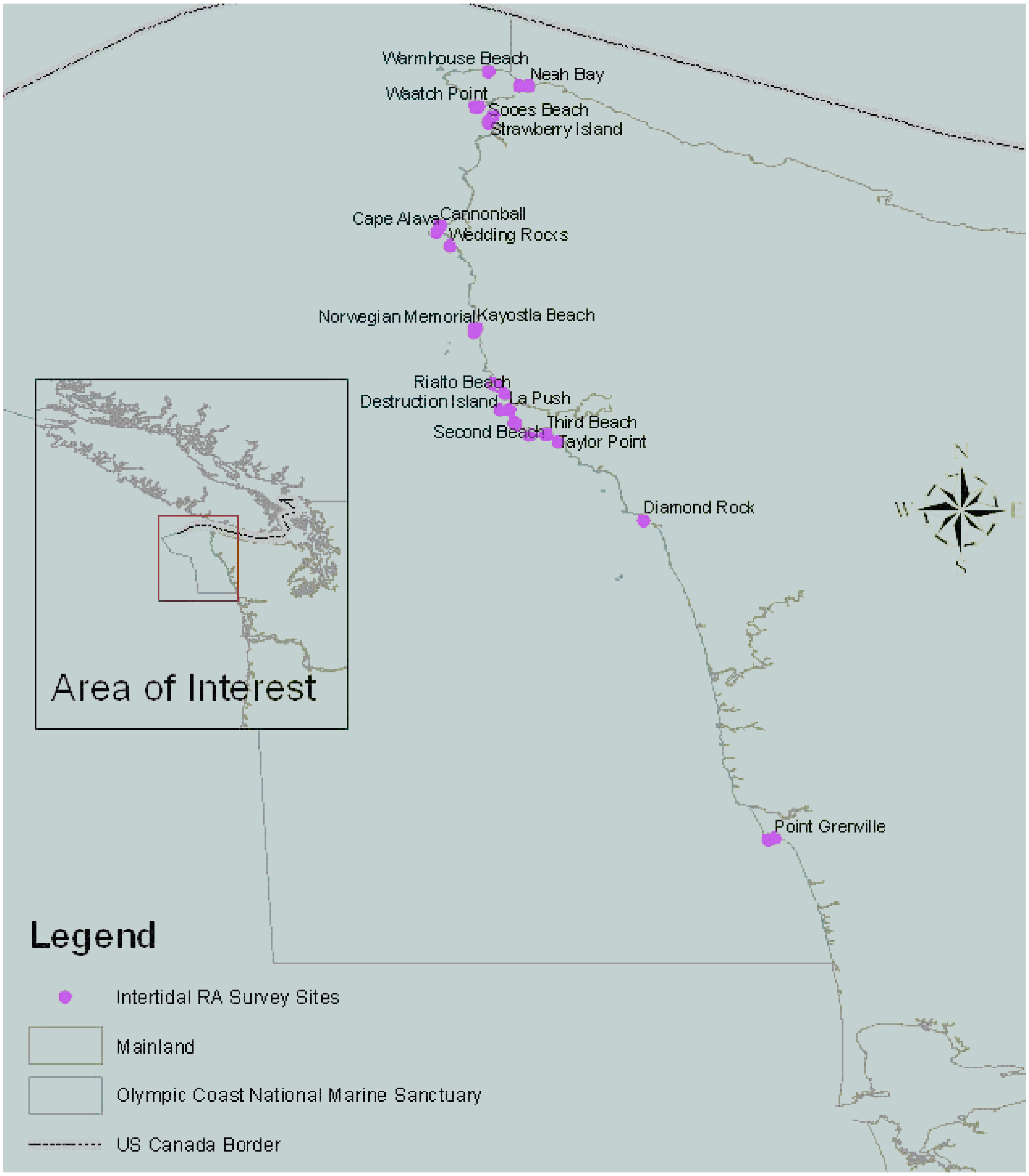


Figure 81. OLYM/OCNMS Rapid Assessment of Invasive Species: Intertidal Survey Sites 2001-2002 (deRivera *et al.* 2005).

Independent of the rapid assessment surveys, OCNMS conducted monitoring to detect the presence of the European green crab (*Carcinus maenas*) from 2001-2005, primarily in Neah Bay and occasionally near the Wa'atch River near its entrance to Makah Bay. No green crabs were found in the course of this monitoring (deRivera *et al.* 2005).

The Draft Lake Ozette Sockeye Limiting Factors Analysis lists a number of non-native fish populations including the Tui chub (*Gila bicolour*), the American shad (*Alosa* *sapidissma*), yellow perch (*Perca flavenscens*), largemouth bass (*Micropterus salmonids*), and the brown bullhead (*Ictalurus nebulosus*). The report also indicates that reed canarygrass has been found in the wetlands adjacent to Lake Ozette and the Ozette River (Haggerty 2007).

A survey of non-indigenous plant species in Lake Ozette was conducted by NPS in 2003 and 2004 (NPS report, unpublished). Twenty-three non-indigenous plant taxa were reported from 15 sites (Table 26).

Table 26. Non-native taxa reported from Lake Ozette (unpublished NPS report).

Locations sampled	**Taxa reported**
Allen's Bay Allen's Slough Baby Island Bloom's Bay Cemetary Point Ericson's Bay Ericson's Lagoon Ericson's Pond Garden Island Olson's Beach Siwash Creek Ozette Lake Campground Swan Bay Swan Bay Lagoon Tivoli Island Umbrella Bay	*Agrostis capillaris* *Callitriche stagnalis* *Cirsium arvense* *Gnaphalium uliginosum* *Hypochaeris radicata* *Hypochaeris sp.* *Iris pseudacorus* *Juncus bulbosus* *Juncus conglomerates* *Lotus pedunculatus* *Mentha X piperita* *Mentha spicata* *Mycelis muralis* *Myosotis scorpioides* *Nymphaea odorata* *Phalaris arundinacea* *Plantago lanceolata* *Polygonum hydropiper* *Ranunculus repens var. repens* *Rubus laciniatus* *Rumex obtusifolius* *Trifolium repens* *Vicia sativa ssp. sativa*

C.3. Harvest and Collection of Organisms

The OCNMS Advisory Council's Marine Conservation Working Group (MCWG)(OCNMS 2003) recognized the following threats with regard to marine intertidal areas of the Sanctuary, including those within OLYM:

> Threats are activities with potential to negatively affect aesthetic qualities, habitat, or organisms in intertidal areas. The MCWG discussed a broad range of issues and activities, and pared the list of threats to those

> associated with current use of the area, or anticipated with increased visitation levels, that can be controlled through intertidal zoning. The principal threats identified were:
>
> - organism gathering and poaching,
> - bait collection,
> - trampling of living resources,
> - wildlife disturbance,
> - destructive tidepool exploration,
> - souvenir collection (i.e., rocks, sticks, shells),
> - erosion on sea stacks; and
> - beach fires.

All but three of the identified threats are associated with the harvest and collection of marine organisms.

Regulations
OLYM provides a comprehensive list of fish and shellfish regulations at its website (NPS 2006g). Fishermen on the coastal strip are required to obtain a state Recreational Fishing License when fishing from shore, although a license is not required for surf smelt. In the coastal area, a state Shellfish/Seaweed License is required in order to collect shellfish. Permissible areas for fishing from boats and "other floating devices" include Ozette, Hoh River, Quillayute River, and Dickey River, and motorized craft are permitted in OLYM's coastal portions of the Hoh, Quillayute, and Dickey rivers. Harvest of seaweed, kelp, and unclassified species is prohibited, and bait and barbed hooks are permitted in the intertidal zone but "the harvest of any organisms for use as bait is prohibited" (NPS 2006g).

Recreational Harvest
Non-tribal harvest of a range of fish and shellfish species occurs throughout the coastal strip (OCNMS 2003); according to that report:

> *Fish* Fishing was the most common harvest activity observed, with surf perch and smelt the primary target species. Most surf fishing occurs off beaches at the southern end [of OLYM], between Ruby Beach and South Beach in May through September. The most popular surf perch fishing areas were Beach Trails 3 and 4. Smelt are collected in July and August from beaches at the southern end [of OLYM]…
>
> *Bivalves* Harvest of bivalve mollusks other than razor clams, i.e. mussels and hardshelled clams, occurs at low intensity throughout [OLYM] beaches and throughout the year. Approximately 3-5% of all groups contacted had or intended to harvest intertidal shellfish…This converts to a rough estimate of 500-1,000 people harvesting hardshelled clams and mussels on [OLYM] beaches each year. At the Ozette area alone, between 300 and 500 people

may be harvesting bivalves for consumption. The daily limits are 40 clams or 10 pounds in the shell for small clams (all species combined), 7 horse clams (*Tresus capax*), or 10 pounds in the shell for mussels (*Mytilus* spp.)…

Enforcement and monitoring of intertidal harvesting is complicated by the fact that [OLYM] staffing levels are at low density year round and reduced in the winter when the area is open for shellfish harvest. Out of season harvest occurs because peak visitation occurs in the summer, when bivalve harvest is closed, and visitors are not aware of regulations or concerned about the risk of contracting shellfish poisoning.

A combination of factors contributes to human health risk associated with the current system for managing bivalve harvest and consumption on [OLYM] beaches. First, it is difficult to effectively inform day visitors and backcountry users about the Park's regulations for food collection on the coast. Moreover, levels of toxins in bivalves on the outer coast are not monitored by state or federal governments. The management solution has been to restrict harvest to all but five months a year during the winter when shellfish poisoning risk is low…Most harvesting occurs at easily accessible locations (Second and Third Beaches, Cape Alava, and Sand Point) or remote but popular destinations for backcountry users (Point of the Arches)… [It has been] estimated that 85% of all shellfish harvest (except razor clams) occurs at the following areas: Toleak Point to Strawberry Point, Second Beach, Sand Point (south to Yellow Banks), Cape Alava, and Point of the Arches to Shi Shi Beach, and Kalaloch Beaches.

Razor Clams [OLYM], WDFW and the Tribes actively manage razor clams on Washington outer coast beaches. Two beach segments in or adjacent to OCNMS, Kalaloch and Mocrocks are managed for recreational razor clam harvest…In recent years, the Quileute, Quinault, and Hoh Tribes have conducted ceremonial and subsistence (C&S) harvest of razor clams from their U&A areas. Favorite harvest sites include Kalaloch, Point Grenville, Hobuck and Sooes Beaches…

Goose Barnacles One classified species susceptible to harvest impacts is goose or gooseneck barnacles (*Pollicipes polymeris*), which grow on exposed headlands and steep or moderate bedrock shores, but not flat rocky beaches or protected sites…Harvesting is typically done by the destructive practice of scraping rock to remove a clump of goosenecks, which leaves a bare patch that takes about 3 years to re-establish sizeable individuals…

> *Unclassified Species* [OLYM] and WSP regulations prohibit harvest of seaweeds and unclassified species, common beach and tidepool animals such as chitons, starfish, snails, anemones, and shore crabs. It is likely that the non-Tribal public collects unclassified species occasionally for consumption and fish bait.

According to park personnel, fishing for winter steelhead, summer steelhead, sea run cutthroat trout, Chinook salmon, and coho salmon is popular at river mouths (e.g., Hoh River, Quillayute River) within OLYM. Prior to 1986, parchment tubeworms (*Eudistylia*) were harvested for bait; current levels of illegal harvest on this species are low.

The recreational Pacific coast razor clam fishery in Washington extends from Kalaloch in the north to Long Beach in the south; five zones have been established by WDFW for management purposes. The Kalaloch zone extends from the South Beach campground to OLYM Beach Trail Three (WDFW 2006b). According to park personnel, the Kalaloch area attracts far fewer clam diggers than beaches farther south, by as much as a factor of ten. Consequently, the monetary value of the Kalaloch harvest to local communities is proportionately smaller.

The razor clam fishery in Washington was completely closed in 1984 and 1985. Over that period, razor clam populations declined by an estimated 95%. This decline has been attributed to an outbreak of the bacterial pathogen NIX (nuclear inclusion X), which causes an "'inflammatory overgrowth of epithelial cells, congestion of respiratory spaces in the gills, rupture of gill epithelial cells, obstruction of gill epithelial cells, and the initiation of secondary infections'" (Elston *et al.* 1986 *in* Lassuy and Simons 1989). Although low levels of the bacterium appear to be persistent in razor clam populations throughout Oregon, Washington, and British Columbia, infrequent outbreaks and associated razor clam mortality have been reported. The environment or other triggers of such outbreaks are not known. In addition to closure due to NIX, The Pacific coast razor clam fishery has been closed three times because of high levels of DA: November 1991 – November 1992, October 1998 – October 1999, and October 2002 – 2003. The 2002 – 2003 closure was "conservatively estimated to represent a $10.4 million loss to the economies of Washington's small coastal communities" (WDFW 2006c).

Recreational Fishing

La Push was a traditional sportfishing port for anglers through the 1970s, but diminished in importance as seasons were shortened to accommodate declining salmon stocks and because of tensions over tribal fishing rights (Johnston 2003). Since then, the Quileute Tribe has encouraged tourism around this site and about three charter companies now operate from La Push (NWFSC 2006), which is known for its chinook and coho salmon fishing. Certain regulations still apply: "the daily limit in the ocean is two salmon, only one of which may be a chinook and any coho kept must be a marked hatchery fish lacking an adipose fin" (Johnston 2003). Additionally, "Quileute Tribal members fish within their U&A for shellfish, groundfish, flatfish, rockfish, lingcod, trout, steelhead, salmon, sablefish, Dungeness crab, and halibut" (NWFSC 2006).

Throughout intertidal portions of OLYM, visitors with a valid Washington shellfish license are permitted to harvest various species, although "the effects of this harvest on populations of marine organisms have not been well documented" (NPCA 2004). A preliminary survey of harvest activity was conducted in the Pacific Coastal Area (PCA) of OLYM between February 1, 1997 and February 1, 1998 to assess the location and level of harvest of intertidal organisms and to develop a basis for a future quantitative survey (Erickson and Wullschleger 1999). The study area extended from the South Beach Campground to Shi Shi Beach. Harvest information was collected through a number of methods including direct observation, informal interviews, the examination of fire pit remains, and input from Park Rangers.

According to Erickson and Wullschleger (1999), organisms targeted for recreational harvest include

- surf perch (Family Embiotocidae-several species)
- surf smelt (*Hypomesus pretiosus*)
- mussels (*Mytilus* sp.)
- razor clams (*Siliqua patula*)
- native littleneck clams (*Protothaca staminea*)
- butter clams (*Saxidomus giganteus*)
- horse clams (*Tresus capax*)
- seaweeds (several genera and species)
- snails (*Littorina* sp. and *Tegula* sp.)
- crabs (*Cancer* sp.)
- barnacles (*Pollicipes polymerus*)
- rockfish (*Sebastes* sp.)

Results indicate that "with the exception of fishing for surf perch and surf smelt, recreation harvest of intertidal organisms in the PCA appears to be low" (Erickson and Wullschleger 1999). Eight areas accounted for approximately 90% of harvest activity: Kalaloch Strip (Southern Boundary of OLYM to Ruby Beach), Toleak Point-Strawberry Point, Third Beach, Second Beach, Rialto Beach, Sand Point, Cape Alava, and Point of Arches-Shi Shi Beach.

According to park personnel, the most attractive, legally harvestable organisms occur either in cobble areas of naturally high disturbance (e.g., hardshell clams), or on rocky platforms. There is little observational or anecdotal evidence to suggest that current recreational harvest activities have a substantial impact on these resources, with the exception of razor clams, which are the target of a popular recreational fishery managed by WDFW.

Indirect impacts of recreational harvest can occur from habitat disturbance due to digging and trampling. The impacts of digging remain unquantified. Trampling impacts on rocky intertidal areas were quantified by Erickson (2003, 2004) in studies performed over two summers across a gradient of visitor use. Significant impacts of trampling were observed only in the abundance of barnacles; other biological metrics failed to show consistent evidence of significant impacts. A high degree of spatial and temporal variation in the abundance of intertidal organisms coupled with a high natural disturbance regime could account for this result.

C.4. Aquaculture

Shellfish and finfish aquaculture occurs in areas outside OLYM boundaries. Currently, culture of oysters and other bivalve species dominates the aquaculture industry on Washington's coast, but salmon aquaculture exists in the region and is responsible for the escape of non-native Atlantic salmon. At current levels, aquaculture practices are unlikely to significantly negatively affect coastal water resources in OLYM. However, new proposals to substantially increase aquaculture in offshore areas could confer additional risk to coastal resources within OLYM.

C.5. Shoreline Development

The shoreline within the coastal strip of OLYM is largely undeveloped. Among the significant built structures is U.S. Highway 101, which runs through the southern portion of OLYM for about eight miles, from around Ruby Beach to South Beach (NPS 2006h).

Portions of Lake Ozette's eastern shoreline are privately owned. Impacts to lake habitat from residential properties include direct inputs of nitrogen, phosphate and pesticides via runoff from lawns, other household chemicals, and pet waste. Landscaping practices may exacerbate impacts by removing native shoreline vegetation that serves to filter excess nutrients and contaminants. Lake Ozette contains the threatened Ozette sockeye salmon species. Factors responsible for the decline of Ozette sockeye are numerous and are postulated to include loss of adequate quality and quantity of spawning habitat; predation and disruption of natural predator-prey relationships; introduction of non-native fish and plant species; prior over-exploitation in fisheries; poor marine survival; and synergistic cumulative impacts of these factors (NPCA 2004; Haggerty *et al.* 2007).

The Quileute Oceanside Resort is located on the beach in La Push (Quileute 2006). The resort includes an RV park, the River's Edge Restaurant, and the Quileute Marina, which offers a full service dock, boat ramp, fish processing, and pump out.

New proposals to develop alternative energy sources from wave energy are emerging. Among the areas of interest are those within northern reaches of the OCNMS. As proposed, none of these arrays or their shoreside linkages would be within park boundaries. However, depending on the design, installation, and size of the arrays, they could potentially affect park resources. For example, disturbance to the seabed could influence sediment supply to coastal areas within the park; changes in wave energy reaching the coast could influence benthic communities within the park; and hardware and anchoring materials detached during storms could wash up on beaches within OLYM. These impacts remain speculative until the design and deployment of such arrays are more fully known.

C.6. Recreation

Recreational harvest of living marine organisms is discussed in Section C.3. above. Here we consider other aspects of recreational use within OLYM.

Visitor Use

Recreational visits to OLYM have increased over the past 25 years (Table 27), and further increases are likely as population centers in western Washington grow.

Table 27. Recreational visits to OLYM 1980-2005 (NPS 2006i).

Year	Visits	Year	Visits	Year	Visits
1980	2,032,418	1989	2,737,611	1998	3,577,007
1981	2,306,032	1990	2,794,903	1999	3,364,266
1982	2,478,739	1991	2,759,673	2000	3,327,722
1983	2,410,722	1992	3,030,195	2001	3,416,069
1984	2,759,011	1993	2,679,598	2002	3,691,310
1985	2,532,145	1994	3,381,573	2003	3,225,327
1986	2,940,034	1995	3,658,615	2004	3,073,722
1987	2,822,850	1996	3,348,723	2005	3,142,774
1988	2,959,122	1997	3,846,709		

Although sites in the interior of the park are the most frequently visited, sites in the coastal strip (Mora/Rialto Beach), Kalaloch, Ozette, and coastal wilderness areas also are frequently visited (Figure 82).

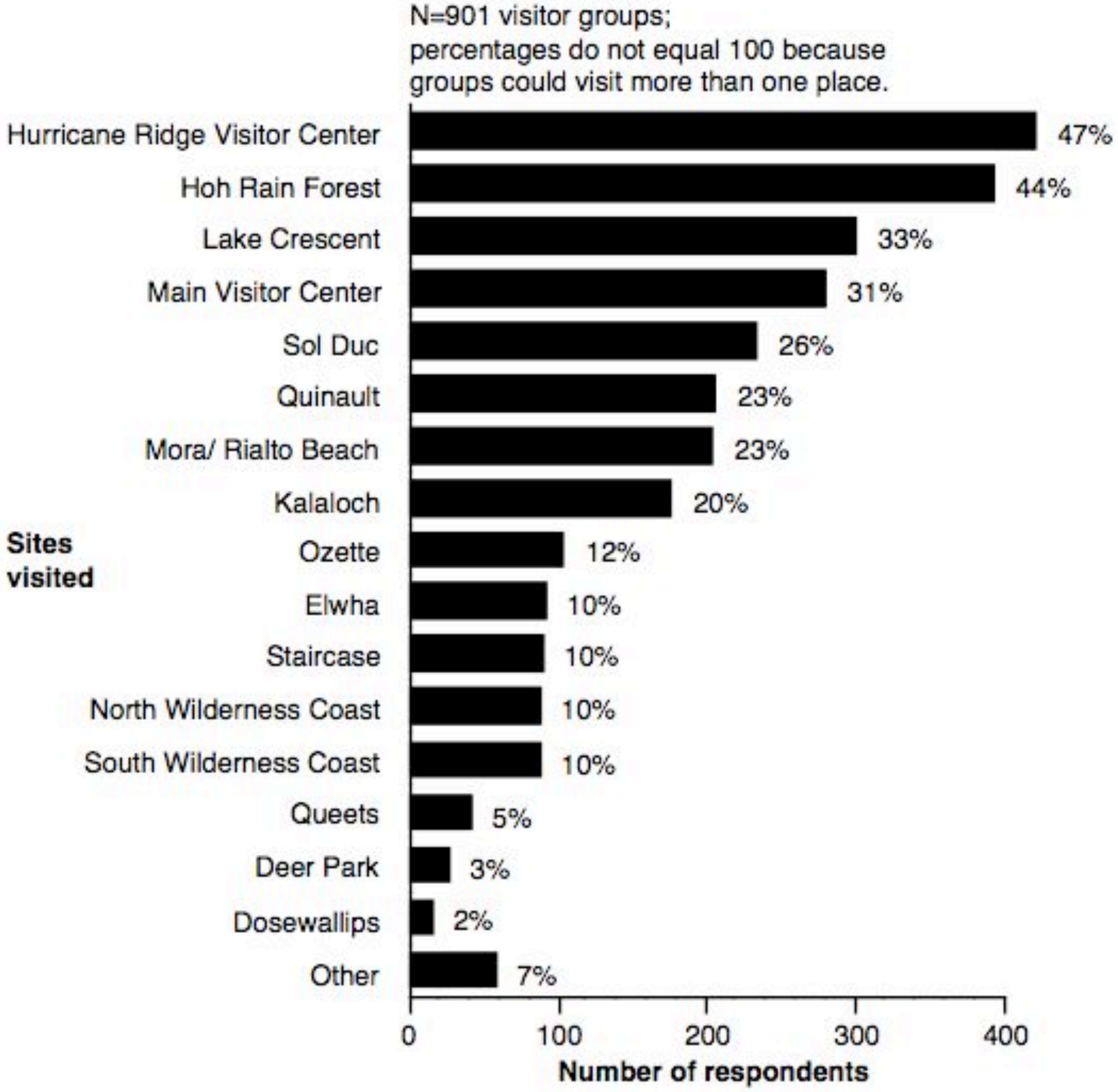


Figure 82. Frequency of visitation to sites within OLYM (NPS 2001).

Visitor Impact

Recreational use of shoreline areas can affect the marine resources of OLYM. Casual beach walking occurs throughout much of the coastal strip, and multi-day hiking and backpacking are popular with many visitors. Beachwalkers and hikers often explore the rocky intertidal areas during low tides. Although water temperatures are cool, visitors are known to swim or surf at the beaches occasionally. Recreational use of shorelines can cause direct harm to intertidal organisms through trampling. This is especially true on rocky platforms. Trampling can cause direct mortality of the organisms or dislodge them, cause structural damage to algae and animals that makes them more vulnerable to other stresses, or result in the loss of habitat when sessile animals and algae are crushed or removed. Erickson (2003, 2004) measured impacts of trampling at several sites within the coastal strip of OLYM. She found detectable impacts of trampling on barnacles, and suggested management alternatives to reduce trampling impacts. Jenkins *et al.* (2002)

conducted an experimental study of the effects of trampling on the rocky shorelines of San Juan County Park. The authors found that trampling reduced the cover of *Fucus* by 30%, and that this reduction persisted through the summer season. Trampling also resulted in a short-term reduction in species diversity. Similar impacts to *Fucus* communities from trampling likely occur in intertidal areas of OLYM.

Other potential environmental impacts of recreational activities include pollution, accidental introduction of non-native species, disruption of wildlife behavior, and habitat degradation. Specific risks of boating activities include discharges of human waste and gray water, engine exhaust, hazardous chemical spills or discharges, litter and garbage dumping, and invasive species transported in bilge water, hulls and bait containers.

The Coastal Observation and Seabird Survey Team (COASST) is a citizen-science program established to identify the carcasses of marine birds found on beaches along the outer coast of Washington State. Volunteers are specially trained in data collection techniques and conduct monthly or bi-monthly surveys. In addition to monitoring for bird carcasses, COASST volunteers note many other parameters about the local environment, including the presence of humans on beaches, as well as their dogs and vehicles. The COASST data are a relative measure of human, pet, and vehicle traffic on beaches. Data collection methodologies are described and marine bird data are available on the COASST program website (COASST 2006). We obtained survey data for OLYM directly from COASST (UW, Kate Litle, pers. comm., 4/11/06).

Many of the beaches surveyed by COASST volunteers fall within the boundaries of OLYM. We have obtained and plotted COASST data for the years 2001 – 2005 to indicate average numbers of humans, dogs, and vehicles observed on beaches within OLYM (Figures 83-85). Because beaches are monitored sporadically by COASST, annual averages were obtained by dividing the total number of people seen by the total number of surveys conducted at each location. Some beaches are surveyed more than once per month while other beaches may be surveyed only a few times per year. Additionally, it must be noted that COASST volunteer beachwalking episodes range in length from 1 to 6 hours. Therefore, the numbers reported are not an indicator of absolute visitor numbers for a beach location. Instead, they are an indicator of the number of humans, dogs, or vehicles seen by COASST volunteers in one beachwalking episode, and can be used to infer relative differences between sites and between seasons. The results are displayed in Figures 83-85. For purposes of display, we divided the coast of OLYM into three sectors, from north to south:

1) Northern sector: Shi-Shi Beach (northern border of coastal OLYM) south to the Quillayute River;
2) Middle sector: Quillayute River south to the Hoh River;
3) Southern sector: Hoh River to South Beach (the southern border of coastal OLYM).

The results can be summarized as follows:

- In the northern sector, five of the beaches averaged 15 or more humans per survey per year. They were: Shi-Shi Beach, Wedding Rocks, Ellen Creek, Hole in the Wall, and

Rialto Jetty. The majority of visitation appears between the months of May through September, with Ellen Creek and Rialto Jetty displaying the highest presence of dogs and vehicles.

- In the middle sector, three of the beaches averaged 10 or more humans per survey per year. They were: First Beach, Second Beach, and Third Beach. Goodman Creek, alternatively, had very low average presence of humans.
- All of the southern sector beaches averaged 20 or more humans in at least one year of the five-year data set. However, two of the beaches averaged more than 30 visitors in an annual survey; they were Beach 3 and Kalaloch South, both of which are located in close proximity to the Kalaloch Information Station at the southern end of the park.

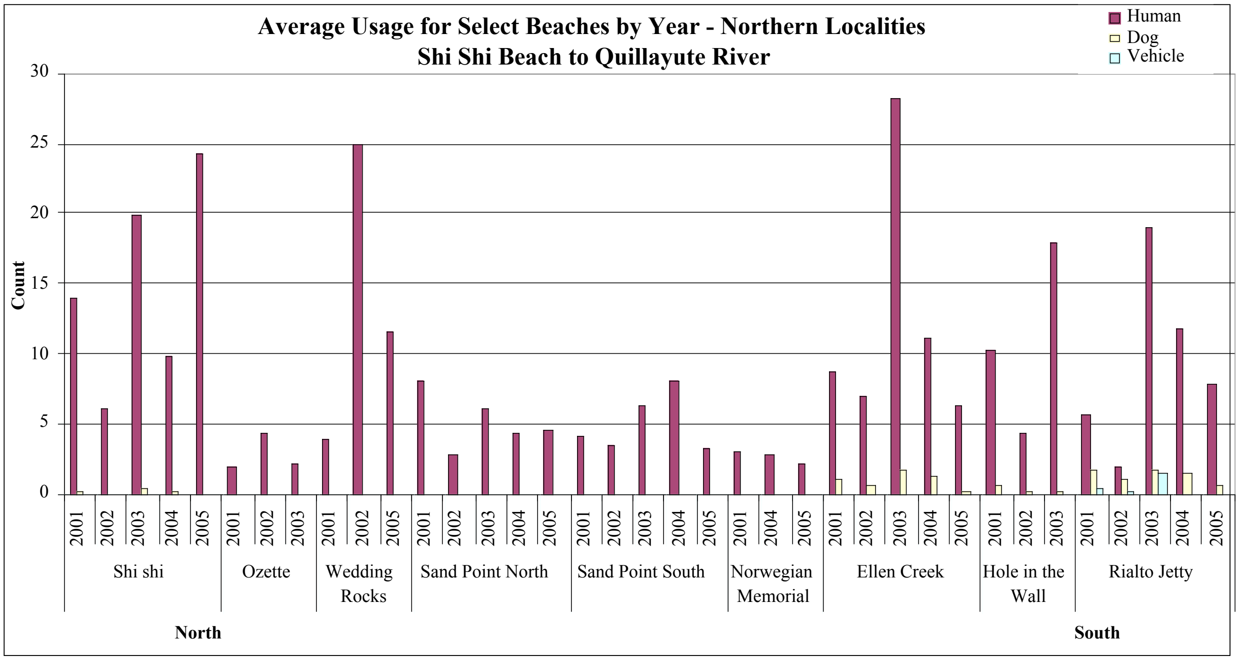


Figure 83. Average numbers of human-related beach usage, Northern localities of OLYM (COASST 2006). Annual averages were obtained by dividing the total number of people seen by the total number of surveys conducted at each location.

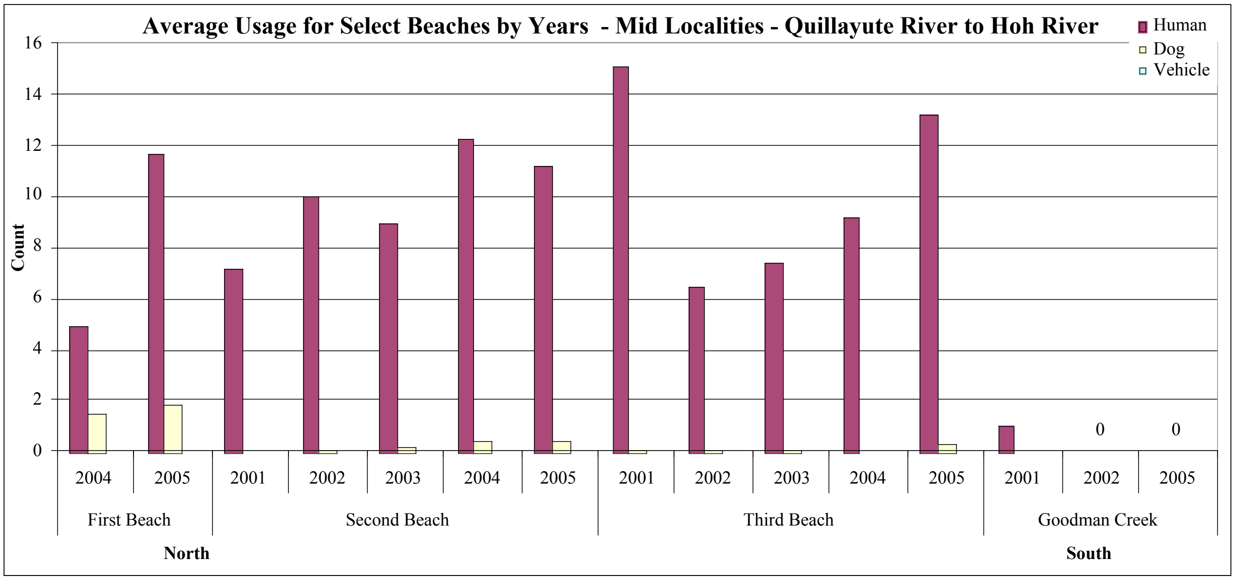


Figure 84. Average numbers of human-related beach usage, mid-localities of OLYM (COASST 2006). Annual averages were obtained by dividing the total number of people seen by the total number of surveys conducted at each location.

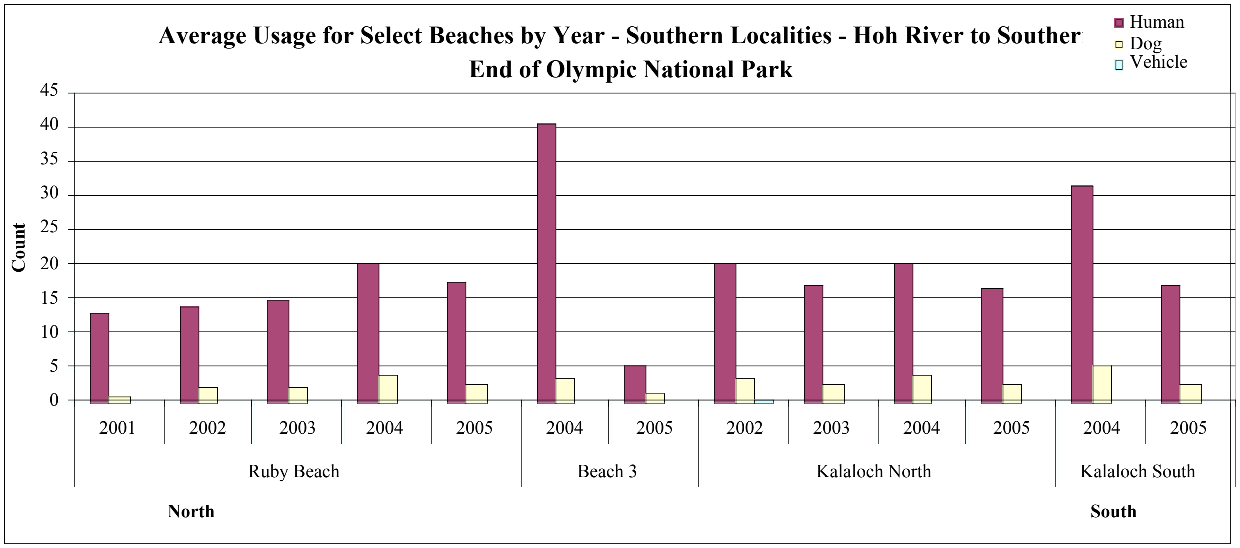


Figure 85. Average numbers of human-related beach usage, Southern localities of OLYM (COASST 2006). Annual averages were obtained by dividing the total number of people seen by the total number of surveys conducted at each location.

OLYM maintains a database of visitor use nights for the coastal strip. These data generally indicate that areas accessible only by foot are less visited than those areas that are accessible by short trails from designated parking areas (Erickson 2003, 2004).

C.7. Habitat Modification

Shorelines with the OLYM coastal strip are relatively unarmored and unmodified in comparison to shorelines in other areas of western Washington. Habitat modification has occurred on the Hoh River and its tributaries. Although there are no barriers to anadromous fish passage on the Hoh, "roads have reduced access to the floodplain and cedar spalts and blocking culverts have cut off tributary habitat" (Harrington 2005). This reduced access can likewise reduce available spawning and rearing habitat for fish. Blocking culverts have affected numerous tributaries, including Dismal, Alder, Nolan, Braden, Canyon, Cassel, Mosquito, Cedar, Rock, Elk, Hell Roaring, and Iota creeks (Harrington 2005). Various roads, such as the Upper Hoh Road, have also reduced floodplain habitat, which is "not only important as rearing habitat for salmonids, but also for ground water recharge and flow moderation in the Hoh" (Smith 2000 *in* Harrington 2005).

C.8. Sea Level Rise, Tsunami Hazards, and Coastal Erosion

Erosion and sea level rise can result from local and regional processes (e.g., land use practices, tectonic processes) or from global processes (e.g., climate change). In this section, we address impacts associated primarily with local and regional processes; those resulting primarily from global climate change are discussed in Section C.13.

Sea Level Rise

The OLYM shoreline is physically variable, consisting of rocky headlands and interspersed pocket beaches, glacially-carved fluvial features, and beaches of sand and gravel. The USGS conducted a coastal vulnerability assessment of OLYM in 2004 to identify areas vulnerable to sea level rise (Pendleton *et al*. 2004). The assessment combined scores for six physical variables (geomorphology, regional coastal slope, rate of relative sea-level rise, shoreline change rates, mean tidal range and mean wave height) to determine vulnerability to future sea level rise in 1-minute grid cells. According to the results of the assessment, erosion/accretion rates along the OLYM shoreline are likely to range from –1.0 and +1.0 m/year. Beaches in gently sloping areas were found to be most vulnerable to future sea level rise. Specifically, Shi Shi Beach, Ruby Beach, and Rialto Beach were identified as the areas of highest vulnerability to sea level rise (Figure 86). Overall, the vulnerability of the OLYM shoreline to erosion and accretion was rated as moderate.

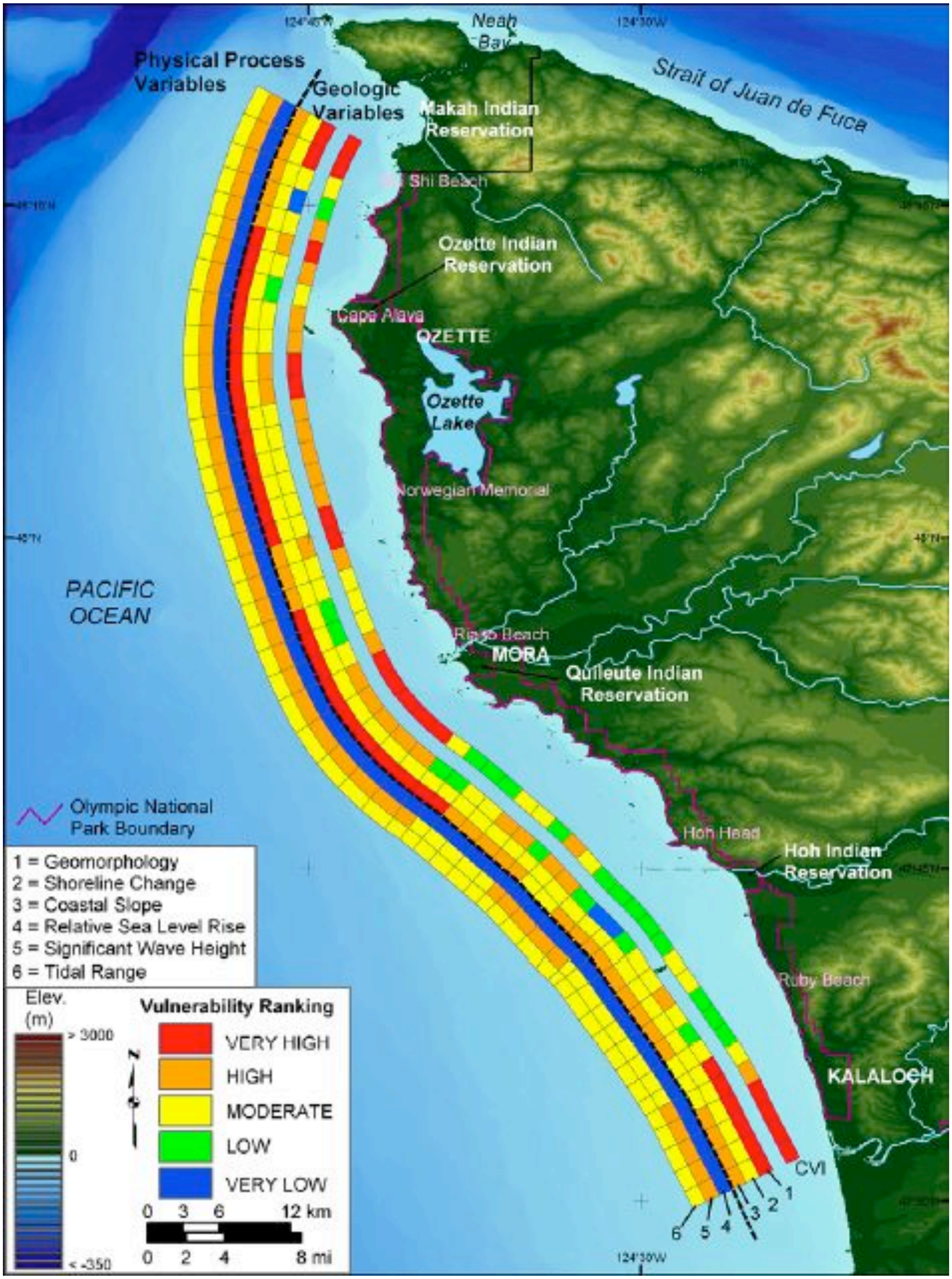


Figure 86. Predicted vulnerability to sea level rise (Pendleton *et al*. 2004).

Tsunami Hazards
Tsunami hazards on the Olympic Coast region are summarized on a WDOE website (WDOE 2006j). The region is vulnerable to tsunamis generated by earthquakes on the Cascadia Subduction Zone, which is located about 70 miles off the Washington coast, as well as from distant sources (Walsh 2005). Tsunami inundation maps for different portions of Washington, including Neah Bay, Port Angeles, Quileute, and the southern Washington coast, are available online (http://emd.wa.gov/hazards/haz_tsunami.shtml) (Walsh 2005).

Erosion
Gravel barrier morphology and stability differs along the coast. The Queets River-South Beach spit is fairly stable, while the South Rock View Beach is experiencing diminished sediment supply and the Rialto Beach barrier is retreating. Storm surge overwash has occurred at Rialto Beach. This is of particular interest due to its immediate proximity to the vessel harbor in La Push at the mouth of the Quillayute River. To reduce potential threat to the harbor, the Army Corps of Engineers (ACOE) has maintained the barrier since 1953 with alterations such as bulkheads, sediment fill, and rip-rap.

Stream erosion on the Bogachiel River, which flows into the Quillayute River before reaching the ocean, is reported in the Jefferson County Shoreline Master Program Update (http://www.co.jefferson.wa.us/commdevelopment/ShorelinePlanning.htm). Areas of the Bogachiel banks have collapsed causing "sedimentation of the streambed [which] has also presented trouble for the roads in the area with several of them having to have been moved back from the river" (Harrington 2005). These effects could potentially occur in other rivers that affect the coastal strip.

C.9. Marine Debris

Marine debris poses a known risk to marine and terrestrial wildlife. The Olympic Coast Cleanup is an annual volunteer event held to remove debris from OLYM beaches, as well as other areas on the Olympic Coast. The 2005 Cleanup resulted in over *37 tons* of debris being removed from the shoreline (NOAA 2005). Large amounts of debris also were removed in preceding years, suggesting that the supply of debris to the coast is substantial and persistent, and that without regular removal, debris will accumulate on shores within the coastal strip.

C.10. Oil and Fuel Spills

Coastal areas of OLYM are vulnerable to oil spills that could occur in coastal waters off Washington State or southern Vancouver Island. This area is heavily used by commercial shipping and tanker traffic transiting to ports in Puget Sound and Georgia Strait (e.g., Seattle, Tacoma, Olympia, and Vancouver, among others) and to refineries. Rough ocean conditions, typical of the coastal region especially in winter months, could cause spilled oil to be very difficult or impossible to contain. Consequently, if a spill should happen, it is likely that some amount of oil will strand on the shores of OLYM.

In order to reduce the likelihood of spills from commercial shipping within the Sanctuary, the International Maritime Organization (IMO) has designated most of the OCNMS waters as an Area To Be Avoided (ATBA). Large commercial ships (greater than 1,600 tons) are encouraged to transit outside Sanctuary boundaries. Data from GIS monitoring of vessel traffic in Sanctuary waters indicates that voluntary compliance is very good. Consequently, the existence of the ATBA reduces the likelihood of a hazardous spill in waters immediately adjacent to OLYM. Spills that occur beyond Sanctuary boundaries, however, could affect resources within OLYM. Two examples are the *Nestucca* oil spill, which occurred on December 23, 1988, and the *Tenyo Maru* oil spill, which occurred on July 22, 1991. Both spills occurred outside Sanctuary boundaries; however coastal currents transported oil to shores within OLYM. Hence, the protections offered by the Sanctuary's ATBA are not fully sufficient to protect resources of OLYM from injury due to hazardous spills.

Washington State's Oil Spill Contingency Plan establishes planning standards for spill events. The proposed standards specify that sensitive areas be protected by sufficient amounts of boom within 48 hours of a spill event. Within OLYM, only the WINWR is designated as a sensitive area. Boom deployment in open and highly dynamic waters such as those surrounding the NWRs may not fully protect the living resources there.

The *Nestucca* oil spill of 1988 provides an example of impacts that could be expected from an oil spill in the region of OLYM. In December 1988, the tank barge *Nestucca* spilled 230,000 gallons of Number 6 fuel oil near the entrance to Grays Harbor. Oil stranded on beaches from Grays Harbor to Vancouver Island, including those within OLYM. Several studies were initiated in response to shoreline oiling. Among the sites studied were eight in OLYM (four oiled and four unoiled), and four oiled sites outside OLYM. Impacts to intertidal communities were found to be relatively minor (Dethier 1991) and levels of residual oil were low 13 months after the spill (Strand *et al.* 1992). The time of year at which the spill occurred (winter), the highly dynamic nature of the OLYM coastline, and the quick response to the spill, are all cited as contributing to this outcome (Strand *et al*. 1992).

A very different outcome was observed following the *Exxon Valdez* oil spill that occurred in Prince William Sound, Alaska in March 1989. Substantial amounts of oil persist on oiled shorelines in Alaska more than 14 years after the spill (Peterson *et al.* 2003), primarily on soft-sediment or cobble-clad beaches. Oil has weathered most quickly on exposed rocky benches. The toxicity of this residual oil continues to impair living marine resources in areas impacted by the spill. Such an outcome cannot be discounted should another spill occur in the vicinity of OLYM.

C.11. Land Use Practices

Land use practices, especially those associated with timber harvest, have the potential to impact coastal water resource condition and water quality. Consequently, impairments to water resources are more likely in watershed basins in which a high proportion of land lies outside park administration. Land administration and ownership by watershed basin and sub-basin with WRIA 20 is given in Lieb and Perry (2005) and reproduced in Table 28. More than 50% of the land within the Sooes, Ozette, Quillayute, and Dickey watersheds is privately owned. Water resources within these watersheds consequently could be more vulnerable to impairments associated with land use practices than those in other areas. In only the Bogachiel and Hoh is more than 50% of the land under park administration.

Table 28. Land administration in WRIA 20 by watershed basin and sub-basin (Lieb and Perry 2005).

Watershed	Land Administration	Area (sq. mi.)	Percent of Total Area
Sooes	Olympic National Park	0.008	0.0
	State of Washington	0.99	2.4
	Makah Indian Reservation	7.55	18.0
	Privately Owned	33.3	79.6
	Total Area	***41.9***	***100***
Ozette	Olympic National Park	8.4	9.6
	Lake Ozette (OLYM)	11.6	13.2
	State of Washington	6.8	7.7
	Privately Owned	61.2	69.5
	Total Area	***88.0***	***100***
Quillayute	Olympic National Park	1.9	27.1
	State of Washington	0.52	7.6
	Quillayute Indian Reservation	0.61	8.8
	Privately Owned	3.9	56.6
	Total Area	***6.9***	***100***
Dickey	Olympic National Park	0.5	0.5
	State of Washington	30.9	28.8
	Privately Owned	75.8	70.7
	Total Area	***107.2***	***100***
Soleduck	Olympic National Park	72.6	32.2
	Late-successional Reserves (USFS)	40.6	18.0
	Adaptive management (USFS)	31.0	13.8
	State of Washington	30.3	13.4
	Privately Owned	50.9	22.6
	Total Area	***225.4***	***100***
Calawah	Olympic National Park	25.9	19.0
	Late-successional Reserves (USFS)	48.6	35.7
	Adaptive management (USFS)	27.7	20.4
	State of Washington	4.7	3.5
	Privately Owned	29.1	21.4
	Total Area	***136.1***	***100***
Bogachiel	Olympic National Park	81.7	53.5
	Late-successional Reserves (USFS)	9.0	5.9
	State of Washington	29.2	19.1
	Privately Owned	32.7	21.5

	Total Area	***152.6***	***100***
Hoh	Olympic National Park	171.7	57.6
	Late-successional/Riparian Reserves (USFS)	0.64	0.22
	State of Washington	72.6	24.4
	Hoh Indian Reservation	0.63	0.21
	Privately Owned	52.5	17.6
	Total Area	***298.2***	***100***

Timber harvest has been shown to affect aquatic ecosystems in the region. Tallis (2006) examined other experimental studies that have shown that logging practices can affect watershed biogeochemistry as well as riverine ecology. These studies have documented "logging impacts on river discharge rates (Chamberlin *et al.* 1991; Jones and Grant 1996), sediment load (Chamberlin *et al.* 1991; Jones and Krygier 1971; Miller *et al.* 1974; Lewis *et al.* 2001), chemistry (Fredriksen 1971; Grier and Cole 1971; Brown *et al.* 1973; Borman and Likens 1979; Vitousek and Matson 1984), trophic interactions and light (Kiffney *et al.* 2003), and fish habitat quality (Murphy and Hall 1981; Beechie and Sibley 1997)." Tallis (2006) notes that these studies have been conducted in small watersheds and therefore may not be relevant at broader spatial and temporal scales. However, timber harvesting on small and large tracts of land typically involves the "direct application of fertilizer, various methods of site preparation (Miller *et al.* 1974; Piatek *et al.* 2003) and the construction and use of roads (Jones and Grant 1996; Jones and Krygier 1971)." Jackson and Sturm (2002) discuss other general effects of logging activities which include "routing road runoff to streams (e.g., Reid and Dunne 1984; Megahan *et al.* 1983; Swift 1984), altering wood loading through harvest practices, altering long term wood loading by changing riparian stands (e.g., Ralph *et al.* 1994), and increasing the probability of landslides from hillslopes and of debris flows in channels (e.g., Swanson and Dyrness 1975; Ziemer and Swanston 1977; Ziemer 1981)." This can result in increased road runoff and fine sediment loads.

Aspects of land use (including but not restricted to forest practices) that could negatively impact water resources include 1) increased erosion and sedimentation due to clearing and grading, stream bed alteration, and stream flow modification, and 2) use of biocides (herbicides, pesticides) to control weeds and insects in agricultural, silvicultural, and horticultural settings, and in road maintenance. The very high rates of precipitation characteristic of the region mobilize sediments and biocides (other contaminants), spreading impacts some distance beyond the source.

C.12. Ocean Productivity

Productivity in coastal areas of OLYM is influenced by the Juan de Fuca eddy (also known as the Tully Eddy and locally referred to as the "Big Eddy"). The eddy is a recurring seasonal feature containing nutrient-rich, upwelled waters. Eddy-associated productivity contributes to regional ocean productivity along the coasts of southern British Columbia and Washington. Nutrient-rich waters from the eddy are being transported to coastal areas within OLYM during periods of southward flow followed by periods of relaxation or northward (onshore) flow. Strong upwelling conditions may prevent eddy waters from reaching the shore.

Phytoplankton blooms are associated with eddy formation. Among these are blooms of the diatom *Pseudo-nitzchia*, which is known to produce domoic acid and is associated with domoic acid poisoning of crabs and razor clams near OLYM (Section C.1. above).

Reduction or failure of spring upwelling conditions reduces productivity along the coast. For example, an unusual seabird mortality event occurred in the spring and early summer of 2005 (Julia Parrish, University of Washington, presentation to the OCNMS Advisory Council, September 2005). Seabird mortality was attributed to regional ocean conditions that resulted in a temporary weakening of upwelling and a consequent reduction in ocean productivity.

Efforts to improve understanding and forecasting of harmful algal bloom formation in the Juan de Fuca eddy (e.g., ECOHAB, ORHAB) are likely to contribute to an understanding of system-wide productivity in the region.

C.13. Climate Change

The coastal section of OLYM is susceptible to a variety of potential effects of climate change. Proximate effects that have already been measured or modeled include changes in air and ocean temperature, sea level, storminess, and the hydrologic cycle. There may also be effects on oceanographic circulation patterns. All of these could have significant effects on terrestrial and marine ecosystems, including increases in erosion, landslides, shoreline retreat, inundation, harmful algal blooms, and flooding, as well as changes in water quality and biotic interactions.

Sea level rise, storminess, and erosion
Global mean sea level has increased on the order of 1 to 2 mm/year over the past century, and is projected to rise by 0.5 +/- 0.4 m over the next century (Church *et al.* 2001). Recent research indicates that the rate of ice cap melting and thus the rate of sea level rise may be much more rapid than previously anticipated (e.g., Rignot and Kanagaratnam 2006), suggesting the higher end of Church *et al.*'s (2001) estimates is more likely to be correct.

In addition to global changes in ocean volume, a number of factors influence actual local changes in sea level. The Canadian Global Climate Model predicts that sea level rise in the Eastern Pacific will be 20 cm greater than the global average by 2100, due primarily to regional atmospheric pressure patterns and differences in rate of sea water temperature change (Hengeveld 2000). Local vertical land movement also influences local sea level. The collision of the North American and Juan de Fuca tectonic plates is causing the plates to warp, with the result that while the coast of Washington is being uplifted, most of central and south Puget Sound is subsiding (Canning 2002). In Neah Bay, at the northwest tip of the Olympic Peninsula, uplift has been about 2.5 mm/year, leading to an apparent sea level trend of -1.2 mm/year, or -0.4 feet/century. As climate change-induced sea level rise accelerates, this regional drop in sea level will slow and ultimately reverse. By 2100, sea level at Neah Bay will rise by approximately 0.4 m (Canning 2002).

In addition to changes in mean sea level, the frequency and severity of major storms has increased over the past 50 years, with a consequent increase in wave height (Allan and Komar 2006; Graham and Diaz 2001). Average winter breaker height has increased by 0.7 m in the past 25 years along the Washington coast, and the average shoreline level reached by swash run-up has shifted landward by five meters during the same period (Allan and Komar 2006). Thus, the effective winter shoreline is moving landward even while mean sea level drops, with significant implications for erosion. Areas of coastline with shallow slopes and soft substrate are generally more vulnerable to erosion than areas with a steep slope and hard substrate.

Against this backdrop of progressive changes in sea level and wave heights is the episodic occurrence of periods of extreme erosion associated with ENSO events. While the effect of climate change on the frequency and severity of ENSOs is uncertain, the effect of even normal ENSOs will be heightened due to the higher background wave heights and, eventually, rising sea levels.

Changes in precipitation and glacial melting

River and stream hydrodynamics in the OLYM will be affected by changes in the timing and type of precipitation expected as a result of climate change, and by the increased rate of glacial melting that is already evident.

Models from the University of Washington's Climate Impacts Group (CIG)/JISAO suggest that the Pacific Northwest will see warmer, wetter winters, warmer summers, decreased flow of freshwater in summer, and increased water flow in fall and winter (CIG 2004). Combined with land use changes and increased population, these changes may contribute to increased erosion in winter, and increased water shortages in summer. They will also affect runoff patterns and thereby the input of non-point-source pollution into the waters along the coast of the Olympic Peninsula. For instance, longer rain-free periods in summer would allow greater build-up of contaminants on land, leading to stronger drops in water quality when those contaminants are washed off during the next big rain. In the Olympics, logging on steep hillsides could combine with heavier rains to increase stream sedimentation and landslide risk. Landslides can significantly degrade water quality, and in some cases block streams altogether.

Glaciers in the Pacific Northwest are melting, probably as a result of global climate change. While there have been periods of advance and retreat, most glaciers in this region have become measurably smaller over the past 150 years, and recent melting rates are often higher than any previously recorded (Hodge *et al.* 1998; Fagre *et al.* 2003). In the Olympic Mountains, a warmer climate may lead to shrinking glaciers through a variety of mechanisms, including faster melting in summer, an expansion of the annual period in which melting typically occurs, and an increase in the amount of precipitation that falls as rain rather than snow in winter.

Because glaciers in the Olympic Mountains feed many rivers that empty onto the Olympic Coast, changes in the volume and timing of glacial runoff may have significant effects on coastal ecosystems. Observed and predicted impacts of climate change in the Pacific Northwest (PNW) are summarized in Table 29.

Table 29. Observed and projected impacts of climate change in major climate and hydrologic indicators (CIG 2004)

Indicator	Observed 20th century changes	Projected mid-century changes
Temperature	Region-wide warming of about 1.5°F (1920-2000) Warming has been fairly uniform and widespread, with little difference between warming rates at urban and rural weather monitoring stations 1990s the warmest decade on record (warmer than any other decade by 0.9ºF) Most warming occurring during winter	2020s: average increase of 2.7°F 2040s: average increase of 4.1°F Temperature changes benchmarked to the decade of the 1990s
Precipitation	Region-wide increase in precipitation since 1920 Median value: +22% Changes upwards of 60% in northeast Washington and British Columbia)	Uncertain, although most models project wetter winters and drier summers
April 1 snowpack	Substantial declines (>30%) at most monitoring stations below 6,000 feet	Continued decrease in April 1 snowpack in mid- and low-elevation basins Projected decrease in April 1 snowpack for the Cascades Mountains in Washington and Oregon relative to 20th century climate: 0 - 44% by the decade of the 2020s (based on +3°F average temp change) 0 - 58% by the decade of the 2040s (based on +4.5°F average temp change)

Timing of peak spring runoff	Advanced 10-30 days earlier into the spring season during the last 50 years	Greatest trends occurred in the PNW Earlier peak spring runoff expected on the order of 4-6 weeks
Summer streamflow	Declining in sensitive PNW basins May-September inflows into Chester Morse Lake (WA) in the Cedar River watershed as a fraction of annual flows have decreased 34% since 1946 Losses in June-Sept flows at Dworshak Dam (ID) on the order of 10% in 82 years	Continued and more wide-spread declines April-September natural streamflow in the Cedar River (WA) projected to decrease 35% by the 2040s (based on a 2.5°F increase in average temp) July-October streamflows in the Tualatin Basin (OR) projected to decrease 10-20% by the 2040s; total average annual runoff projected to be less than the historic average

Biological effects

The physical effects of climate change can alter species ranges, interactions, and behaviors. In particular, invasive species may benefit from climate change, enhancing their rate of spread and their competitive advantage over native species. This is due in part to the generally cosmopolitan nature of invasive organisms.

Of particular concern, the potential changes in pollution, sedimentation, and landslides expected as a result of altered hydrological dynamics could have detrimental effects on populations of threatened and endangered salmonids. Salmonids are also at risk from increased stream temperatures that can result from both increases in air temperature and decreases in water flow. Flooding resulting from earlier snowmelt and changes in timing of peak flow rates in spring may decrease salmon populations by scouring eggs out of the gravel beds or forcing juvenile salmon downstream before they are ready (National Assessment Synthesis Team 2000).

Existing oceanographic circulation patterns currently bring water high in nutrients to the nearshore environment at the northern end of the Olympic coast, creating an area that is both more productive and more subject to harmful algal blooms (HABs). Warmer water temperature could increase the frequency and severity of HABs in this area. It is also possible that climate change could alter oceanographic circulation patterns, which would in turn alter the structure of coastal ecosystems. For instance, decreased upwelling during ENSO years can lead to dramatic declines in primary productivity and alter the behavior of keystone species (Sanford 1999), and an unprecedented intrusion of oxygen-poor subarctic deep water onto Oregon's continental shelf in 2002 caused massive mortality of fish and invertebrates (Grantham *et al*. 2004). While there is little clarity as yet on how climate change will affect oceanographic circulation patterns in the northeast Pacific, the potential effects are significant.

The potential impacts of climate change on the PNW are predicted to have adverse effects on both hydrologic and biological components. The potential management implications for mitigating these changes are discussed in Table 30.

Table 30. Potential management implications associated with projected climate change impacts on water resources in the Pacific Northwest (CIG 2004).

Projected Hydrologic Impact	**Potential Management Implications**
Increased winter streamflow	- Increases the risk for more winter flooding in low (rain dominant) and midelevation (rain/snow mix) basins, possibly requiring more active management of floods and floodplains - Increases the potential for more streambed scouring events (affecting salmon redds), possibly impacting salmon recovery and management activities - Increases the potential for more winter hydropower production, possibly increasing revenues
Reduced snowpack	- Reduces the amount of water available for spring reservoir refill and summer streamflows, potentially requiring operations adjustments to meet summer water demands (with implications for summer hydropower production and salmon) - Reduces the risk for spring flooding in large snowmelt dominant basins - Likely to increase competition for summer water uses
Earlier snowmelt and earlier peak runoff	- Increases length of the summer low flow season, potentially increasing competition for summer water - May have implications for salmon management and recovery where there is a mismatch between salmon migration patterns and peak flows
Reduced summer streamflow	- Increases frequency of significant low flow events and potential for drought, potentially increasing competition for water and stressing abilities to meet water quality parameters and instream flow requirements (re: warmer water temperatures)

D. Recommendations

D.1. Condition Overview

We summarize the condition of water resources in OLYM in Table 31, based on our review of available data and on our best professional judgment. We provide brief rationale for individual assessments in Tables 32-34. We rate the level of uncertainty in these estimates as moderate, due to limitations of the data, especially those pertaining to water quality. Data indicating the condition of coastal water resources, especially those pertaining to water quality, are fragmented and most are fairly recent. Consequently, it is difficult or impossible determine trends in the condition of coastal water resources with confidence. Emerging and recent events (e.g., hypoxia, elevated levels of domoic acid, changes in ocean productivity) suggest that the condition of marine waters may be changing is ways that are difficult or impossible to predict, underscoring the importance of regular monitoring of key variables across a range of habitats. More comprehensive treatment of specific elements is provided in Sections B and C above.

Table 31. Summary of water resource conditions in OLYM.

Stressor/ Environmental Indicator	**Lake Ozette**	**Coastal River Drainages***	**Marine Waters**
WATER QUALITY INDICATOR			
Nutrients	ID	ID	OK
Dissolved Oxygen	ID	IP	IP
Fecal Bacteria	ID	ID	IP
Metals	ID	ID	ID
Contaminants/Toxicants	PP	PP	OK
LAND-USE RELATED STRESSORS			
Sedimentation	EP	EP	EP
Septic / Wastewater	ID	PP	PP
Stormwater Runoff	PP	IP	PP
Pesticides	PP	PP	PP
HABITAT MODIFICATION			
Coastal and Marine Habitat Modification	NA	NA	OK
Upland Habitat Modification/Land Use	EP	EP	EP
OTHER STRESSORS/ INDICATORS			
Non-Native Invasive Species	EP	EP	PP
Harmful Algal Blooms	OK	OK	IP
Fuel / Oil Spills	NA	OK	PP

Legend:
EP = existing problem; PP = potential problem; IP = intermittent problem; OK = no detectable problem; ID = insufficient data to evaluate; NA = not applicable
*Sooes, Ozette, Quillayute, and Hoh River drainages, coastal portions only

Table 32. Condition of water resources in Lake Ozette. Legend as in Table 31.

Stressor/ Environmental Indicator	**Lake Ozette**	**Explanation**
WATER QUALITY INDICATOR		
Nutrients	ID	Insufficient data to determine. No specific information on nutrients in Lake Ozette (pg. 58).
Dissolved Oxygen	ID	Insufficient data to determine. No specific information on dissolved oxygen levels in Lake Ozette (pg. 58).
Fecal Bacteria	ID	Insufficient data to determine. No specific information on fecal bacteria in Lake Ozette (pg. 58).
Metals	ID	Insufficient data to determine. No specific information on metals in Lake Ozette (pg. 58).
Contaminants/Toxicants	PP	Data from 2004 Washington State Toxics Monitoring Program (WSTMP) indicate presence of organochlorine pesticides, PCBs (polychlorinated biphenyls), PBDEs (polybrominated diphenyl ethers) and DDT (dichloro-diphenyl-trichloroethane*)*, ranging in concentration from 0.11 µg/kg to 11.2 µg/kg of wet fish muscle tissue of four species (cutthroat trout, largemouth bass, northern pikeminnow, and yellow perch). Other data on PCBs and DDTs found in fish tissue samples are available; however, the quality assurance assessment levels for the data are annotated as "data not verified, validated, or assessed for usability" (Table 8, pg. 60).
LAND-USE RELATED STRESSORS		
Sedimentation	EP	Sediment is a limiting factor in the Ozette Basin, "resulting in degraded spawning habitat for lake spawning sockeye, but the cause of the high levels of fines is uncertain" (Smith 2000). The banks of Umbrella Creek, Big River, and Siwash Creek (tributaries that drain into Lake Ozette) are hardened by the invasive reed canarygrass, and fine sediment levels are high (Smith 2000). In addition, high road density in the basin is likely to contribute to sediment loads (pg. 58, 60).
Septic / Wastewater	ID	Insufficient data to determine. No specific information on wastewater in Lake Ozette (pg. 58).
Stormwater Runoff	PP	High road density in the Ozette Basin (Smith 2000) and runoff from residential properties (NPCA 2004) could pose a problem (pg. 58).
Pesticides	PP	Pesticides found by WSTMP in 2004 (pg. 60).

Table 32, continued.

HABITAT MODIFICATION		
Coastal and Marine Habitat Modification	NA	
Upland Habitat Modification/Land Use	EP	Land use practices like timber harvest have reduced sockeye salmon spawning habitat and riparian vegetation, altered sedimentation and erosion regimes, and caused increases in water temperature and turbidity (pg. 67). Impacts from residential properties include direct inputs of nitrogen, phosphate and pesticides via runoff from lawns, along with other household chemicals, as well as pet waste. Landscaping practices may exacerbate the impacts by removing native shoreline vegetation that serves to filter excess nutrients and contaminants. (NPCA 2004) (pg. 128).
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	EP	Non-native fish populations have been found including the Tui chub (*Gila bicolour*), the American shad (*Alosa sapidissma*), yellow perch (*Perca flavenscens*), largemouth bass (*Micropterus salmonids*), and the brown bullhead (*Ictalurus nebulosus*) (Haggerty 2007). Reed canarygrass has been found in the wetlands adjacent to Lake Ozette and the Ozette River and 23 other non-native plant taxa were found during an NPS survey conducted from 2003-2004 (Haggerty 2007) (Table 26; pg. 123).
Harmful Algal Blooms	OK	No indication that HABs are an issue in Lake Ozette (pg. 117).
Fuel / Oil Spills	NA	

Table 33. Condition of water resources in coastal river drainages. Legend as in Table 31.

Stressor/ Environmental Indicator	**Coastal River Drainages***	**Explanation**
WATER QUALITY INDICATOR		
Nutrients	ID	Insufficient data to determine. No specific information on nutrients in the Coastal River Drainages (pg. 56-64).
Dissolved Oxygen	IP	Low levels found in Quillayute basin about 20 years ago, possibly associated with waste dumping from boats (Smith 2000); unknown if this is a current problem (pg. 60). 303(d) Category 5 listings are shown in Tables 6 and 7.
Fecal Bacteria	ID	Insufficient data to determine. No specific information on fecal bacteria in the Coastal River Drainages (pg. 56-64).
Metals	ID	Insufficient data to determine. Little specific information on metals in the Coastal River Drainages (pg. 56-64).
Contaminants/Toxicants	PP	Radionuclides and polynuclear aromatic hydrocarbons found in sediments near the Hoh River mouth; sources believed to be aluminum smelters on the lower Columbia River (Smith 2000) (pg. 64).

Table 33, continued.

LAND-USE RELATED STRESSORS		
Sedimentation	EP	High percentage of fine sediments in all streams of the Ozette Basin (Smith 2000; Smith and Caldwell 2001) (pg. 56-64). Sediment is a limiting factor in the Ozette Basin, “resulting in degraded spawning habitat for lake spawning sockeye, but the cause of the high levels of fines is uncertain” (Smith 2000). High road density in the basin is likely to contribute to sediment loads. Increased sedimentation found in the Quillayute Basin. In the Hoh Basin, source of sediment loads include road erosion and mass wasting. Sedimentation found to be a problem in some reaches of smaller salmon and steelhead-producing streams (Smith 2000). Forestry has increased sedimentation to Quillayute estuary.
Septic / Wastewater	PP	Wastewater runoff in Quillayute Basin believed to be low (Smith 2000). No major problems with wastewater facility near Kalaloch (NPS 2006f, pg. 115).
Stormwater Runoff	IP	Runoff in Quillayute Basin believed to be low (Smith 2000). Generally, sources of pollutants associated with urban, suburban, and industrial areas are largely absent; some do exist as shown in Table 24 (pg. 115). Runoff from Highway 101 may cause a problem (pg. 115).
Pesticides	PP	Pesticide use in Quillayute Basin believed to be very low in comparison to other West Coast regions (Smith 2000) (pg. 116).

Table 33, continued.

HABITAT MODIFICATION		
Coastal and Marine Habitat Modification	NA	
Upland Habitat Modification/Land Use	EP	Quillayute Basin region "regularly dredged and has armored and diked banks" (Smith 2000, pg. 60). Culverts and cedar spalts in Hoh Basin constitute a major limiting factor for salmon habitat (pg. 62; Harrington 2005, pg. 134). In the lower Quillayute River, the Army Corps dredges a navigational channel and boat basin every two to three years (Smith 2000; pg. 61). Upland forestry is about 94% of land use in Quillayute (pg. 60). More than 50% of the land within Sooes, Ozette, Quillayute and Dickey watersheds is privately owned; in Bogachiel and Hoh, more than 50% under park administration (Table 28, pg. 138).
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	EP	Reed canarygrass present in the Ozette Basin (pg. 60).
Harmful Algal Blooms	OK	Do not appear to be a problem in the Coastal River Drainages (pg. 117-120).
Fuel / Oil Spills	OK	Do not appear to be a problem in the Coastal River Drainages (pg. 136-137).

Table 34. Condition of water resources in marine waters. Legend as in Table 31.

Stressor/ Environmental Indicator	**Marine Waters**	**Explanation**
WATER QUALITY INDICATOR		
Nutrients	OK	Do not appear to be a problem in marine waters (pg. 41).
Dissolved Oxygen	IP	Potential hypoxic event in July 2006 near southern boundary of OLYM coastal strip; preliminary data from OCNMS buoys indicate low oxygen concentrations at depth within Sanctuary (pg. 49).
Fecal Bacteria	IP	Table 4 (pg. 43) shows exceedances in 2005 at both Neah Bay and La Push. Table 5 (pg. 44) shows two sampling dates of "moderate to high" levels of bacteria at Shi Shi Beach and Second Beach.
Metals	ID	Insufficient data to determine. No specific information on metals in marine waters (pg. 40-49).
Contaminants/Toxicants	OK	Do not appear to be a problem in marine waters. NCCOS Mussel Watch does not monitor within OLYM (pg. 45).
LAND-USE RELATED STRESSORS		
Sedimentation	EP	Sediment loads from upstream reaches (pg. 54-68).
Septic / Wastewater	PP	Potential wastewater from facilities like Ozette Campground, Mora Campground, and Kalaloch Campground (pg. 115).
Stormwater Runoff	PP	Runoff from Highway 101 is potential source of pollution (pg. 115).
Pesticides	PP	Pesticide uses in forestry practices (pg. 67).

Table 34, continued.

HABITAT MODIFICATION		
Coastal and Marine Habitat Modification	OK	No indication of a problem in marine waters because much of the region is designated as wilderness. Shorelines relatively unarmored and unmodified (pg. 128-129, 133-134).
Upland Habitat Modification/Land Use	EP	Logging practices (pg. 67-68; 137-139) have reduced sockeye salmon spawning habitat and riparian vegetation, altered sedimentation and erosion regimes, and caused increases in water temperature and turbidity.
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	PP	Proximity to Straits of Juan de Fuca shipping lanes makes region susceptible to non-native species introduction via ballast water. Eleven non-native and thirteen cryptogenic species found between 2001 and 2002 (pg. 120-122).
Harmful Algal Blooms	IP	PSP levels exceeded standards 21 times and DA levels exceeded standards 195 times from 1990-2005 (Figures 78-80; pg. 117-120). Elevated DA levels were reported at Kalaloch Beach in July 2006 (WDFW 2006a).
Fuel / Oil Spills	PP	Area vulnerable to oil spills that could occur off Washington State or southern Vancouver Island, a region used heavily by marine traffic. Examples include the *Nestucca* oil spill (December 23, 1988) and the *Tenyo Maru* oil spill (July 22, 1991) (pg. 136-137).

D.2 Recommendations

D.2.a. Prior Recommendations

We recognize that recent recommendations pertaining to the management of coastal water resources in OLYM have been offered by others (Weeks 1999; Jenkins *et al*. 2003; OCNMS 2003). We begin by reviewing these recommendations.

Weeks (1999) made the following recommendations based on a visit to OLYM, interviews with NPS personnel, and a limited review of published information and technical reports. Treatment here is restricted to issues relevant to this report; the original language has been modified by this report's authors for summary purposes:

1) Integrate baseline inventory and monitoring activities into overall natural resources planning and management processes.

2) Manage bank erosion near Kalaloch Lodge in the short term by monitoring rates of bluff retreat, directing surface water runoff away from bluff line, preventing runoff from flowing over bluff line, and retaining any woody vegetation on the bluff. Longer-term management actions could include relocating existing structures near the eroding bank, installing a drainpipe network to removed subsurface water, and encourage the re-establishment of woody vegetation on or near the bluff line.

3) Review existing timber harvest practices for protection of riparian zones to determine i) whether existing harvest practices adequately protect OLYM's coastal water resources; ii) what recourse OLYM has when standards are violated, and iii) what is the most effective monitoring program to evaluate current conditions?

4) Determine whether and to what extent alterations to the Quillayute River channel influence sediment supply and contribute to erosion of Rialto Beach.

5) Develop a Spill Prevention Control and Countermeasure Plan to i) allow park personnel to request assistance from qualified federal, state, and private sources to respond to oil and other hazardous spills in a time-efficient manner, and ii) define appropriate park management for hazardous materials use in park operations, for example at Kalaloch Lodge and at park maintenance facilities.

6) Develop and maintain interagency partnerships to manage water resources with OLYM.

The OCNMS Advisory Council's Marine Conservation Working Group (MCWG) (2003) made recommendations regarding management of intertidal resources within OLYM. The MCWG defined intertidal reserves as areas "between extreme high water and extreme low water that is closed to all collection of living and non-living things and other extractive uses." The stated purposes of such reserves (paraphrased by the authors of this report) would be to protect the integrity of biological communities from harvest pressures, provide areas for scientific research, protect areas that supply new individuals to surrounding populations, encourage the development of a public conservation ethic, and protect accumulations of non-living resources (e.g., shells, sticks, rocks) in a state undisturbed by visitors. The MCWG offered four recommendations for management of intertidal reserves:

1) Prohibit collection of all living organisms, except for treaty uses in all Usual and Accustomed Areas

2) Prohibit souvenir collection of rocks, sticks, shells, and other beach materials of natural origin

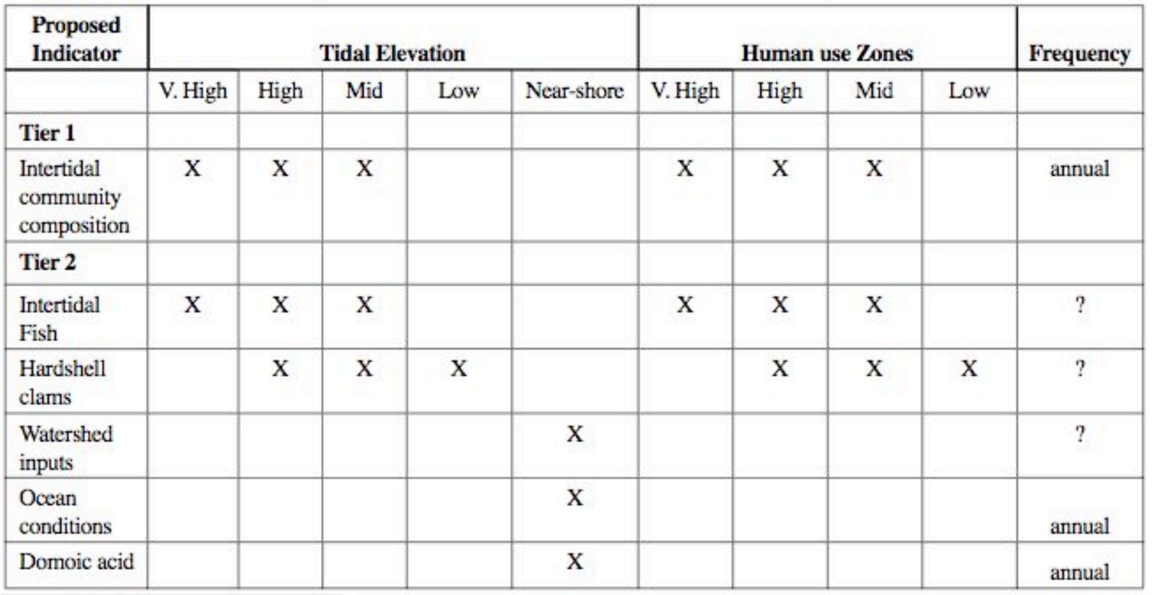
3) Prohibit beach fires to preserve the natural abundance and distribution of woody flotsam and jetsam on the shore

4) Implement the intertidal reserve status for a long-term, indefinite period.

The MCWG identified seven potential intertidal no-take reserve sites within OLYM according to criteria that included habitat types, sensitivity, and accessibility. The sites identified were Point of Arches, Cape Alava-Sand Point, Two-Bit Point, Cape Johnson/Hole-in-the-Wall, Teawhit Head, Taylor Point, and Goodman Creek-Hoh River.

The USGS prepared in cooperation with OLYM a Framework for Long-term Ecological Monitoring in Olympic National Park (Jenkins *et al*. 2003). Much of the focus of the Framework concerns elements of the coniferous forest biome in park areas beyond the coastal strip. However, elements of the report focus on coastal aquatic and intertidal habitats. Especially relevant in this context is the subsection by Fradkin on development of monitoring programs in the coastal environment. Table 35 is reproduced from that report, and indicates the scope of the current and proposed monitoring program in shoreline areas:

Table 35. Intertidal shoreline monitoring programs (reproduced from Jenkins *et al*. 2003).



Proposed Indicator	Tidal Elevation					Human use Zones				Frequency
	V. High	High	Mid	Low	Near-shore	V. High	High	Mid	Low	
Tier 1										
Intertidal community composition	X	X	X			X	X	X		annual
Tier 2										
Intertidal Fish	X	X	X			X	X	X		?
Hardshell clams		X	X	X			X	X	X	?
Watershed inputs					X					?
Ocean conditions					X					annual
Domoic acid					X					annual

Fradkin (*in* Jenkins *et al*. 2003) makes the following recommendations with regard to monitoring coastal habitats in OLYM (paraphrased by the authors of this report):

1) Determine population trends of mussels, hard-shelled clams, and key unclassified intertidal species (e.g., barnacles, seastars)

2) Determine effects of visitor trampling on intertidal communities

3) Determine the status and susceptibility of intertidal zone to invasion by non-indigenous species

4) Create habitat inventories to guide multi-agency cooperative habitat protection

5) Determine linkages between indicators

6) Determine trends and effects of sediment transport in intertidal and subtidal areas

7) Determine patterns of long- and cross-shore water movement

8) Determine contingency monitoring plans for oil spill response

9) Develop methods to improve spatial inference of intertidal monitoring program

10) Determine background toxin levels (in intertidal organisms).

Recommendations proposed by Weeks (1999) and Jenkins *et al*. (2003) are in various stages of implementation. For example, studies to determine the impacts of human trampling on intertidal communities have been performed (Erickson 2003, 2004), as has an initial survey of aquatic invasion of shoreline habitats (deRivera *et al*. 2005). Coastal ocean condition is monitored seasonally by OCNMS and the ORHAB partnership. If fully developed and funded, the Northwest Association of Networked Ocean Observing Systems (NANOOS) will implement an integrated system of ocean monitoring along the coasts of Washington, Oregon, and northern California.

OLYM released a draft general management plan (GMP) in June 2006 (NPS 2006c). The draft GMP specifies a number of strategies to accomplish park-specific objectives with respect to natural resources management. Many of these strategies address water resource issues. Measures to protect water quality currently are being applied and will continue to be applied under the four alternatives specified in the draft GMP. The alternatives include additional measures that could be used to protect water resources and minimize impacts of implementation. These include (paraphrased by the authors of this report):

- Conduct projects in or adjacent to waterways during the dry summer months
- Implement erosion control measures, inspect equipment for petroleum and other leaks, and minimize use of heavy equipment in waterways
- Integrate runoff control systems into the design of new parking areas
- Develop sediment control prevention plans
- Delineate wetlands and apply protection during project activities
- Delineate 100-year floodplains and minimize development in floodplain areas.

Implementation of any of the four alternatives would continue to protect water quality within OLYM. We refer the reader to the GMP for full discussion of park-specific objectives and strategies for management of coastal water resources.

D.2.b. Summary Recommendations

Based on prior recommendations as reported in Section D.2.a. and on our review and assessment of water resource condition and threats in coastal areas of OLYM, we offer the following recommendations (Table 36). The order in which the recommendations are presented does not reflect relative importance or urgency. In offering these recommendations, we acknowledge that moderate uncertainty exists in our evaluation of several aspects of water resource condition. This uncertainty reflects the limitations of the data. Consequently, our recommendations include suggestions for closing data gaps, especially those pertaining to water resources that could become impaired in the near-to-mid-term.

Table 36. Specific Recommendations

- Develop and implement a water quality monitoring program for coastal streams and estuaries. Parameters could include (at a minimum) water temperature, dissolved oxygen, and sediment load. Parameters could be expanded to include nutrients, PCBs and PAHs.
- Integrate inventory and monitoring activities into natural resources planning and management processes.
- Manage stormwater runoff to reduce impacts to riparian and nearshore environments.
- Measure the amounts of toxins and contaminants introduced to coastal streams and rivers and to beach areas by surface water flow from primary and secondary roadways and parking areas. Determine whether toxins and contaminants from roadway sources impair water resources in OLYM.
- Continue to develop and implement protections for marine intertidal areas.
- Manage shoreline erosion in vulnerable areas, especially around Mora and Kalaloch.
- Pursue opportunities to reduce degradation in Lake Ozette, for example by acquisition of key watershed parcels.
- Develop a plan for managing non-indigenous marine and estuarine species.
- Partner with watershed groups in WRIAs 20 and 21 and continue to partner with coastal tribes to restore impaired stream habitats in coastal areas. Protect and restore sensitive shoreline areas that provide essential fish habitat.
- Partner with OCNMS and others (e.g., ORHAB, ECOHAB) to monitor coastal water conditions. Track development and implementation of NOAA’s Ocean Observing System via NANOOS (Northwest Association of Networked Ocean Observing Systems).
- Track NOAA’s planned project for Biogeographic Assessment of Living Marine and Cultural Resources of the Olympic Coast National Marine Sanctuary. Identify shoreline resources within OLYM that could be included in the Biogeographic Assessment of OCNMS.
- Track the OCNMS Management Plan Review Process. Identify synergies between OCNMS and OLYM planning and management, and provide input to the OCNMS planning process where appropriate.
- Track revisions to the State of Washington’s Oil Spill Contingency Plan rule. Consider whether the definition of sensitive areas under the Contingency Plan rule could be expanded to include shoreline areas of OLYM beyond National Wildlife Refuge sites.
- Continue to participate in the annual Olympic Coast Cleanup to remove marine debris from beaches.

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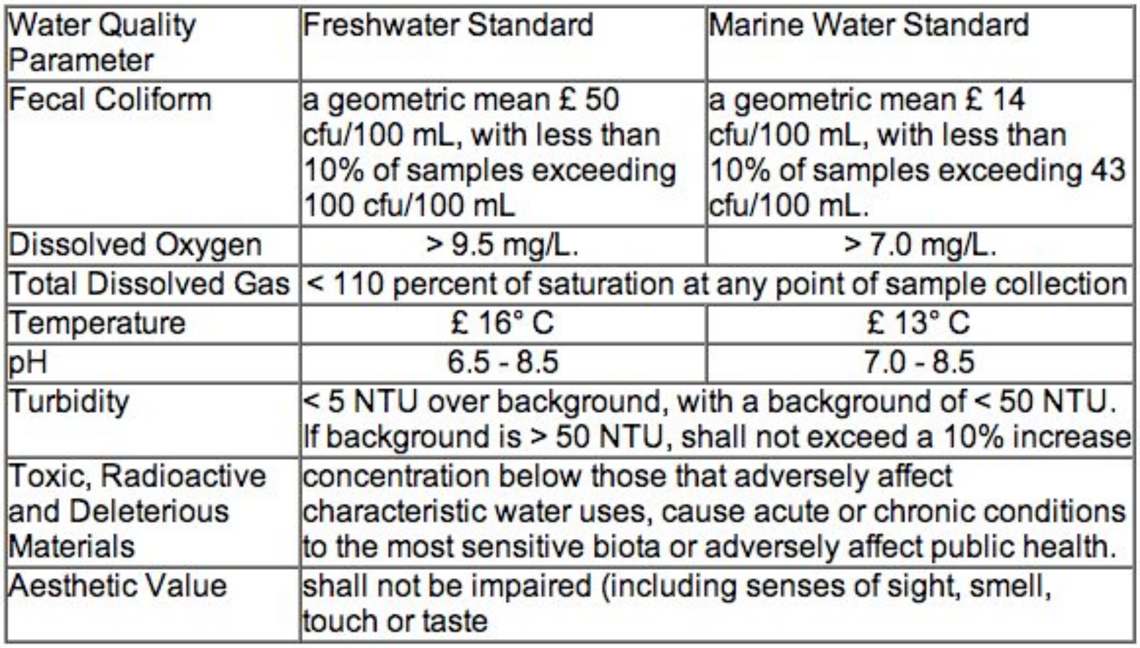
Appendix A. Water Quality Standards

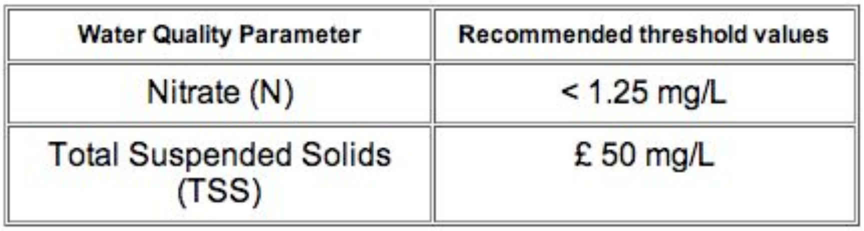
Table A1. EPA Water Quality Standards for Marine Waters.

EPA Water Quality Standards for Marine waters		Source
Dissolved Oxygen (DO)	Criteria evaluated for freshwater levels only. Coldwater values were used because the EPA identifies the presence of salmonid species to be indicative of coldwater areas. The acute lethal limit for salmonids is at 3 mg/L, but the coldwater minimum has been established at 4 mg/L due to more sensitive insect populations. Because the criteria are generalized, it is required that states evaluate the species in their own waters to establish appropriate minimum levels of dissolved oxygen.	U.S. EPA. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003; EPA Gold Book
Temperature	For marine aquatic life, the maximum increase in the weekly average temperature due to artificial causes is 1°C (1.8°F) during all seasons of the year, and daily temperature cycles of a body of water are not to be altered, neither in amplitude nor frequency.	EPA Gold Book
pH	Shall fall between the range of 6.5-8.5	EPA Gold Book
Turbidity		
Toxic Substances		
Primary Contact Recreation		Source
Fecal Coliforms	The median value for a fecal coliform standard is 15 per 100mL and the 90th percentile should not exceed 43 for a 5-tube, 3-dilution method.	EPA Gold Book

Table A2. Washington State Water Quality Standards and recommended threshold values.



Water Quality Parameter	Freshwater Standard	Marine Water Standard
Fecal Coliform	a geometric mean £ 50 cfu/100 mL, with less than 10% of samples exceeding 100 cfu/100 mL	a geometric mean £ 14 cfu/100 mL, with less than 10% of samples exceeding 43 cfu/100 mL.
Dissolved Oxygen	> 9.5 mg/L.	> 7.0 mg/L.
Total Dissolved Gas	< 110 percent of saturation at any point of sample collection	
Temperature	£ 16° C	£ 13° C
pH	6.5 - 8.5	7.0 - 8.5
Turbidity	< 5 NTU over background, with a background of < 50 NTU. If background is > 50 NTU, shall not exceed a 10% increase	
Toxic, Radioactive and Deleterious Materials	concentration below those that adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota or adversely affect public health.	
Aesthetic Value	shall not be impaired (including senses of sight, smell, touch or taste	



Water Quality Parameter	Recommended threshold values
Nitrate (N)	< 1.25 mg/L
Total Suspended Solids (TSS)	£ 50 mg/L

Appendix B. Benthic taxa reported from OLYM marine intertidal areas.
Source: Dethier 1988.

Taxonomic Group	**Number of taxa reported**
Vascular plants	2
Chlorophyta (green algae)	7
Phaeophyta (brown algae)	25
Rhodophyta (red algae)	65
Lichens	2
Porifera (sponges)	4
Cnidaria (hydroids, stauromedusans, anemones)	8
Platyhelminthes (flatworms)	1
Nemertea (ribbon worms)	4
Annelida (polychaete worms)	10
Sipuncula (acorn worms)	1
Mollusca: Chitons	7
Mollusca: Gastropods (snails, limpets)	40
Mollusca: Bivalves (mussels, clams, etc)	16
Arthropoda: Isopods	4
Arthropoda: Amphipods	2
Arthropods: Decapods (crabs, shrimp)	11
Arthropods: Barnacles	5
Bryozoa	3
Echinodermata: Urchins	2
Echinodermata: Sea Cucumbers	8
Echinodermata: Seastars	6
Echinodermata: Brittle Stars	1
Urochordata: Tunicates (seasquirts)	6
Vertebrates: Intertidal Fishes	3

APPENDIX C. Benthic Intertidal Species

Adapted from: Dethier, M.N. 1991. The effects of an oil spill and freeze event on intertidal community structure in Washington. U.S. Department of the Interior, Minerals Management Service.

Species found in or adjacent to Rock Transects

LICHENS
Verrucaria spp.
Arthopyrenia spp.

CYANOBACTERIA
bluegreen film

VASCULAR PLANTS
Physllospadix scouleri
Phyloospadix torreyi

ALGAE

CHLOROPHYTA

Order Acrosiphoniales
Acrosiphonia spp.

Order Cladophorales
Cladophora spp.

Order Codiales
Codium fragile
Bryopsis corticulans
Bryopsis plumose
Derbesia marina

Order Ulvales
Ulva spp.
Enteromorpha spp.

PHAEOPHYTA

Order Laminariales
Laminaria sinclairii
Laminaria setchellii
Alaria marginata
Egregia menziesii
Hedophyllum sessile
Lessoniopsis littoralis
Macrocystis integrifolia

Order Fucales

Fucus gardneri
Fucus spiralis
Pelvetiopsis limitata

Order Ectocarpales

Ralfsia pacifica
Ralfsia fungiformis
Ralfsia californica
Cylindrocarpus rugosus
Leathesia difformis
Analipus japonicus
Scytosiphon lomentaria
Haplogloia andersonii
Petalonia fascia
Phaeostrophion irregulare
Myelophycus intestinalis
Colpomenia spp.

Order Sphacelariales

Sphacelaris racemosa
Sphacelaris norrisii

RHODOPHYTA

Order Bangiales

Prophyra spp.

Order Nemaliales

Cumagloia andersonii

Order Palmariales

Halosaccion glandiforme
Palmaria mollis

Order Hildenbrandiales

Hildenbrandia spp.

Order Gelidiales

Gelidium coulteri

Order Corallinales

Bossiella orbigniana subsp. *dichotoma*
Bossiella plumosa

Bossiella chiloensis
Chiharaea bodegensis
Corallina vancouveriensis
Corallina officinalis
Lithophyllum impressum
Lithothamnion phymatodeum
Pseudolithophyllum whidbeyense
Pseudolithophyllum neofarlowii
Titanoderma sp.

Order Gigartinales

Constantinea simplex
Cryptosiphonia woodii
Dilsea californica
Farlowia mollis
Endocladia muricata
Gigartina exasperata/corymbifera
Iridaea splendens
Iridaea cornucopiae
Gloiosiphonia capillaries
Grateloupia doryphora
Halymenia schizymenioides
Prionitis spp.
Prionitis filiformis
Erythrophyllum delesserioides
Mastocarpus jardinii
Mastocarpus papillatus
“Petrocelis”
Peyssonnelia pacifica
Ahnfeltia plicata
Gymnogongrus spp.
Plocamium cartilagineum
Plocamium violaceum
Plocamium oregonum

Order Rhodymeniales

Gastroclonium subarticulatum

Order Ceramiales

Callithamnion pikeanum
Ceramium pacificum
Ceramium rubrum
Microcladia borealis
Neoptilota asplenioides
Neoptilota hypnoides
Cryptopleura spp.

Delesseria decipiens
Laurencia spectabilis
Neorhodomela larix
Odonthalia floccose
Odonthalia washingtoniensis
Polysiphonia hendryi
Polysiphonia pacifica
Polysiphonia urceolata
Pterosiphonia dendroidea
Pterosiphonia bipinnata
Membranoptera sp.

ANIMALS

PH. SARCOMASTIGOPHORA

Gromia oviformis

PH. PORIFERA (SPONGES)

Leucosolenia sp.
Halichondria panicea
Ophlitaspongia pennata
Haliclona spp.
white sponge
yellow sponge

PH. CNIDARIA (hydroids, anemones)

erect hydroids
Anthopleura elegantissima
Anthopleura xanthogrammica
Anthopleura artemisia
Urticina spp.
Epiactis prolifera

PH. PLATYHELMINTHES (FLATWORMS)

Polyclads

PH. NEMERTEA (RIBBONWORMS)

Paranemertes peregrina
Emplectonema gracile
Amphiporus imparispinosus

PH. ANNELIDA (POLYCHAETE WORMS)

Serpulids
Sabellids
Potamilla neglecta + *P. occelata*

Other Sabellids
Nereids (unidentified)
Pista elongata
Eudistylia vancouveri
Syllis stewartii
Nephtyds
Nephtys ferruginea

PH. SIPUNCULA (ACORN WORMS)
Phascolosoma agassizii

PH. MOLLUSCA: CHITONS
Lepidochitona dentiens
Tonicella lineate
Mopalia ciliata + lignosa + hindsii
Mopalia muscosa
Katharina tunicate
Cryptochiton stelleri
Dendrochiton flectens

GASTROPODS
Tricolia pulloides
Tegula funebralis
Lirularia succincta
Diodora aspera
Acmaea mitra
Lottia pelta
Lottia digitalis
Lottia strigatella
Lottia painei
Tectura scutum
Tectura persona
Lacuna spp.
Littorina scutulata
Littorina sitkana
Littorina tattoshensis
Nassarius fossatus
Margarites spp.
Bittium eschrichtii
Crepidula perforans
Ceratostoma foliatum
Ocenebra lurida
Nucella lamellose
Nucella canaliculata
Nucella emarginata
Searlesia dira

Alia carinata
Alia gausapata
Amphissa Columbiana
Archidoris montereyensis
Cadlina luteomarginata
Hermissenda crassicornis
Onchidella borealis
Siphonaria thersites
Triopha sp.
Dendronotus frondosus

BIVALVES

Mytilus californianus
Mytilus edulis
Petricola carditoides
Semele rubropicta
Hiatella arctica
Boring clams

PH. ARTHROPODA: ISOPODS

Idotea spp. (*wosnesenskii* + *ochotensis* + *schmitti* + *montereyensis*)
Synidotea ritteri + *pettiboneae*
Ligia spp.
Gnorimosphaeroma oregonense
Dynamenella benedictii

AMPHIPODS

Gammarid Species, including *Hyale frequens* + *anceps* + *pugettensis*
Jassa spp.
Parallorchestes sp.
Corophium brevis

DECAPODS

Hemigrapsus nudus
Oedignathus inermis
Pagurus spp.
Petrolisthes spp.
“spider crabs” (majids)
Cancer oregonensis
Pugettia producta
Shrimp (unidentified)

BARNACLES

Semibalanus cariosus
Balanus glandula
Balanus nubilus

Chthamalus dalli
Pollicipes polymerus
Pycnogonids including *Achelia alaskensis*

PH. BRYOZOA

Heteropora magna
Bugula spp.
encrusting spp.
Flustrellida sp.
Alcyonidium polyoum
Membranipora membranacea
Tricellaria spp.

PH. ECHINODERMATA: URCHINS

Strongylocentrotus droebachiensis
Strongylocentrotus purpuratus

SEA CUCUMBERS

Cucumaria miniata
Eupentacta quinquesemita

SEASTARS

Pisaster ochraceus
Leptasterias hexactis
Pynopodia helianthoides
Henricia leviuscula

PH. UROCHORDATA: TUNICATES

Styela montereyensis
Perophora annectens
Clavelina huntsmani
Aplidium spp.
Didemnum spp.
Pyrua sp.

VERTEBRATES: FISHES

Gobies (clingfish)
Blennies
Cottids (sculpins)

Species Found in or Adjacent to Cobble Transects

LICHENS

Verrucaria spp.

CYANOBACTERIA
bluegreen crusts

VASCULAR PLANTS
Phyllospadix scouleri
Phyllospadix torreyi
Phyllospadix serrulatus

ALGAE

CHLOROPHYTA

Order Acrosiphoniales
Acrosiphonia spp.

Order Cladophorales
Cladophora spp.

Order Codiales
Derbesia marina
Bryopsis corticulans
Codium fragile

Order Ulvales
Ulva spp.
Enteromorpha spp.

PHAEOPHYTA

Order Laminariales
Costaria costata
Laminaria setchellii
Laminaria sinclairii
Alaria marginata
Egregia menziesii
Hedophyllum sessile
Macrocystis integrifolia
Nereocystis luetkeana

Order Fucales
Fucus gardneri
Fucus spiralis

Pelvetiopsis limitata
Cystoseria geminate
Sargassum muticum

Order Ectocarpales

Ralfsia pacifica
Ralfsia fungiformis
Ralfsia californica
Leathesia difformis
Analipus japonicus
Colpomenia peregrine
Colpomenia bullosa
Scytosiphon lomentaria
Phaeostrophion irregulare
Myelophycus intestinalis
Soranthera ulvoidea

Order Sphacelariales

Sphacelaria spp.

Order Desmarestiales

Desmarestia ligulata

RHODOPHYTA

Order Compsopogonales

Smithora naiadum

Order Bangiales

Porphyra spp.

Order Acrochaetiales

Audouinella spp.

Order Nemaliales

Scinaia confusa

Order Palmariales

Halosaccion glandiforme
Rhodophysema elegans

Order Hildenbrandiales

Hildenbrandia spp.

Order Gelidiales

Gelidium coulteri

Order Corallinales

Bossiella orbigniana, subsp. *dichotoma*
Bossiella cretacea
Bossiella plumose
Calliarthron tuberculosum
Chiharaea bodegensis
Corallina vancouveriensis
Corallina officinalis
Corallina frondescens
Lithothrix aspergillum
Lithophyllum impressum
Lithothamnion phymatodium
Pseudolithophyllum whidbeyense
Pseudolithophyllum neofarlowii
Serraticardia macmillanii
Titanoderma sp.

Order Gigartinales

Constantinea simplex
Cryptosiphonia woodii
Dilsea californica
Farlowia mollis
Endocladia muricata
Gigartina exasperata/corymbifera
Iridaea splendens
Iridaea heterocarpa
Iridaea cornucopiae
Rhodoglossum affine
Grateloupia setchellii
Grateloupia doryphora
Halymenia schizymenioides
Callophyllis spp.
Prionitis spp.
Schizymenia pacifica
Mastocarpus jardinii
Mastocarpus papillatus
"Petrocelis"
Peyssonnelia pacifica
Ahnfeltia fastigiata
Gymnogongrus leptophyllus
Gymnogongrus chiton

Order Rhodymeniales

Gastroclonium subarticulatum

Order Ceramiales

Callithamnion pikeanum
Ceramium pacificum
Ceramium washingtoniense
Microcladia borealis
Microcladia coulteri
Neoptilota asplenioides
Cryptopleura lobulifera
Cryptopleura ruprechtiana
Polynerua spp.
Laurencia spectabilis
Neorhodomela larix
Odonthalia floccose
Odonthalia washingtoniensis
Polysiphonia spp. (*hendryi* + *pacifica* + *urceolata* + *paniculata* + *eastwoodae*)
Pterosiphonia spp. (*bipinnata* + *dendroidea*)

ANIMALS

PH. SARCOMASTIGOPHORA

Gromia oviformis

PH. PORIFERA (SPONGES)

Halichondria panicea
Ophlitaspongia pennata
Haliclona spp.
other sponges (unidentified)

PH. CNIDARIA (hydroids, stauromedusans, anemones)

erect hydroids
Anthopleura elegantissima
Anthopleura xanthogrammica
Urticina spp.
Epiactis prolifera
Alcyonium sp.

PH. NEMERTEA (RIBBONWORMS)

Tubulanus polymorphus
Paranemertes peregrine
Emplectonema gracile
Amphiporus spp.
unidentified nemerteans

PH. ANNELIDA (POLYCHAETE WORMS)

Serpulidae (including *Serpula vermicularis* + *Protula pacifica*)
Spirorbidae
Sabellidae (including *Indanthyrsus armatus, Oriopsis* spp., + unidentified)
Spionidae
    Spio filicornis
    Pygospio elegans
    Polydora proboscidea
Maldanidae: *Euclymene zonalis*
Terebellidae
    Thelepus crispus
    Nicolea zostericola
    Pista elongate + brevibranchiata
Flabelligeridae
    Pherusa plumose + inflata
Nereidae
    Platynereis bicanaliculata
    Nereis vexillosa
Arabellidaie: *Drilonereis longa*
Capitellidae
    Decamastus gracilis
    Capitella capitata
Oweniidae: *Owenia fusiformis*
Orbiniidae
    Naineris dendritica
    Naineris quadricuspida + uncinata
    Scoloplos sp.
Onuphidae: *Nothria conchylega*
Arenicolidae
    Arenicola marina
    Abarenicola pacifica
Lumbrineridae
    Lumbrineris luti + latreilli + californiensis + zonata + japonica
Cirratulidae
    (*Chaetonzone acuta* + unidentified)
Syllidae: *Syllis variegate*
Nephtyidae
    Nephtys californiensis
    N. caecoides
Opheliidae
    Ophelina sp.
    Armandia brevis
    Euzonus sp.
Polynoidae
    Halosydna brevisetosa
    Tenonia priops

Sabellariidae
    Sabellaria cementarium
    Idanthyrsus armatus

PH. SIPUNCULA (ACORN WORMS)

Phascolosoma agassizii

PH. MOLLUSCA: CHITONS

Lepidozona willetti + cooperi
Lepidochitona dentiens
Tonicella lineate
Mopalia ciliate + lignose
Mopalia muscosa
Katharina tunicate
Dendrochiton flectens
Leptochiton nexus
Placiphorella velata

GASTROPODS

Tegula funebralis
Tegula brunnea
Lirularia succincta
Margarites pupillus
Diodora aspera
Acmaea mitra
Lottia pelta
Lottia digitalis
Lottia strigatella
Lottia painei
Tectura scutum
Tectura fenestrata
Tectura persona
Lacuna spp.
Amphissa versicolor
Granulina margaritula
Tricolia pulloides
Opalia borealis
Alvaria sp.
Barleeia haliotiphila
Littorina scutulata
Littorina sitkana
Bittium eschrichtii
Crepidula adunca
Crepidula perforans
Opalia borealis
Calliostoma ligatum

Ocenebra lurida
Nucella lamellose
Nucella canaliculata
Nucella emarginata
Searlesia dira
Alia carinata + gausapata
Dialula sandiegensis
Rostanga pulchra
Archidoris montereyensis
Cadlina luteomarginata
Hermissenda crassicornis
Onchidella borealis
Triopha sp.

BIVALVES

Mytilus californianus
Mytilus edulis
Adula spp.
Spehnia ovoidea
Tellina nucleoides
Macoma spp. (juv. + unid.)
Macoma inquinata
Protothaca staminea
Transennella tantilla
Saxidomus giganteus
Petricola carditoides
Semele rubropicta
Pododesmus cepio
Mya arenaria
Hiatella arctica
Penitella spp.
Cryptomya californica

PH. ARTHROPODA: ISOPODS

Idotea wosnesenskii
Idotea ochotensis + schmitti + urotoma + aculeata + kirchanskii + fewkesi
Cirolana harfordi
Exosphaeroma inornata + rhomburum + crenulatum
Gnorimosphaeroma noblei + oregonense + insulare
Dynamenella glabra
Littorophiloscia richardsonae
Alloniscus perconvexus

AMPHIPODS

Paramoera Columbiana
Pontogeneia cf. *ivanovi*

Amphilochus litoralis
Corophium sp.
Melita sp.
Maera simile + danae
Hyale plumulosa
H. frequens
Parallorchestes sp.
Ampithoe lacertosa
Atylus levidensus
Megalorchestia pugettensis
M. californiana + columbiana
Traskorchestia traskiana
T. georgiana
Eohaustorius sawyeri
Orchomene pinguis
Cymadusa uncinata

DECAPODS

Hemigrapsus nudus
Hemigrapsus oregonensis
Cancer oregonensis
Cancer productus
Lophopanopeus bellus
Pagurus spp.
Upogebia pugettensis
Petrolisthes cinctipes
Petrolisthes eriomerus
Pachycheles rudis
majid crabs (spider + decorator spp.)
Shrimp, including *Sergia tenuiremis + Heptacarpus sitchensis + littoralis pugettensis + Hippolyte clarki + Crangon nigricauda*
TANAIDS: *Leptochelia savignyi*
INSECTS: *Cercyon fimbriata*

BARNACLES

Semibalanus cariosus
Balanus glandula
Chthamalus dalli
Pollicipes polymerus
Balanus crenatus

PH. BRYOZOA

encrusting spp., including
    Tricellaria spp.
    Eurystomella spp.
Dendrobeania sp.

Alcyonidium polyoum

PH. ECHINODERMATA: URCHINS

Strongylocentrotus droebachiensis

SEA CUCUMBERS

Leptosynapta clarki
Paracaudina chilensis

SEASTARS

Pisaster ochraceus
Leptasterias hexactis
Pynopodia helianthoides
Henricia leviuscula

BRITTLE STARS

Amphipholis squamata
Amphiodia periercta
Amphiodia occidentalis
Ophiopholis aculeate
Amphioplus sp.

PH. UROCHORDATA: TUNICATES

Perophora annectens
Metandrocarpa sp.
Clavelina huntsmani
Aplidium spp.
Didemnum sp.
Distaplia sp.
thin tan encrusting ascid.

PH. HEMICHORDATA

(?) *Glossobalanus* sp.

VERTEBRATES: FISHES

Gobies: *Gobiesox meandricus*
Blennies: *Pholis ornate + Xiphister mucosis + Anoplarchus insignis*
Cottids: *Oligocottus* spp. + *Artedius lateralis*

*Spirorobids found include: *Spirorbis bifurcatus, Neodexiospira pseudocorrugata, Bushiella abnormis, Paradexiospira vitrea,* and *Circeis armoricana*

Species Found in or Adjacent to Sandy Transects

AMPHIPODS

Fam. Haustoriidae

Unidentified *Eohaustorius*
Eohaustorius brevicuspis
Eohaustorius sawyeri
Eohaustorius washingtonianus

Fam. Oedicerotidae

Monoculodes sp.

Fam. Phoxocephalidae

Grandiphoxus grandis
Foxiphalus major
Mandibulophoxus sp.1
Mandibulophoxus gilesi
Rhepoxynius sp.

Fam. Talitridae: Beachoppers

Megalorchestia californiana
Megalorchestia columbiana
Megalorchestia pugettensis
Traskorchestia georgiana
Traskorchestia traskiana

Fam. Ampithoidae

Ampithoe simulans?

Fam. Hyaleidae

Hyale frequens
Hyale plumulosa
Parallorchestes sp.

Fam. Ischyroceridae

Ischyrocerus cf. *anguipes*
Jassa spp.

Fam. Pontogeneiidae

Paramoera serrata
Pontogeneia cf. *ivanovi*

Fam. Dogielinotidae

Proboscinotus loquax

ISOPODA

Suborder Flabellifera
Excirolana spp.

Suborder Oniscoidea
Alloniscus perconvexus
Littorophiloscia richardsonae
Porcellio scaber

MYSID
Archaeomysis grebnitzkii

BIVALVE
Siliqua patula

GASTROPODA
Olivella biplicata

POLYCHAETES
Fam. Phyllodocidae
Eteone tuberculata

Fam. Nephtyidae
Nephtys brachycephala
Nephtys californiensis
Nephtys ferruginea?
Nephtys longosetosa

Fam. Opheliidae
Euzonus mucronatus

Fam. Orbiniidae
Leitoscoloplos pugettensis

Fam. Lumbrineridae
Lumbrineris luti

Fam. Spionidae
Unidentified spionids
Pygospio elegans
Scolelepis squamata
Scolelepis foliosa

NEMERTEANS
Unidentified nemert.
Amphiporus tigrinus
Cerebratulus ? *californiensis*

Tubulanus pellucidus
Zygonemertes virescens

APPENDIX D. Non-indigenous and cryptogenic species found in Olympic Coast National Marine Sanctuary.

Taken from: deRivera, C.C.*, et al*. (2005). Broad-scale non-indigenous species monitoring along the West Coast in National Marine Sanctuaries and National Estuarine Research Reserves. National Fish and Wildlife Foundation, unpublished report.

Sargassum muticum
Proceraea kiiensis
Proceraea okadi
Caprella penantis
Schizoporella unicornis
Mya arenaria
Nuttallia obscurata
Venerupis philippinarum
Crassostrea gigas
Botrylloides violaceus
Styela clava
Arabella iricolor
Capitella capitata
Exogone lourei
Lumbrineris japonica
Myxicola sp.
Neanthes virens/brandti
Nepthys longosetosa?
Scolelepis "squamata"
Microjassa sp.
Synidotea sp.
Dynamenopsis cf. dianae
Diplosoma listerianum
Adula diegensis
Idotea (Pentidotea) recta
Joeropsis dubia dubia

Appendix E. Olympic Peninsula Marine Intertidal Algae Species List 2005.

Source: Rob Fitch, Biology Department, Wenatchee Valley College.

Rialto Beach (Monday, July 18, 2005; -1.8 5:10 AM)

Chlorophyta (Greens):

Acrosphonia coalita/spinescens
Cladophora columbiana
Ulva fenestrata
Ulva intestinalis (Genus changed from *Enteromorpha* to *Ulva* in 2004)
Ulva linza (Genus changed from *Enteromorpha* to *Ulva* in 2004)

Phaeophyta (Browns):

Alaria marginata
Analipus japonicus
Fucus gardneri
Haplogloia andersonii
Hedophyllum sessile - exposed coast morphology
Laminaria setchellii – broader, segmented blade
Laminaria sinclairii – narrow, single intact blade
Leathesia difformis
Lessoniopsis littoralis
Nereocystis luetkeana
Pelvetiopsis limitata
Phaeostrophion irregulare
Ralfsia californica
Scytosiphon lomentaria
Soranthera ulvoidea

Phodophyta (Reds):

Constantinia simplex
Corallina vancouveriensis
Cryptopleura lobulifera
Cryptopleura ruprechtiana
Cryptosiphonia woodii
Cumagloia andersonii
Delesseria decipiens
Dilsea californica - less than 4" in length, yellow-maroon
Endocladia muricata
Erythrophyllum delesserioides
Farlowia mollis
Mastocarpus jardinii
Mastocarpus papillatus

Mazzaella affinis
Mazzaella linearis - lower intertidal, long, narrow, spiraled
Mazzaella oregonum - intertidal, irregular shape
Mazzaella parksii - high intertidal, small, yellow-green
Mazzaella splendens - lower intertidal, irridescent, oval blades
Melobesia mediocris – crustose coralline epiphyte on seagrasses
Membranoptera spinulosa
Microcladia borealis
Neodilsea californica – greater than 4” in length, blackish-red
Neorhodomela larix
Odonthalia floccosa
Osmundea spectabilis
Phycodrys setchellii
Pikea californica
Plocamium violaceum
Polyneura latissima
Polysiphonia sp.
Porphyra occidentalis - subtidal, red cellophane
Porphyra perforata - high intertidal, black cellophane
Prionitis lanceolata
Ptilota filicina

Second Beach: (Monday, July 18, 2005; -1.8 5:10 AM)

Chlorophyta (Greens):
Acrosphonia coalita/spinescens
Cladophora columbiana
Ulva fenestrata
Ulva intestinalis (Genus changed from *Enteromorpha* to *Ulva* in 2004)
Ulva linza (Genus changed from *Enteromorpha* to *Ulva* in 2004)

Phaeophyta (Browns):
Alaria marginata
Analipus japonica
Egregia menziesii
Fucus gardneri
Haplogloia andersonii
Hedophyllum sessile
Laminaria setchellii
Laminaria sinclairii
Leathesia difformis
Lessoniopsis littoralis
Pelvetiopsis limitata

Phaeostrophion irregulare
Postelsia palmaeformis
Ralfsia californica
Scytosiphon lomentaria
Soranthera ulvoidea

Rhodophyta (Reds):
Ahnfeltia fastigiata (smallest)
Ahnfeltiopsis gigartinoides (middle-sized)
Ahnfeltiopsis/Gymnogongrus linearis (largest)
Bossiella plumosa
Callithamnion pikeanum
Constantinea simplex
Corallina vancouveriensis
Cryptopleura lobulifera
Cumagloia andersonii
Dilsea californica
Endocladia muricata
Farlowia mollis
Gloiosiphonia verticillaris
Grateloupia doryphora
Grateloupia pinnata (low intertidal, bottoms/sides of vertical boulders)
Mastocarpus jardinii
Mastocarpus papillatus
Mazzaella linearis
Mazzaella oregonum
Mazzaella parksii
Mazzaella splendens
Microcladia borealis
Neorhodomela larix
Odonthalia floccosa
Plocamium oregonum
Polyneura latissima
Polysiphonia sp.
Porphyra occidentalis
Porphyra perforata
Prionitis lanceolata
Prionitis lyallii
Ptilota filicina

<u>Cape Alava</u> (Tuesday, July 19, 2005; -2.6 6:00 AM)

Chlorophyta (Greens):
Acrosiphonia coalita/spinescens
Bryopsis corticulans
Cladophora columbiana
Codium fragile
Ulva fenestrata
Ulva intestinalis - remains tubular (Genus changed from *Enteromorpha* to *Ulva* in 2004)
Ulva linza - tubular @ holdfast, opens to blade (Genus changed from *Enteromorpha* to *Ulva* in 2004)
Ulva taeniata – long & spiraled

Phaeophyta (Browns):
Alaria marginata
Analipus japonica
Colpomenia peregrina
Desmarestia ligulata - bladed, less than 1 cm. width
Desmarestia munda - bladed, greater than 1 cm width
Desmarestia viridis - stringy, “witch’s hair”
Egregia menziesii
Fucus gardneri
Laminaria setchellii - large, broad blade
Laminaria sinclairii - long stipe, single, narrow blade
Leathesia difformis
Macrocystis integrefolia
Nereocystis leutkeana
Pterygophora californica
Ralfsia californica
Sargassum muticum
Scytosiphon lomentaria
Soranthera ulvoidea

Rhodophyta (Reds):
Ahnfeltia fastigiata
Ahnfeltiopsis leptophyllus
Bossiella plumosa
Callithamnion pikeanum
Callophyllis flabellulata
Callophyllis violacea
Ceramium codicola – epiphyte on Codium
Ceramium pacificum
Ceramium washingtoniensis

Chondracanthus canaliculata
Chondracanthus exasperata
Constantinea simplex
Corallina vancouveriensis
Cryptopleura lobulifera - highly ruffled
Cryptopleura ruprechtiana - larger, many veins, marginal ruffles
Cryptopleura violacea - thin, narrow blades, no ruffles
Cryptosiphonia woodii
Cumagloia andersonii
Delesseria decipiens
Endocladia muricata
Erythrophyllum delesseroides
Gastroclonium subarticulatum
Gelidium coulteri
Gloiosiphonia capillaris
Gonimophyllum skottsbergii - parasite on Cryptopleura ruprechtiana
Grateloupia doryphora (often very greenish, highly branched)
Griffithsia pacifica
Halosaccion glandiforme
Janczewskia gardneri – (parasite on Osmundea)
Mastocarpus jardinii - thin, dichotomous branches
Mastocarpus papillatus - broader blades
Mazzaella affinis – dichotomous branching
Mazzaella linearis
Mazzaella oregonum (used to be M. heterocarpa)
Mazzaella parksii (used to be M. cornucopiae)
Mazzaella splendens
Melobesia mediocris – encrusting coralline epiphyte on seagrasses
Microcladia borealis - epilithic
Microcladia coulteri - epiphyte on other reds
Neodilsea borealis (larger than 4")
Neorhodomela larix
Odonthalia floccosa
Osmundea spectabilis
Plocamium cartilaginium - larger, pinker
Plocamium violacea - smaller, darker
Plocamiocolax sp. (parasite on Plocamium)
Polyneura latissima
Polysiphonia sp.
Porphyra perforata - hi intertidal, “black cellophane”
Prionitis cornea – densely branched, very stiff & wiry
Prionitis lanceolata
Prionitis lyallii

Pterosiphonia dendroidea
Ptilota filicina
Rhodymenia californica
Rhodymenia pacifica
Rhodymeniocolax botryoides - parasite on Rhodymenia
Scinaia confusa
Smithora naiadum – red bladed epiphyte on seagrasses

Appendix F. Inventory of Intertidal Fish Species in OLYM, 2002-2005.
Source: Dr. Steve Fradkin, OLYM.

Scientific name	**Common name**
Ammodytes hexapterus	Pacific Sandlance
Amphistichus koelzi	Calico Surfperch
Amphistichus rhodoterus	Redtail Surfperch
Anoplarchus purpurescens	High Cockscomb
Apodichthys flavidus	Penpoint Gunnel
Apodichthys fucorum	Rockweed Gunnel
Artedius fenestralis	Padded Sculpin
Artedius harringtoni	Scalyhead Sculpin
Artedius lateralis	Smoothhead Sculpin
Artedius notospilotus	Bonyhead Sculpin
Ascelichthys rhodorus	Rosylip Sculpin
Aulorhynchus flavidus	Tubesnout
Blepsias cirrhosus	Silverspotted Sculpin
Chirolophis nugator	Mosshead Warbonnet
Clinocottus acuticeps	Sharpnose Sculpin
Clinocottus embryum	Calico Sculpin
Clinocottus globiceps	Mosshead Sculpin
Clupea pallasii	Pacific Herring
Cymatogaster aggregata	Shiner Surfperch
Damalichthys vacca	Pile Surfperch
Embiotoca lateralis	Striped Surfperch
Engraulis mordax	Northern Anchovy
Enophrys bison	Buffalo Sculpin
Gasterosteus aculeatus	Threespine Stickleback
Gibbonsia montereyensis	Crevice Kelpfish
Gobiesox maeandricus	Northern Clingfish
Hemilepidotus hemilepidotus	Red Irish Lord
Hemilepidotus spinosus	Brown Irish Lord
Hexagrammos decagrammus	Kelp Greenling
Hexagrammos superciliosus	Rock Greenling
Hyperprosopon anale	Spotfin Surfperch
Hyperprosopon ellipticum	Silver Surfperch
Hypomesus pretiosus	Surf Smelt
Leptocottus armatus	Staghorn Scuplin
Liparis callyodon	Spotted Snailfish
Liparis florae	Tidepool Snailfish

Appendix E., (continued)

Liparis fucensis	Slipskin snailfish

Liparis rutteri	Ringtail Snailfish
Microgadus proximus	Pacific Tomcod
Oligocottus maculosus	Tidepool Sculpin
Oligocottus rubellio	Rosy Sculpin
Oligocottus snyderi	Fluffy Sculpin
Oncorhynchus tshawytscha	Chinook Salmon
Osmeridae	larval smelts
Pallasina barbata	Tubenose Poacher
Pholis laeta	Crescent Gunnel
Pholis ornata	Saddleback Gunnel
Pholis schultzi	Red Gunnel
Platichthys stellatus	Starry Flounder
Pleuronichthys decurrens	Curlfin Sole
Polypera greeni	Lobefin Snailfish
Psettichthys melanostictus	Sand Sole
Raja binoculata	Big Skate
Sardinops sagax	Pacific Sardine
Scorpaenichthys marmoratus	Cabezon
Sebastosomus subgenus	Rockfish Sebastastosomus
Spirinchus starksi	Night Smelt
Spirinchus thaleichthys	Longfin Smelt
Syngnathus leptorhynchus	Bay Pipefish
Trichodon trichodon	Pacific Sandfish
Xiphister atropurpureus	Black Prickleback
Xiphister mucosus	Rock Prickleback

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