

Oiled Wildlife Response in California

A Summary of Current Knowledge of
Populations at Risk and Response Techniques

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Table of Contents

CHAPTER 1. INTRODUCTION	1
CHAPTER 2. SPECIES DISTRIBUTION AND ABUNDANCE	3
<i>Statewide Distribution and Abundance Surveys</i>	3
Birds	3
Cetaceans	4
Pinnipeds	5
Southern Sea Otter	6
Sea Turtle	8
<i>Distribution and Abundance Surveys by Geographic Area</i>	9
North Coast	9
San Francisco Bay Area	12
Monterey Bay Area and Central Coast	17
Southern California	19
<i>Distribution and Abundance of Species of Concern</i>	25
California Least Tern (<i>Sterna antillarum browni</i>)	25
Marbled Murrelet (<i>Brachyramphus marmoratus</i>)	26
California Brown Pelican (<i>Pelecanus occidentalis californicus</i>)	26
Elegant Terns (<i>Sterna elegans</i>)	27
Xantus' Murrelet (<i>Synthliboramphus hypoleucus</i>)	27
Ashy Storm-Petrel (<i>Oceanodroma homochroa</i>)	28
California Gulls (<i>Larus californicus</i>)	28
California Clapper Rail (<i>Rallus longirostris obsoletus</i>)	28
California Black Rail (<i>Laterallus jamaicensis coturniculus</i>)	29
Western Snowy Plover (<i>Charadrius alexandrinus nivosus</i>)	29
Aleutian Canada Goose (<i>Branta canadensis leucopareia</i>)	29
White-faced Ibis (<i>Plegadis chihi</i>)	30
Steller Sea Lion (<i>Eumatopius jubatus</i>)	30

CHAPTER 3. SPECIES SENSITIVITY TO PETROLEUM 31

CHAPTER 4. OIL SPILL RESPONSE—INITIAL EFFORTS AND EVENTS 37

Hazing 37
Search and Collection 40
Capture Techniques 41

CHAPTER 5. OIL SPILL RESPONSE—REHABILITATION 43

Detection of Petroleum Products on or in Wildlife 43
 Direct Measures of Petroleum Product Exposure 43
 Indirect Measures of Petroleum Product Exposure 45
Medical Effects of Oil on Marine Wildlife 47
 Review 47
 Effects on the Immune System 49
 Effects on Plumage 49
 Effects on Hematology 50
Additional References on Effects of Oil on Wildlife 50
Rehabilitation 52
 Removing Oil from Fur and Feathers 53
 Anesthesia 53
 Captivity Stress 56
 Diseases and Diagnostics 58
 Special Procedures 58
 Husbandry and Therapeutics 59
Bibliography of Diseases of Marine Wildlife 60
Bibliography of Parasites of Marine Wildlife 74
Bibliography of Normal Blood Values of Marine Wildlife 80

CHAPTER 6. OIL SPILL RESPONSE—POST-RELEASE SURVIVAL 83

***Post-Release Survival Studies* 83**

- Birds 83
- Marine Mammals 84

***Marking and Transmitter Attachment Techniques* 85**

- Birds 85
- Marine Mammals 86
- Sea Turtles 86

***The Effects of Band, Tag, and Transmitter Attachment* 87**

- Birds 87
- Marine Mammals 88

***Bibliography of Topics Relevant to Post-Release Survival Studies* 88**

- Birds 88
- Marine Mammals 91
- Sea Turtles 93

REFERENCES CITED 95

***Cited Personal Communications* 117**

INDEX 119

Introduction

The purpose of this document is to review the current baseline information available for effective oiled wildlife response in California. This includes a review of what is known to date on marine wildlife species distribution and abundance in the state; current techniques for initial response to oil spill events including hazing, searching affected areas, collecting carcasses, and capturing wildlife; detecting petroleum products on feathers, fur or in tissues; sensitivity of species to the toxic effects of petroleum exposure; health status of populations; medical techniques relevant to the care and rehabilitation of oiled wildlife, and techniques for releasing and monitoring rehabilitated wildlife.

The body of literature on these subjects is vast: in the interest of keeping this document to a readable (and therefore useful) length, emphasis has been placed on scientific papers and reports generated by universities, government agencies, industry, or the private sector which elaborate upon established methods, techniques or knowledge. For example, this document does not serve as an overall guide for the clinical care of birds in a rehabilitation setting, but does review the latest

information on evaluating the avian stress response and on the effect of captivity stress on bird health. Similarly, this document does not contain exact counts of wintering waterfowl on coastal lagoons in southern California for the last 10 years, but does contain information on the agencies or institutions involved with monitoring waterfowl populations on those lagoons, how often censuses are conducted, etc. The idea is to put in one place current, cutting-edge information pertinent to oiled wildlife response: it is our hope that Oiled Wildlife Care Network administrators, board members, and rehabilitators will use this document as a resource, enabling us to provide best achievable care for oiled wildlife in California. In addition, this document may be useful as a general reference for oiled wildlife response outside of California, and will be made available through the OWCN website (<http://www.vetmed.ucdavis.edu/OWCN>).

This “living” document will be periodically revised and updated. Contributions from OWCN members and participants, including data, new techniques or methods, or relevant reports or papers, are highly encouraged.

Species Distribution and Abundance

This section summarizes the work that has been or is being done by universities, government agencies, organizations and individuals to assess and/or monitor populations of birds and marine mammals that inhabit the California coastline. The first three sections summarize statewide surveys for birds, cetaceans, pinnipeds, sea otters and sea turtles. Next, the coastline is divided into four geographical regions for the purpose of summarizing distribution data on seabirds, shorebirds, waterfowl, wading birds, and pinnipeds. The section concludes with information regarding several species of concern in the state. Readers are also referred to a review of California coastal areas and wildlife species at risk compiled by the California Department of Fish and Game's Office of Spill Prevention and Response (OSPR, 1993).

Statewide Distribution and Abundance Surveys

Birds

Statewide surveys of seabirds at-sea and on breeding colonies have been conducted by various agencies since the late 1970s. The U.S. Fish and Wildlife Service (USFWS) conducted surveys of all breeding seabirds in the state in the late 1970s (Sowls et al., 1980). The Bureau of Land

Management Minerals Management Service (BLM/MMS) contracted with the University of California to conduct at-sea surveys for several (but not all) seabird species off southern California from 1975-1983 (Briggs et al., 1981; Briggs et al., 1983; Briggs et al., 1987) and off northern California in 1980-1983 (Briggs et al., 1983; Dohl et al., 1983). These surveys were conducted monthly, and are some of the most thorough data obtained to date on seasonal at-sea distribution and abundance for several seabird species. Surveys of all breeding seabirds on-colony in southern California were conducted in 1975-1977 by the University of California under contract to the BLM/MMS (Hunt, 1980). The USFWS and U.S. Geological Survey Biological Resources Division (USGS/BRD) conducted surveys of all breeding seabirds in the entire state during 1989-91 (Carter et al., 1992; Carter et al., 1992a) breeding seasons. Breeding season surveys were by definition seasonal, occurring in the spring/summers.

Common Murre (*Uria aalge*), Brandt's Cormorant (*Phalacrocorax penicillatus*) and Double-crested Cormorant (*Phalacrocorax auritus*) breeding colonies in central and northern California have been surveyed in most years since 1985 (Takekawa et al., 1990).

An intensive survey of shorebirds in all major coastal California wetlands from Morro Bay north was coordinated by Point Reyes Bird Observatory (PRBO) in fall 1988 (Stenzel et al., 1989): These

surveys set the stage for a large-scale effort to census shorebirds of the entire Pacific Flyway, again coordinated by PRBO: annual surveys took place in the fall, winter and spring from 1988-1992, and the entire California coastline was censused (Page et al., 1992). This report tabulates species abundance by geographic location and season. Point Reyes Bird Observatory is continuing annual surveys during at least one season in most of these census areas (Dave Shuford, PRBO, pers. comm.).

The California Department of Parks and Recreation Natural Heritages Section sponsored a comprehensive seasonal survey of wildlife occurring in all coastal California state parks in 1991 (Jaques and Strong, 1996). This survey covered every state beach, park and preserve along the California coast, and the report describes in detail the occurrence of seabirds, shorebirds, waterfowl and wading birds in these areas in all four seasons.

Cetaceans

One of the first systematic in-depth cetacean surveys was conducted by the Minerals Management Service in the Southern California Bight from 1975-78 (Dohl et al., 1978) and off central and northern California in 1980-83 (Dohl, 1983; Dohl et al., 1983). In the Southern California Bight study, aerial surveys were conducted once or twice a month year-round from shore out to 120 NM offshore. Additionally, five boat-based surveys in fall, winter and spring months were conducted during the 3-year study. This report includes maps of species-specific sightings as well as tables presenting abundance by season for each species. In the central and northern California study, aerial surveys were performed once or twice a month from Point Conception north to the Oregon border, from shore out to 100 NM (185 km) offshore. This report includes species abundance by season, a map and list of areas of special importance to cetaceans, and maps illustrating "average cetacean biomass" by season. As of the mid-1980s, these surveys represented the most comprehensive quantitative database assembled on seasonal distribution and abundance of cetaceans in California.

Overall, the agency presently performing most cetacean survey work off the coast of California is the National Marine Fisheries Service, Southwest Fisheries Science Center in La Jolla. NMFS has conducted several cetacean surveys in the Pacific between 1974 and 1985, a few of which included California (Lee, 1993). This report includes maps of the species encountered along various transects. The National Marine Fisheries Service has conducted several surveys of small and large cetaceans in California waters in the last five years, producing several internal reports and scientific publications. Their most comprehensive surveys were conducted in 1991-1992 as part of an effort to assess the impact of gillnet fisheries on marine mammal populations. In March-April 1991 and February-April 1992, NMFS/SWFSC conducted aerial surveys for cetaceans out to 100 NM (185 km) offshore in northern California and 150 NM (278 km) offshore in southern California to estimate winter abundance (Carretta and Forney, 1993; Forney et al., 1995; Forney and Barlow, 1998). The latter report contains detailed maps of species-specific sighting locations for all cetaceans and pinnipeds observed. The 1998 paper discusses differences in species abundance between seasons. Later that year, from July through November, a ship survey along the entire California coast out to 300 NM (555 km) estimated summer/fall cetacean species distribution and abundance (Hill and Barlow, 1992; Barlow, 1995). The 1992 report (Hill and Barlow, 1992) contains detailed maps of species-specific sighting locations of all cetaceans and three pinniped species encountered.

Since then, NMFS/SWFSC censused marine mammals within a portion of the Navy Outer Sea Test Range west of San Nicolas Island via aerial surveys in winter/spring 1993-1994 (Carretta, 1995). This report tabulates species-specific sightings by season, and includes species-specific maps locating all sightings, including pinnipeds. The status of large whales in California waters was updated by NMFS/SWFSC in 1994 (Barlow, 1994). This report notes that all large whale species, all of which are federally listed as endangered with the exception of minke whales (*Balaenoptera acuturostrata*), are seen at least seasonally off California, with the exception of bowhead whales (*Balaena mysticetus*). For each

species, this report reviews population structure, size, growth rates and trends, and gives generalized information on distribution. Species seen in California primarily in winter include right whales (off northern California); species seen in summer / fall include humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus*) and rarely sei (*Balaenoptera borealis*) whales; species seen year-round include fin (*Balaenoptera physalus*), minke and sperm (*Physeter macrocephalus*) whales; and species seen too rarely to estimate seasonal abundance include Bryde's (*Balaenoptera edeni*) and right whales (*Eubalaena glacialis*).

The status of odontocetes (toothed whales, e.g. dolphins, porpoises and small whales) in California was reviewed by NMFS/SWFSC in 1994 (Forney, 1994). This report also reviews population structure, size, growth rates and trends, and distribution of 20 species of odontocetes (excluding harbor porpoises). Harbor porpoise (*Phocoena phocoena*) distribution and abundance in the nearshore waters of the California coast (harbor porpoises range in shallow waters up to the 50 m isobath) from Point Conception north were assessed in aerial surveys performed in the summer / fall of 1986-1991 and in 1993 (Forney, 1995). This paper contains figures detailing harbor porpoise abundance by transect area, and concludes that there has been a decline in the harbor porpoise population in California between 1986 and 1993. These surveys followed up on surveys conducted from 1974-1985 assessing harbor porpoise abundance along the North American west coast, including California (Barlow, 1988; Barlow et al., 1988; Lee, 1993). The abundance of coastal bottlenose dolphins (*Tursiops truncatus*), a distinct population from the bottlenose dolphins that range farther offshore, along the southern California coast was assessed via aerial surveys from 1991-1994, and estimated to be between 240-306 animals (Carretta and Forney, 1998).

While NMFS/SWFSC has been the primary agency involved in cetacean survey work, several other papers and reports by other individuals / institutions on cetacean distribution and abundance have been published in recent years. Surveys for cetaceans out to 80 km offshore from Bodega Bay south to Monterey Bay were con-

ducted in May and June from 1985-1992 (Allen, 1994): the four most abundant species were Dall's porpoises (*Phocoenoides dalli*), Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), harbor porpoises, and Risso's dolphins (*Grampus griseus*). This document contains density and distribution maps for all cetacean species in this area. California gray whale (*Eschrichtius robustus*) population size and distribution during fall and spring migrations to and from calving grounds in Baja in 1979-1980 and 1984-1988 has been estimated (Buckland et al., 1993). Point Reyes National Seashore (PRNS) has logged cetacean sightings for over 20 years from the Point Reyes lighthouse (Sarah Allen, PRNS, pers. comm.); while sighting efforts have not been entirely consistent and systematic with regards to sighting methods, these records do represent thousands of hours of observation of a section of the coastline past which whales migrate quite close to shore and are therefore easily observed and identified. PRNS is planning on collating this data into report-form in the near future. Similarly, several years of line transect data on the distribution and abundance of harbor porpoises off the northern California coast have been collected but not yet collated (Jeffrey Jacobsen, Humboldt State University, pers. comm.)

Finally, The Gulf of the Farallones National Marine Sanctuary initiated a Beach Watch program in 1993. This program surveys 86 pre-defined sections of the coastline (approx 241 km total) from Bodega Head to the San Mateo/Santa Cruz County border once or twice monthly year-round (Roletto et al., 1998). Trained volunteers survey beaches for live and dead birds and marine mammals, including cetaceans, and pay particular attention to the presence of oiled organisms and tar balls. A report is produced annually which tallies the counts of live vs. dead marine wildlife and the incidence of oiled wildlife, and tabulates encounter rates for selected taxa by season.

Pinnipeds

While geographic-specific data on pinniped distribution and abundance are outlined in the next section, it is worth reviewing here both statewide population estimates for various

species, as well as at-sea surveys for pinnipeds. The most recent systematic in-depth marine mammal surveys of the California coast, which included surveys of pinnipeds, were conducted by the Minerals Management Service in the Southern California Bight from 1975-78 (Bonnell et al., 1978) and off central and northern California in 1980-83 (Bonnell et al., 1983). In the southern California study, pinnipeds on land and at sea were censused annually from both air and water. This report contains extensive sections on the distribution and abundance of each species, including maps and tables. In the central and northern California study, aerial surveys were performed once or twice a month from Point Conception north to the Oregon border, from shore out to 100 NM (185 km) offshore. This report includes a map of major haul-out sites for pinnipeds in California, maps depicting pinniped distribution by season, and tables presenting at-sea and on-land counts of pinniped species by season and geographical location.

Recent estimates for population sizes and trends in abundance of pinniped species in California include approximately 525 Steller sea lions (*Eumatopius jubatus*) (extrapolated from early 1990s counts, and given a 10 percent rate of decline on Año Nuevo Island) (Stewart, 1997), 32,000 harbor seals (*Phoca vitulina*) (Brown et al. 1997), 84,000 northern elephant seals (*Mirounga angustirostris*), with an estimated 74.8 percent of all births of northern elephant seals in the world occurring in California (Stewart et al., 1994) and 10,000 northern fur seals (*Callorhinus ursinus*) (Stewart, 1997). The total population of California sea lions (*Zalophus californianus*), estimated from counts made by the California Department of Fish and Game in July and September 1995, is 14,300 (Brown et al. 1997). Northern fur seals, California sea lions, harbor seals and northern elephant seal populations are all on the rise, whereas Steller sea lion populations are on the decline, and few Guadalupe fur seals (*Arctocephalus townsendi*) are seen in California.

As of 1997, there were approximately 32,000 Pacific harbor seals in California (Brown et al. 1997) with at least 860 documented haul-out sites on the California mainland, exclusive of the Channel Islands. Probably the most comprehensive census work on Pacific harbor seals in Cali-

fornia was conducted from 1983 to 1995 (Hanan, 1996). These were aerial surveys conducted during the molting period when harbor seals are at their peak onshore abundance. They included a five-year tagging study in southern California to allow for estimation of what portion of the population was actually observed during the aerial surveys. Several annual reports of this survey work were produced, (e.g. Hanan and Beeson, 1994), but collated in 1996 (Hanan, 1996). The California Department of Fish and Game continues to periodically census Pacific harbor seals in California, with the next survey scheduled for winter/spring 1999 (Kim McKee-Lewis, CDFG, pers. comm).

In 1998, the National Marine Fisheries Service/Southwest Fisheries Science Center started conducting seasonal aerial surveys of California sea lions on-colony and at-sea from Point Conception north to the Oregon border (Mark Lowry, NMFS/SWFSC, La Jolla, CA, pers. comm).

Southern Sea Otter

The Southern sea otter (*Enhydra lutris nereis*) was federally listed as threatened under the Endangered Species Act in 1977 due to the small size of the population and the perceived threats of human disturbance, fisheries interactions and pollution to the viability of the population. The history of the distribution and abundance of the southern sea otter was reviewed in 1990 (Riedman and Estes, 1990). In summary, prior to the commencement of the fur trade in the mid-18th century, the sea otter population in California was believed to number approximately 16,000–20,000 animals. By the time sea otter hunting was banned in 1911 under the International Fur Seal Treaty, only 9 remnant populations of sea otters remained worldwide, one of those occurring in California off Big Sur. This population was estimated to consist of only 50 animals as of 1914. With the exception of this California population, the sea otter has become extinct along the Pacific coast of North America from south of Prince William Sound, Alaska to Baja, California.

The California Department of Fish and Game (CDFG) conducted aerial surveys of the southern sea otter population from 1958 to 1979 (Riedman and Estes, 1990). Summaries of surveys conducted

by the CDFG from 1977 to 1983 and by the USGS/BRD between 1982 and 1990 have been produced (Wendell et al., 1986; Riedman and Estes, 1990). The Minerals Management Service conducted surveys off central and northern California in 1980-83, which included sea otter censusing (Dohl et al. 1983). In this study, aerial surveys were performed once or twice a month from Point Conception north to the Oregon border, from shore out to 100 NM (185 km) offshore. This report includes a map detailing sea otter abundance by sector of coastline from Año Nuevo south to Point Sal in June 1983.

Presently, the U.S. Geologic Survey/Biological Resources Division (USGS/BRD) is the primary agency charged with monitoring the southern sea otter population, and a report that reviews the last ten years of USGS/BRD southern sea otter surveys in California is in preparation and due to be completed in 1999 (Brian Hatfield, pers. comm.). The USGS conducts two surveys annually, once in spring (May) and once in fall (late October/early November) using ground-based and aerial techniques, and summarizes the survey results in internal memorandums. Sea otter survey methods have been tested and validated by various agencies (Geibel and Miller, 1984; Estes and Jameson, 1988; Udevitz et al., 1995).

In May 1998, there were approximately 2100 southern sea otters in California, ranging from Pigeon Point in the north to Government Point (just east of Point Conception) in the south (Brian Hatfield, pers. comm.). The Government Point group represents an extension of the southern limits of the sea otter's range, despite the fact that the southern sea otter population has been declining at a rate of approximately 5 percent a year since 1995, and pup mortality in 1998 was very high (thought to be due to extreme weather related to the El Niño/Southern Oscillation event). The California sea otter population has never expanded at as great a rate as other sea otter populations along the Pacific coast: as of 1990, the California sea otter population was expanding at 4-5 percent annually, whereas northern sea otter populations in Alaska were growing at 17-20 percent per year. There has been no significant increase in population size since the mid-1970s (Estes et al., 1995). The pattern of sea

otter range expansion in California as well as the demographic variables (emigration rates, birth rates, mortality rates) and ecological characteristics affecting population dynamics of the California sea otter population have been evaluated, modeled, and debated (Hines and Pearse, 1982; Lubina and Levin, 1988; Estes, 1990a; Garshelis et al., 1990; Riedman and Estes, 1990; Wendell, 1994; Eberhardt, 1995).

In California, sea otters typically occupy coastal waters along the 5-fathom (9 m) isobath, although they are also often seen far offshore and will cross large expanses of open deep water (e.g. from the Channel Islands to the mainland). Several studies have described activity and foraging patterns and habitat use of California sea otters (Benech, 1979; Loughlin, 1980; Ribic, 1982; Ribic, 1982a; Estes et al., 1986; Wendell et al., 1986; Jameson, 1989; Ralls and Siniff, 1990; Ralls et al., 1995).

Individual southern sea otters are occasionally seen beyond the normal limits of their range: the Gulf of the Farallones National Marine Sanctuary Beach Watch program has documented sightings of sea otters in Drake's Bay and Half Moon Bay (Roletto et al., 1998), and otters have been seen as far north as Cape Mendocino (Bonnell et al., 1983) and as far south as central Baja (Leatherwood et al., 1978; Rodriguez Jaramillo and Gendron, 1996; Gallo Reynoso and Rathbun, 1997). These are considered incidental sightings of far-ranging individuals, and are not considered to represent the normal range of the southern sea otter at this time.

In an effort to re-establish a sea otter population in the Channel Islands, the USFWS translocated a total of 112 otters over a 3-year period in the late 1980s to San Nicolas Island. This effort proved unsuccessful because most animals either returned to the mainland (some to their exact location of capture) or disappeared (Estes, 1990). Efforts to re-establish populations of northern sea otters in Alaska, British Columbia, Washington and Oregon in the 1950-1970s were similarly problematic and essentially unsuccessful (Jameson et al., 1982).

Recent population genetics studies of sea otters have confirmed three subspecies of sea otter in the Pacific and have documented genetic

differences between subspecies and geographically separate populations (Cronin et al., 1996; Lidicker and McCollum, 1997). Both papers confirm that genetic variation of the southern sea otter did not suffer as a result of the population bottleneck that occurred in the early 20th century.

Sea Turtle

All sea turtles known to occur in California are federally listed as either endangered (leatherbacks: *Dermochelys coriacea*) or threatened (greens, *Chelonia mydas*; loggerheads, *Caretta caretta*; olive ridleys, *Lepidochelys olivacea*). To date, there have not been any systematic surveys of sea turtles off the coast of California; the National Marine Fisheries Service/Southwest Fisheries Science Center is in the early stages of establishing a sea turtle censusing program, and is planning to conduct aerial surveys for sea turtles off the coast of California in 1999, concentrating on Monterey and San Francisco Bays (Peter Dutton, NMFS/SWFSC, pers. comm.).

Green sea turtles migrate annually to San Diego Bay to an area at the southern end where an electrical power plant discharges warm water effluent (Stinson, 1984); this is the only resident population of sea turtles on the North American west coast. Turtles arrive in November, stay through April, and are absent from the bay from May to October. As of 1979, this population consisted of approximately 25-30 individuals. Green sea turtles have also been reported in warm-water effluents elsewhere in California (e.g. at the San Gabriel River in Los Angeles, San Onofre nuclear power plant). NMFS continues to monitor green sea turtles in San Diego Bay (Peter Dutton, pers. comm.), and also monitors accidental take of sea turtles in the California gill net and drift net fisheries. Currently, several agencies (e.g. USFWS, U.S. Navy) are involved in developing a San Diego Bay Integrated Natural Resources Management Plan, which has involved studies of green sea turtles (Mitch Perdue, U.S. Navy, pers. comm.)

Sea turtles inhabit tropical and subtropical waters around the world. By far the most common species off California, and the reptile with the largest range of any reptile in the world, is the

leatherback, the only “soft-shelled” sea turtle, and largest of the sea turtle species (Dutton and Eckert, 1994a). Other “hard-shell” species do occur in California, e.g. the green, olive ridley and loggerhead sea turtles, but these species very rarely range north of the Southern California Bight, and occur there only when sea surface temperatures rise above 15 degrees C, usually in the summer (Dutton and Eckert, 1994; Dutton and Eckert, 1994b; Dutton and Eckert, 1994c).

To determine the geographic distribution and frequency of sightings of sea turtles in the north-eastern Pacific, brochures were distributed to fisherman along the western coast of North America every year from 1977 to 1981, requesting that they relay any information regarding sightings, strandings or captures of sea turtles (Stinson, 1984). This survey, while not systematic, and subject to observer-related bias in terms of season and geographical area covered, does serve as some of the first recent data regarding the occurrence of sea turtles off California. This study reported that over half of the 363 sightings reported from northern Baja to the Gulf of Alaska were made south of Pt. Conception, and approximately 15 percent of the sightings were made from central and northern California. Most sightings were made during summer months when sea surface temperatures were highest (>13 degrees C), but turtles were also present in the north during winter months in El Niño/Southern Oscillation years, and year-round in southern California south of Pt. Conception, where sea surface temperatures stay above 13 degrees C. In general, most turtles were sighted in water no deeper than 100 m, though the study makes no attempt to determine whether this observation was affected by observer-related bias (e.g. most fisherman staying within the 100 m isobath for fishery-related reasons). Leatherbacks were by far the most commonly encountered species, with greens, loggerheads, and olive ridley turtles also recorded. This study found a significant correlation between the presence of sea turtles in north-eastern Pacific waters and the occurrence of El Niño/Southern Oscillation events.

A green sea turtle and an olive ridley turtle have been caught or have stranded in Humboldt County (Smith and Houck, 1984). NMFS/SWFSC has recorded incidental sightings of sea turtles

while conducting aerial and boat surveys for marine mammals in California in the last decade (Carretta and Forney, 1993; Karin Forney, NMFS/SWFSC, pers. comm): most sightings have been of leatherbacks, but other sea turtle species (often unidentified) have been recorded. In the Minerals Management Service's three-year survey (aerial and boat) of seabirds and marine mammals off central and northern California from 1980-1983, there were 29 sightings of leatherback sea turtles (Dohl, 1983). Most turtles were seen from 5-100 NM offshore, in the 1000 m isobath, and almost 90 percent of sightings occurred in late summer/early autumn, during periods of maximum seawater temperature. Incidental sightings of leatherbacks (n=96) within 50 km of Monterey Bay by recreational fishing boat skippers between 1986 and 1991 were summarized (Starbird et al., 1993): this paper determined that the greatest density of leatherbacks occurs in August, when sea surface temperatures are at their highest, and no turtles were sighted in winter months (Dec-Feb). This paper also recorded sightings of two olive ridleys and one green sea turtle. Between January 1991 and December 1994, seven stranded leatherbacks were reported from central California, including an adult female found dead on a beach in Half Moon Bay in February 1992, and an adult female found dead on a beach in Bolinas in August 1993 (both turtles were presumably killed by sharks) (Long, 1996). Leatherback, loggerhead and green sea turtles were observed entangled in set- and drift-nets off California between July 1990 and December 1995 (Julian and Beeson, 1998).

Distribution and Abundance Surveys by Geographic Area

North Coast—From the Oregon Border to North of Bodega Bay

Seabirds

Seabird monitoring at Castle Rock National Wildlife Refuge began in spring/summer 1997 (Jaques and Strong, 1998). Castle Rock NWR is the second largest seabird breeding colony in California, and supports the largest breeding colonies of

Common Murres, Rhinoceros Auklets (*Cerorhinca monocerata*), and Tufted Puffins (*Fratercula cirrhata*) in California. Significant findings during this survey were relatively low numbers of Common Murres, a near-absence of Tufted Puffins, and the establishment of a new Double-crested Cormorant (*Phalacrocorax auritus*) breeding colony. Monitoring of Castle Rock NWR occurs intermittently in the fall and winter.

All Common Murre, Brandt's Cormorant (*Phalacrocorax penicillatus*) and Double-crested Cormorant breeding colonies in central and northern California, including Castle Rock, have been surveyed in most years since 1985 (Carter, et al., 1995a; Carter et al., 1996; Takekawa et al., 1990). Data regarding Double-crested Cormorant breeding populations from Humboldt Bay north to the Oregon border, and from the Russian River south to Tomales Bay were tallied from all available data up to 1991 (Carter et al., 1995). Breeding colonies of Common Murres, Brandt's Cormorants and Double-crested cormorants along this section of the northern California coast were aerially surveyed in 1993-1995 as part of a state-wide annual survey of these species (Carter et al., 1996).

Humboldt Bay was surveyed between July 1987 and June 1988 (Nelson, 1989): all waterbirds were censused, including seabirds, and counts were correlated with season and geographic distribution in the bay. A U.S. Fish and Wildlife Service report published in 1992 collated species accounts for Humboldt Bay from information compiled for a U.S. Army Corps of Engineers report completed in 1980, as well as from work conducted by Humboldt State University's Department of Wildlife (Barnhart et al., 1992). This report lists several seabirds and comments on abundance by season and habitat preferences within the bay.

The California Department of Parks and Recreation Natural Heritages Section sponsored a comprehensive seasonal survey of wildlife occurring in all coastal California state parks in 1991 (Jaques and Strong, 1996). This survey covered 20 different state beaches, parks and preserves along the northern California coast, including Lakes Earl and Talawa, Prairie Creek Redwoods State Park, and Salt Point State Park. The report de-

scribes in detail the occurrence of seabirds in these areas in all four seasons.

Shorebirds

Currently, the California Department of Fish and Game (CDFG) conducts monthly aerial surveys of the northern California coast from the Eel River delta north to the Oregon Border, including Humboldt Bay, censusing primarily waterfowl, but also easily identifiable shorebirds (Herb Pierce, CDFG, pers. comm).

Shorebird surveys conducted by Point Reyes Bird Observatory have included Lakes Talawa and Earl, Point St. George, Crescent City Harbor, Humboldt Bay, Bodega Bay, Sea Ranch and Estero Americano, as well as the mouths of the Smith, Eel, Mattole, Garcia, and Gualala Rivers, and Pudding Creek. Point Reyes Bird Observatory is continuing annual surveys during at least one season in most of these census areas (Dave Shuford, PRBO, pers. comm.).

Humboldt Bay is an important overwintering and stopover site for shorebirds migrating along the Pacific Flyway. In addition to the aforementioned surveys, Humboldt Bay was systematically censused in 1989–1991 in the fall, early winter, late winter and in spring (Colwell, 1994). This survey showed that Humboldt Bay supports approximately 10,000–100,000 shorebirds comprising 19–24 species at any one time during spring and fall migrations and during overwintering. South Humboldt Bay was surveyed between July 1987 and June 1988 (Nelson, 1989): all waterbirds, including shorebirds, were censused and counts were correlated with season and geographic distribution in the bay. Day versus night use of North Humboldt Bay by shorebirds was assessed by season from January 1992–January 1993 (Dodd and Colwell, 1996; Dodd and Colwell, 1998). These studies showed that occurrence and abundance of nonbreeding shorebirds varied considerably between day and night, and while they found that shorebirds foraged primarily during the day, nocturnal foraging predominated during the fall migration. Humboldt Bay represents the northernmost wintering site for the American Avocet (*Recurvirostra americana*), and this species was censused during the winters of 1982–1985 (Evans and Harris, 1994).

The California Department of Parks and Recreation Natural Heritages Section surveys in 1991 (Jaques and Strong, 1996) included Lakes Earl and Talawa, Prairie Creek Redwoods State Park, and Salt Point State Park.

A U.S. Fish and Wildlife Service report published in 1992 collated species accounts for Humboldt Bay from information compiled for a U.S. Army Corps of Engineers report completed in 1980, as well as from work conducted by Humboldt State University's Department of Wildlife (Barnhart et al., 1992). This report lists several shorebird species and comments on abundance by season and habitat preferences within the bay.

Waterfowl and Wading Birds

Currently, the CDFG conducts monthly aerial surveys of the northern California coast from the Eel River delta north to the Oregon Border, including Humboldt Bay, censusing primarily waterfowl, but also wading bird species (Herb Pierce, CDFG, pers. comm). The impetus for conducting the surveys has been primarily to monitor Brant (*Branta bernicia*): Humboldt Bay is the most important location in California for Brant, especially as a spring staging area (Nelson, 1989).

Humboldt Bay was surveyed between July 1987 and June 1988 (Nelson, 1989): all waterbirds, including waterfowl and wading birds, were censused and counts were correlated with season. A U.S. Fish and Wildlife Service report published in 1992 compiled species accounts for Humboldt Bay from information compiled for a U.S. Army Corps of Engineers report completed in 1980, as well as from work conducted by Humboldt State University's Department of Wildlife Bay (Barnhart et al., 1992). This report lists several waterfowl and wading bird species and comments on abundance by season and habitat preferences within the bay.

The California Department of Parks and Recreation Natural Heritages Section sponsored a comprehensive seasonal survey of wildlife occurring in all coastal California state parks in 1991 (Jaques and Strong, 1996). This survey covered 20 different state beaches, parks and preserves along the northern California coast, including Lakes

Earl and Talawa, Prairie Creek Redwoods State Park, and Salt Point State Park, and describes in detail the occurrence of waterfowl and wading birds in these areas in all four seasons.

Large numbers of migrating Aleutian Canada Geese (*Branta canadensis leucopareia*) have been observed using Castle Rock NWR as a night roost (Jaques and Strong, 1998).

The CDFG periodically censuses the heron/egret colony on Indian Island in Humboldt Bay, which is believed to be the largest heron/egret colony in California (Herb Pierce, CDFG, pers. comm). There are other known heron and egret colonies in this region, including one on the Lower Eel River delta, but they are not presently being monitored (John Kelly, Audubon Canyon Ranch, pers. comm.)

The survey of shorebirds in all major coastal California wetlands from Morro Bay north conducted in Fall 1988 (Stenzel et al., 1989) also counted bitterns, herons and egrets in Humboldt Bay, but not in Del Norte County.

Pinnipeds

Currently, there are no large-scale, systematic, centrally-coordinated surveys being performed for all pinniped species on the northern California coast (Joe Lesh, CDFG, pers. comm.). What is known about pinniped distribution and abundance along the northern California coast is primarily from past surveys, supplemented by on-going, more species-specific surveys and observations.

Recent (i.e. since 1980) large-scale surveys for pinnipeds in this region include monthly surveys of marine mammals, including pinnipeds, along the central and northern California coast from 1980-1983 (Dohl et al., 1983). This survey identified several major hauling grounds for pinnipeds in this region. For example Southwest Seal Rock supports a breeding population of Steller sea lions (*Eumatopius jubatus*). Castle Rock supports California sea lions (*Zalophus californianus*), Pacific harbor seals (*Phoca vitulina richardsii*), and northern elephant seals (*Mirounga angustirostris*). Trinidad Rocks is a haul-out site for California sea lions and Steller sea lions. Over 1000 harbor seals haul out on the mudflats of Humboldt Bay and at the mouth of the Eel River. Sugarloaf Rock at

Cape Mendocino is the second-largest Steller sea lion rookery in California with a population of about 1000 animals. One of the largest contiguous harbor seal pupping and hauling grounds in California occurs at Mistake Point (halfway between Cape Mendocino and Fort Bragg). California sea lions also haul out at Mistake Point.

The California Department of Parks and Recreation Natural Heritages Section sponsored a comprehensive seasonal survey of wildlife occurring in all coastal California state parks in 1991 (Jaques and Strong, 1996). This survey covered 20 different state beaches, parks and preserves along the northern California coast, and describes in detail the occurrence of pinnipeds in these areas in all four seasons.

The National Marine Fisheries Service/Southwest Fisheries Science Center is currently conducting seasonal surveys of California sea lions on colony and at-sea from Point Conception north to the Oregon border (Mark Lowry, NMFS/SWFSC, La Jolla, CA, pers. comm).

The northern California region is estimated to support approximately 7300 harbor seals (Brown et al., 1997). Probably the most comprehensive census work on Pacific harbor seals in California was conducted from 1983 to 1995 (Hanan, 1996). These were aerial surveys conducted during the moulting period (when harbor seals are at their peak onshore abundance). Several annual reports of this survey work were produced; e.g. Hanan and Beeson, 1994; Hanan, 1996. The California Department of Fish and Game continues to periodically census Pacific harbor seals in California, with the next survey scheduled for winter/spring 1999 (Kim McKee-Lewis, CDFG, pers. comm).

There are Steller sea lion rookeries at Cape Mendocino/Sugarloaf and at St. George Reef (National Marine Fisheries Service, 1992). Between 1990-1995, average counts of Steller sea lions at St. George Reef numbered 400-700 animals. The National Marine Fisheries Service coordinates Steller sea lion monitoring for the entire United States west coast.

Northern elephant seals are known to haul-out on Castle Rock NWR; a report about the recent use of Castle Rock NWR by northern elephant seals is in preparation (D. Jaques, Cres-

cent Coastal Research, pers. comm.). A few elephant seal pups have been born at Point St. George (Bonnell et al., 1983).

Sightings of free-ranging and stranded Guadalupe fur seals (*Arctocephalus townsendi*) between 1988-1995 have been summarized (Hanni et al., 1997): one stranded animal was recovered at Blind Beach in Sonoma County in July 1988.

San Francisco Bay Area—From Bodega Bay south to Pigeon Point, including Point Reyes, Gulf of the Farallones, and San Francisco Bay

Seabirds

The Farallon Islands is the site of one of the largest seabird colonies on the North American west coast. The Farallones support a breeding assemblage of 11 different species comprising hundreds of thousands of seabirds year-round, and support some of the largest breeding populations in the world of Ashy Storm-Petrels (*Oceanodroma homochroa*), Brandt's Cormorants (*Phalacrocorax penicillatus*) and Western Gulls (*Larus occidentalis*). A permanent field station is staffed by Point Reyes Bird Observatory (PRBO) through a cooperative agreement with and funding from the U.S. Fish and Wildlife Service. As a result, intensive year-round monitoring of the seabird populations on these islands has been conducted since 1971. Work from 1972-1983 was summarized (Ainley and Boekelheide, 1990) and partially updated in 1994 (Ainley et al., 1994). In addition to continual monitoring of species distribution and abundance on the islands year-round, many specific studies and censuses have been and are conducted, e.g. oiled bird surveys conducted daily on Southeast Farallon Island since 1977 (Nur et al., 1997), Common Murre (*Uria aalge*) survivorship studied from 1985-1991 (Sydeman, 1993), Common Murre population trends studied for 1985-1995 (Sydeman et al., 1997), and Western Gull dispersal patterns documented in 1978-1981 (Spear, 1988).

At-sea surveys for foraging seabirds out to 80 km offshore from Bodega Bay south to Monterey Bay were conducted in May and June from 1985-1992 (Allen, 1994). This document contains density and distribution maps for seabirds species observed frequently, as well as maps of sightings

of seabird species seen too rarely to generate density estimates.

The California Department of Parks and Recreation Natural Heritages Section survey (Jaques and Strong, 1996) covered 9 different state beaches, parks and preserves in the San Francisco Bay region, including Tomales Bay State Park and Pescadero Marsh Nature Preserve and State Beach, but excluding San Francisco Bay proper.

The coincidence of Common Murre foraging areas with shipping lanes between Pt. Reyes and Año Nuevo was studied from 1985-1994 (Ainley and Allen, 1997): it was determined that probably the entire adult Common Murre population in this area forages in shipping lanes in this region during the summer, and Common Murres are abundant in the heavily-trafficked shipping lane through the Golden Gate.

Foraging distribution of Cassin's Auklets (*Ptychoramphus aleuticus*) in the Gulf of the Farallones in relation to oceanographic events was studied via boat survey in 1985 (Briggs et al., 1988). This paper includes maps of at-sea distribution of Cassin's Auklets.

Data regarding the breeding success of Double-crested Cormorants (*Phalacrocorax auritus*) residing year-round in San Francisco Bay was studied in 1988-90 (Stenzel et al., 1995). Population trends of Brandt's Cormorants at Point Reyes Headlands were reviewed from 1979-1997 (McChesney et al., 1998a).

Point Reyes Bird Observatory conducted extensive waterbird surveys of all the large bodies of water in the Point Reyes area (Bollinas Lagoon, Limantour Estero, Abbott's Lagoon, Drake's Estero, Bodega Harbor, and the nearshore coastal waters between Stinson Beach and the Point Reyes lighthouse) seasonally between 1971 and 1982 (Shuford et al., 1989) and annually after that until 1993, and will resume these surveys this year (Lynn Stenzel, pers. comm.). The 1989 paper provides species accounts for approximately 31 seabird species. For all species, tables are presented which depict abundance by season.

The San Francisco Estuary Institute (SFEI) has gathered data from multiple agencies/groups working in the San Francisco Bay Area to create a GIS-based "EcoAtlas" which, among other things,

maps avian species and distribution in the bay (Josh Collins, pers. comm).

The San Francisco Bay Bird Observatory (SFBBO) monitors several seabird species in the South Bay during the breeding season, including Forster's (*Sterna forsteri*) and Caspian Terns (*Sterna caspia*), California (*Larus californicus*) and Western Gulls, and Double-crested Cormorants (Tom Ryan, pers. comm.). They have color-banded a portion of the California Gull population, and are also monitoring the California Gull colony at NAS Alameda.

Audubon Canyon Ranch recently reported the results of winter surveys for several waterbird species using Tomales Bay in the winters of 1989-1996 (Kelly and Tappen, 1998). These latter surveys did not census gulls due to the difficulty of detecting gulls on extensive tidal mudflats from survey boats on the water, but did survey all other seabird species occurring there (e.g. loons, grebes, pelicans, cormorants, scoters, terns, coots). Audubon Canyon Ranch continues to monitor wintering waterbirds on Tomales Bay (John Kelly, pers. comm.)

Western Gulls, Brandt's and Pelagic Cormorants (*Phalacrocorax pelagicus*), Pigeon Guillemots (*Cepphus columba*) and a pair of Black Oystercatchers (*Haematopus bachmani*) breeding on Alcatraz Island in the San Francisco Bay are censused and monitored by the Golden Gate National Recreation Area (Daphne Hatch, pers. comm.). This is the second largest breeding colony of Western Gulls in northern California. Point Reyes Bird Observatory monitors Brandt's Cormorants, Oystercatchers and Pigeon Guillemots breeding on Alcatraz Island (Julie Thayer, PRBO, pers. comm.).

Restoration of a historic Common Murre colony on Devil's Slide Rock was initiated in 1996, and as of 1997, breeding pairs had returned for a second year of egg-laying and chick-rearing on the colony (Parker et al. 1998). This project also monitors Common Murres, Brandt's Cormorants and other species.

The Gulf of the Farallones National Marine Sanctuary initiated a Beach Watch program in 1993. This program surveys 86 pre-defined sections of the coastline (approx 241 km total)

year-round from Bodega Head to the San Mateo/Santa Cruz border once or twice monthly (Roletto et al., 1998). Trained volunteers survey beaches for live and dead birds (most commonly seabirds, shorebirds, or waterfowl) and marine mammals, and pay particular attention to the presence of oiled organisms and tar balls. A report is produced annually which tallies the counts of live vs. dead marine wildlife and the incidence of oiled wildlife, and tabulates encounter rates for selected taxa by season.

The remaining three California Least Tern (*Sterna antillarum*) breeding sites in northern California (NAS Alameda, Oakland Airport and PG&E Pittsburg) are monitored closely by the California Department of Fish and Game (Ron Jurek, CDFG, Sacramento, pers. comm).

Shorebirds

Shorebirds are highly migratory, and for the most part are present in California wetlands, bays and on shorelines during the late fall, winter and early spring. The Point Reyes Bird Observatory (PRBO) and the U. S. Fish and Wildlife Service (USFWS) have been the primary organizations/agencies monitoring migrating and wintering shorebirds in the San Francisco Bay area. Point Reyes Bird Observatory has coordinated the large-scale effort to census shorebirds of the entire Pacific Flyway. Annual surveys have been conducted in the fall, winter and spring of 1988-1992 (Stenzel et al., 1989; Page et al., 1992), and censused areas in the San Francisco Bay region included Tomales Bay, Abbotts Lagoon, Drakes Estero, Limantour Estero, Bolinas Lagoon, Bolinas Sewage Ponds, and San Francisco Bay. This survey effort is by far the most comprehensive of its kind for California, and the report tabulates species abundance by geographic location and season. Point Reyes Bird Observatory is continuing annual surveys during at least one season in most of these census areas.

Point Reyes Bird Observatory has also conducted extensive waterbird surveys of several of the large bodies of water in the Point Reyes area (Bolinas Lagoon, Limantour Estero, Abbott's Lagoon, Drake's Estero, Bodega Harbor, and the nearshore coastal waters between Stinson Beach and the Point Reyes lighthouse) seasonally

between 1971 and 1982 (Shuford et al., 1989) and annually after that until 1993, and will resume these surveys this year (Lynn Stenzel, PRBO, pers. comm.). The 1989 paper provides species accounts for approximately 35 shorebird species. For all species, tables are presented which depict abundance by season.

Audubon Canyon Ranch monitors waterbirds in Tomales Bay: they have reported on fall, winter and spring shorebird surveys for 1992-1993 (Kelly, 1993), and more recently reported on results of winter surveys for several waterbird species using Tomales Bay in the winters of 1989-1996 (Kelly and Tappen, 1998). These surveys do not census sandpipers and plovers, due to the difficulty of detecting these species on extensive tidal mudflats from survey boats on the water. However, they do census phalaropes. Audubon Canyon Ranch continues to conduct these wintering waterbird surveys annually (John Kelly, pers. comm.).

Tor many years, the University of California's Bodega Bay Marine Laboratory has conducted mid-winter shorebird surveys in Bodega Bay (Peter Connors, Bodega Bay Marine Laboratory, pers. comm.). This data has been collated at various times for larger studies/reports, but primarily exists as raw data at this time.

The California Department of Parks and Recreation Natural Heritages Section survey covered 9 different state beaches, parks and preserves in the San Francisco Bay region, including Tomales Bay State Park and Pescadero Marsh Nature Preserve and State Beach, but excluding San Francisco Bay proper (Jaques and Strong, 1996). It describes in detail the seasonal occurrence of shorebirds in these areas.

The San Francisco Bay estuary contains 90 percent of the remaining coastal wetlands in California, and is therefore of extreme importance to wintering and migrating shorebirds. The Pacific Flyway project has identified it as one of the key stopover points for migrating shorebirds on the western coast of North America, and the most populated, with up to 1,000,000 shorebirds visiting annually. The first comprehensive census of San Francisco Bay was conducted in April 1988 by PRBO (Page et al., 1992) followed by a September 1988 census (Stenzel et al., 1989) of San Francisco Bay and several other major wetlands in central

and northern California. In addition to the large-scale censuses coordinated by PRBO and the USFWS, several shorebird ecology studies have been conducted in this region, the reports of which provide species-specific data on distribution and habitat use (Warnock et al., 1995; Warnock and Takekawa, 1995; Iverson et al., 1996; Kelly et al., 1996; Warnock and Takekawa, 1996; Warnock et al., 1997).

The San Francisco Bay Bird Observatory (SFBBO) monitors several species in the south bay during the breeding season, including Snowy Plovers (*Charadrius alexandrinus*), Avocets (*Recurvirostra americana*), Killdeer (*Charadrius vociferus*) and Black-necked Stilts (*Himantopus mexicanus*) (Tom Ryan, pers. comm.).

Waterfowl and Wading Birds

San Francisco Bay has been identified as one of the nation's 34 waterfowl "habitats of major concern". The USFWS estimates that approximately 425,000 individual waterfowl comprising 32 species spend winter on the bay. It has been identified as one of the most important wintering areas for the Pacific Flyway's population of Canvasbacks (*Aythya valisineria*), and in fact San Pablo Bay NWR was established specifically for Canvasback protection and management. San Francisco Bay on the whole is not considered a significant breeding area for waterfowl, as waterfowl populations are low in the spring and summer months, with the exception of small numbers of dabbling and Ruddy Ducks (*Oxyura jamaicensis*) and Canada Geese (*Branta canadensis*). Suisun Marsh bordering Suisun Bay harbors greater numbers of breeding waterfowl in the spring/summer.

Waterfowl surveys in San Francisco Bay are conducted on an annual or semi-annual basis by several agencies and organizations. The USFWS coordinates a bay-wide survey every year in January as part of the Pacific Flyway program (Greg Menzik, USFWS, pers. comm.). USFWS mid-winter counts of waterfowl in 1988-1990 were summarized and analyzed (Accurso, 1992). The CDFG conducts monthly waterfowl surveys from September to January in Suisun Marsh and a bird count in December (coordinated by the Audubon Society). (Dennis Becker, CDFG, pers. comm.).

The San Francisco Estuary Institute has collated much of the existing data on waterfowl censuses in San Francisco Bay (Josh Collins, SFEI, pers. comm.) .

The first nesting of Black Skimmers (*Rhynchops niger*) in southern San Francisco Bay was recorded in 1994 (Layne et al., 1996): this species had been observed in south San Francisco Bay previously, but until 1994 had never been recorded breeding north of Tulare Basin (an inland site). Another pair (presumably the 1994 pair) bred again in southern San Francisco Bay in 1995.

PRBO conducted extensive waterbird surveys of several of the large bodies of water in the Point Reyes area (Bolinás Lagoon, Limantour Estero, Abbott's Lagoon, Drake's Estero, Bodega Harbor, and the nearshore coastal waters between Stinson Beach and the Point Reyes lighthouse) seasonally between 1971 and 1982 and annually after that until 1993 (Shuford et al., 1989), and will resume these surveys this year (Lynn Stenzel, pers. comm). The 1989 paper provides species accounts for approximately 35 waterfowl and 12 wading bird species. For all species, tables are presented which depict abundance by season.

Audubon Canyon Ranch recently reported on results of winter surveys for several waterbird species using Tomales Bay in the winters of 1989-1996, including over 25 species of waterfowl (Kelly and Tappen, 1998). Audubon Canyon Ranch continues to monitor wintering waterbirds on Tomales Bay (John Kelly, pers. comm.).

The California Department of Parks and Recreation Natural Heritages Section survey covered 9 different state beaches, parks and preserves in the San Francisco Bay region, including Tomales Bay State Park and Pescadero Marsh Nature Preserve and State Beach, but excluding San Francisco Bay proper (Jaques and Strong, 1996).

Point Reyes Bird Observatory conducted extensive waterbird (waterfowl, shorebirds, wading birds) surveys in Bolinas Lagoon, Drakes Estero and Limantour annually from the early 1970s until 1993, and will resume these surveys this year (Lynn Stenzel, pers. comm).

Heron and egret colonies in the San Francisco Bay Area are surveyed regularly by the Audubon Canyon Ranch (John Kelly, pers. comm.). Surveys of herons and egrets in the area, including the coastline from Bodega Bay south, are conducted regularly, and were most recently collated and published in 1993 (Kelly et al., 1993). This paper includes a map of all breeding colonies of Great Blue Herons (*Ardea herodias*), Great Egrets (*Casmerodius albus*), Snowy Egrets (*Egretta thula*) and Black-crowned Night Herons (*Nycticorax nycticorax*) in the San Francisco Bay area (including the Bodega and Tomales Bay colonies). This study identified central San Francisco Bay islands as accounting for 35 percent of the nests in the region. The National Park Service monitors Black-crowned Night Herons and Snowy Egrets nesting on Alcatraz Island (Daphne Hatch, pers. comm.) The San Francisco Bay Bird Observatory (SFBBO) monitors a large heron/egret rookery in southern San Francisco Bay during the breeding season, and is also censusing Virginia Rail (*Rallus limicola*) and Sora (*Porzana carolina*) populations in South San Francisco Bay (Thomas Ryan, SFBBO, pers. comm.). Audubon Canyon Ranch recently reported on results of winter surveys for several waterbird species using Tomales Bay in the winters of 1989-1996, including several species of wading birds (Kelly and Tappen, 1998). Audubon Canyon Ranch continues to monitor wintering waterbirds on Tomales Bay (John Kelly, ACR, pers. comm.).

Pinnipeds

Six species of pinnipeds occur in this region: northern elephant seals (*Mirounga angustirostris*), California sea lions (*Zalophus californianus*), Pacific harbor seals (*Phoca vitulina richardsii*), northern fur seals (*Callorhinus ursinus*), Guadalupe fur seals (*Arctocephalus townsendi*) and Steller's sea lions (*Eumatopius jubatus*).

Monthly surveys of marine mammals, including pinnipeds, along the central and northern California coast from 1980-1983 identified several major hauling grounds for pinnipeds in the San Francisco Bay region (Dohl et al., 1983): California sea lions haul out on Bodega Rock, with maximum numbers occurring in late fall and winter, and California sea lions and Steller sea lions haul

out at Fort Ross Reef in Sonoma County in spring. Drakes Estero is an important pupping ground for harbor seals, and a bit further down the coast at Double Point is another harbor seal hauling ground (maximum numbers in June). California sea lions also haul out at Seal Rocks in San Francisco in spring.

Pinnipeds breeding on the Farallon Islands include elephant seals (Stewart et al., 1994) and Steller sea lions (National Marine Fisheries Service, 1992). Over the years, a very small number of Pacific harbor seals and California sea lions have been born on the Farallones, and breeding populations of these species have been monitored by Point Reyes Bird Observatory since 1972 (Sydeman and Allen, in press), and continue to be censused annually. The Farallon Islands are the largest haul-out site in central/northern California for California sea lions, with peak abundance usually occurring when adult and subadult males migrate northward to or from breeding colonies during the spring or fall (Brown et al. 1997).

Dynamics (abundance, distribution, birth-rates) of the harbor seal population in the region, including the Farallon Islands, Tomales Bay and Drakes Estero, was summarized for the years 1974-1987 based on observations of harbor seals at haul-out sites (Allen et al., 1989). Known harbor seal haul-out and pupping sites include Tomales Point, Point Reyes Headland, Double Point, Duxbury Reef, Tomales Bay, Drakes Estero and Bolinas Lagoon. The Farallon Islands are the only offshore haul-out sites in this region. From March-June an estimated 3500 harbor seals occur in the region during the breeding season. A sizable percentage (>10 percent during all months except February and March) have reddish-colored pelts, due to the adherence of iron oxides to the surface of the hair shaft (Allen et al., 1993). The Gulf of the Farallons National Marine Sanctuary monitors harbor seal haul-out in Tomales Bay and Bolinas Lagoon.

In addition to the South Farallon Island northern elephant seal rookery, there is a breeding colony on the Point Reyes Headlands (Allen et al., 1989), which is monitored by Point Reyes National Seashore (Sarah Allen, PRNS, pers. comm.).

Sightings of free-ranging and stranded Guadalupe fur seals in this region between 1988-

1995 were summarized (Hanni et al., 1997): four of the five sightings of free-ranging animals occurred on Southeast Farallon Island from August 1992 to August 1995, and one live animal was seen near Bodega Head in August 1993. Stranded Guadalupe fur seals were recovered at Fort Funston and Sutro Baths in San Francisco in May 1993 and May 1994, respectively.

The San Francisco Bay region is estimated to support approximately 6870 harbor seals (Brown et al. 1997). Probably the most comprehensive census work on Pacific harbor seals in California was conducted from 1983 to 1995 (Hanan, 1996). These were aerial surveys conducted during the moulting period (when harbor seals are at their peak onshore abundance), and included a five-year tagging study to allow for estimation of what portion of the population was actually observed during the aerial surveys. Several annual reports of this survey work were produced (e.g. Hanan and Beeson, 1994) but collated in 1996 (Hanan, 1996). The CDFG continues to periodically census Pacific harbor seals in California, with the next survey schedule for winter/spring 1999 (Kim McKee-Lewis, CDFG, pers. comm.).

The National Marine Fisheries Service/Southwest Fisheries Science Center is conducting seasonal surveys of California sea lions on-colony and at-sea from Point Conception north to the Oregon border (Mark Lowry, NMFS/SWFSC, pers. comm.). California sea lions have been hauling out on Pier 39 in San Francisco Bay since 1990, with peak numbers occurring in winter. The Marine Mammal Center monitors this population and censuses periodically (Michelle Lander, TMMC, pers. comm.): at last count in August 1998, almost 700 sea lions were present at the pier.

Major harbor seal haul-outs in San Francisco Bay have been closely monitored since 1989 via both aerial and ground counts (D. Kopec, CSU Tiburon Center for Environmental Studies, pers. comm.). The most recent aerial survey conducted during peak haul-out season counted an estimated 450 animals. Surveys are ongoing, conducted monthly year-round and bi-monthly during the pupping season.

At-sea surveys for pinnipeds from Bodega Bay south to Monterey Bay were conducted in May and June from 1985-1992 (Allen, 1994): the

most abundant pinnipeds seen at sea were northern fur seals and California sea lions. This document contains density and distribution maps for all pinniped species in this area.

The California Department of Parks and Recreation Natural Heritages Section sponsored a comprehensive seasonal survey of wildlife occurring in all coastal California State Parks in 1991 (Jaques and Strong, 1996). This survey covered 9 different state beaches, parks and preserves in the San Francisco Bay region, including Tomales Bay State Park and Pescadero Marsh Nature Preserve and State Beach, but excluding San Francisco Bay proper. It describes in detail the seasonal occurrence of pinnipeds in these areas.

Monterey Bay Area and Central Coast—From Pigeon Point to Point Conception, including Año Nuevo, Monterey Bay, Big Sur and Morro Bay

Seabirds

The California Department of Parks and Recreation Natural Heritages Section survey covered 32 different state beaches, parks and preserves in the Monterey Bay/Big Sur region, including Año Nuevo State Reserve, several beaches in Santa Cruz, Point Lobos State Reserve, several sites in Morro Bay, and Pismo State Beach (Jaques and Strong, 1996).

Since 1996, monthly distribution and abundance surveys of seabirds in Monterey Bay have been conducted (S. Benson, pers. comm.). At-sea surveys for foraging seabirds out to 80 km offshore from Bodega Bay to the northern part of Monterey Bay were conducted in May and June from 1985-1992 (Allen, 1994). This document contains density and distribution maps for seabirds species observed frequently, as well as maps of sightings of seabird species seen too rarely to generate density estimates.

Common Murre (*Uria aalge*) abundance and distribution in Monterey Bay was studied via boat-based transects bimonthly in 1981-82. Common Murre and Brandt's Cormorant (*Phalacrocorax penicillatus*) breeding colonies in

this part of central California were surveyed in most years since 1985 (Takekawa et al., 1990).

Año Nuevo State Reserve maintains a bird list for the reserve, which lists all species seen on the mainland and island, including seabirds, with reference to abundance by season (Metropulos et al., 1997). Rhinoceros Auklets (*Cerorhinca monocerata*) breeding on Año Nuevo are currently monitored weekly in the spring and summer by Point Reyes Bird Observatory (Julie Thayer, PRBO, pers. comm.) and intermittently during the fall and winter. PRBO also monitors Brown Pelicans (*Pelecanus occidentalis*), Brandt's and Pelagic Cormorants (*Phalacrocorax pelagicus*), Oystercatchers, and Pigeon Guillemots (*Cephus columba*) roosting on the island.

The Gulf of the Farallones National Marine Sanctuary initiated a Beach Watch program in 1993. Once or twice monthly this year-round program surveys 86 pre-defined sections of the coastline (approx 241 km total) from Bodega Head to the San Mateo/Santa Cruz border, including the Año Nuevo area (Roletto et al., 1998). Trained volunteers survey beaches for live and dead birds (most commonly seabirds, shorebirds, or waterfowl) and marine mammals, and pay particular attention to the presence of oiled organisms and tar balls. Annually, a report is produced that tallies the counts of live vs. dead marine wildlife and the incidence of oiled wildlife, and tabulates encounter rates for selected taxa by season. A similar Beach Watch program, primarily for seabirds, was established for Monterey Bay in May 1997 (Benson et al., 1998). These weekly or monthly surveys cover approximately 47 km of pre-defined Monterey Bay shoreline.

Foraging site preferences of Brandt's Cormorants off the Santa Cruz coast were recently studied, and showed that Brandt's Cormorants preferred rocky reef habitats versus sandy-bottom habitats (Hebshi, 1998).

Shorebirds

An intensive survey of shorebirds in all major coastal California wetlands from Morro Bay north was conducted fall 1988 (Stenzel et al., 1989): surveyed areas in the Monterey Bay/Big Sur region included Pescadero Marsh, Waddell Creek mouth, Pajaro River mouth, Watsonville Slough,

the Salinas River mouth, and Morro Bay. These initial surveys set the stage for a large-scale effort to census shorebirds of the entire Pacific Flyway: annual surveys took place in the fall, winter and spring from 1988-1992 (Stenzel et al., 1989; Page et al., 1992), and censused areas in this region included Pescadero Marsh, Año Nuevo and Waddell Beach, Pajaro River/Watsonville Slough, Elkhorn Slough, Salinas River, Morro Bay and the Santa Maria River mouth and several other lagoons and beaches. These surveys identified Elkhorn Slough as harboring up to 30,000 shorebirds in fall and winter. This survey effort is by far the most comprehensive of its kind for California, and the report tabulates species abundance by census location and season. PRBO is continuing annual surveys during at least one season in most of these census areas.

Seasonal distribution and abundance of shorebirds in Elkhorn Slough was described based on surveys conducted between November 1977 and February 1980 (Ramer et al., 1991): this report contains tables depicting abundance of select species by month, and describes use of different habitat types by different shorebird species. Elkhorn Slough ranks as the third most important wetland for migrating and overwintering shorebirds in the state in terms of overall numbers of birds supported.

The California Department of Parks and Recreation Natural Heritages Section survey covered 32 different state beaches, parks and preserves in the Monterey Bay/Big Sur region, including Año Nuevo State Reserve, several beaches in Santa Cruz, Point Lobos State Reserve, several sites in Morro Bay, and Pismo State Beach (Jaques and Strong, 1996).

Año Nuevo State Reserve maintains a bird list for the reserve which lists all species seen on the mainland and island, including shorebirds, with reference to seasonal abundance (Metropulos et al., 1997).

Morro Bay State Park monitors Snowy Plovers (*Charadrius alexandrinus*) nesting along Estero Bay (Vince Cicero, MBSP, pers. comm.).

Waterfowl and Wading Birds

The California Department of Parks and Recreation Natural Heritages Section survey

covered 32 different state beaches, parks and preserves in the Monterey Bay/Big Sur region, including Año Nuevo State Reserve, several beaches in Santa Cruz, Point Lobos State Reserve, several sites in Morro Bay, and Pismo State Beach (Jaques and Strong, 1996).

A large heron and egret rookery in Elkhorn Slough is monitored via biennial aerial photographs by the Elkhorn Slough National Estuarine Research Preserve (Martha Nitzberg, Elkhorn Slough National Estuarine Research Reserve, pers. comm.) This colony consists of approximately 20 Great Blue Heron (*Ardea herodias*) pairs and 60 Great Egret (*Casmerodius albus*) pairs. Great Blue Herons nesting at Morro Bay are monitored, though not closely, by Morro Bay State Park ecologists (Vince Cicero, MBSP, pers. comm.). At last count in 1996 there were approximately 25 breeding pairs. There are also Great Egrets, Black-crowned Night Herons (*Nycticorax nycticorax*), and smaller egrets nesting at this rookery, but they are not censused by the park.

Año Nuevo State Reserve maintains a bird list for the reserve which lists all species seen on the mainland and island, including waterfowl and wading birds, with reference to seasonal abundance (Metropulos et al., 1997).

Pinnipeds

The National Marine Fisheries Service is currently conducting seasonal surveys of California sea lions (*Zalophus californianus*) on-colony and at-sea from Point Conception north to the Oregon border (Mark Lowry, NMFS/SWFSC, La Jolla, CA, pers. comm.).

Monthly surveys of marine mammals, including pinnipeds, conducted along the central and northern California coast from 1980-1983 identified several major hauling grounds for pinnipeds along the Monterey/Big Sur coast (Dohl et al., 1983) including Año Nuevo State Reserve for northern elephant seals (*Mirounga angustirostris*), California sea lions (*Zalophus californianus*), and Steller sea lions (*Eumatopius jubatus*), the Monterey Breakwater and rocks in the Point Lobos area for California sea lions, Cape San Martin for northern elephant seals and California sea lions; and Point Piedras Blancas, Lion Rock, Pecho Rock and Pt. Sal Rock for California sea lions.

Año Nuevo Island is an important pinniped rookery in California, and is monitored primarily by Año Nuevo State Reserve and UC Santa Cruz. Elephant seals pup on both mainland beaches and on the island (Stewart et al., 1994), and Año Nuevo Island is also the southernmost and largest breeding colony of Steller sea lions in California (National Marine Fisheries Service, 1992). The best methods for censusing Steller sea lions on Año Nuevo have been evaluated (Westlake et al., 1997). Año Nuevo Island is also one of the most important hauling grounds for California sea lions in central and northern California, with peak numbers occurring in fall (Dohl, 1983).

The other elephant seal breeding colony in this region is at Cape San Martin/Gorda, halfway between Monterey and Point Conception (Stewart et al., 1994). Elephant seals have also been reported to haul-out near the Diablo Canyon Nuclear Power Plant in San Luis Obispo County, south of Cape San Martin (King et al., 1989).

Sightings of free-ranging and stranded Guadalupe fur seals (*Arctocephalus townsendi*) between 1988-1995 were summarized (Hanni et al., 1997): six of the stranded animals were found in the Monterey Bay/Big Sur region, from Año Nuevo to Port San Luis in San Luis Obispo County between May 1992 and June 1995.

At-sea surveys for pinnipeds from Bodega Bay to the northern part of Monterey Bay were conducted in May and June from 1985-1992 (Allen, 1994): the most abundant pinnipeds seen at sea were northern fur seals and California sea lions. This document contains density and distribution maps for all pinniped species in this area.

The California Department of Parks and Recreation Natural Heritages Section sponsored a comprehensive seasonal survey of wildlife occurring in all coastal California State Parks in 1991 (Jaques and Strong, 1996). This survey covered 32 different state beaches, parks and preserves in the Monterey Bay/Big Sur region, including Año Nuevo State Reserve, several beaches in Santa Cruz, Point Lobos State Reserve, several sites in Morro Bay, and Pismo State Beach. It describes in detail the seasonal occurrence of pinnipeds in these areas.

The Monterey Bay and central California coast region is estimated to support approximately 8000 harbor seals (*Phoca vitulina*), with the number of harbor seals in Monterey Bay alone estimated at 2850 seals present year-round, using 26 documented haul-out sites (Brown et al. 1997). Probably the most comprehensive census work on Pacific harbor seals in California was conducted from 1983 to 1995 (Hanan, 1996). Several annual reports of this survey work were produced e.g. Hanan and Beeson, 1994; Hanan, 1996. The California Department of Fish and Game continues to periodically census Pacific harbor seals, with the next survey scheduled for winter/spring 1999 (Kim McKee-Lewis, CDFG, pers. comm.). Seasonal abundance, movements, and food habits of harbor seals in Elkhorn Slough were recently studied (Oxman, 1995). In addition, the abundance, foraging and diving behavior, and mother-pup interactions of harbor seals in Monterey Bay were studied from June 1991–May 1992 (Trumble, 1995). This study included weekly counts of hauled out harbor seals along a stretch of coastline in the southern part of Monterey Bay, from Hopkins Marine Station to Seal Rock.

Currently, monthly boat-based surveys of at-sea distribution of marine wildlife in Monterey Bay, including pinnipeds, are being conducted (Scott Benson, Moss Landing Marine Laboratory, pers. comm.). Also, a Beach Watch program consisting of monthly surveys for live and dead marine organisms on pre-defined sections of beach along Monterey Bay is coordinated through Moss Landing Marine Laboratory (Benson et al., 1998): these beach surveys census hauled-out pinnipeds.

Southern California—From Point Conception to the Mexican border, including the Channel Islands and San Diego Bay

Seabirds

Channel Islands National Park (CINP: Anacapa, Santa Cruz, Santa Rosa, San Miguel, and Santa Barbara Islands) has monitored six seabird species within the park since 1985: Double-crested and Pelagic Cormorants (*Phalacrocorax auritus* and *P. pelagicus*), California Brown Pelicans (*Pelecanus occidentalis*), Western Gulls (*Larus occidentalis*),

Cassin's Auklets (*Ptychoramphus aleuticus*) and Xantus' Murrelets (*Synthliboramphus hypoleucas*). Other seabird species nesting in the park include Ashy, Black and Leach's Storm-Petrels (*Oceanodroma homochroa*, *O. melania*, and *O. leucorhoa*) Brandt's Cormorants (*Phalacrocorax penicillatus*), Pigeon Guillemots (*Cepphus columba*), Rhinoceros Auklets (*Cerorhinca monocerata*) and Tufted Puffins (*Fratercula cirrhata*). Reports of CINP's on-going monitoring programs covering 1990–1992 have been completed (Ingram, 1992; Ingram and Carter, 1997). These reports contain detailed maps of all nesting colonies of monitored species. Since 1993, the park has contracted with Point Reyes Bird Observatory to monitor Double-crested and Brandt's Cormorants, Western Gulls and Xantus' Murrelets, and since 1995, three species of Storm-petrel on Santa Barbara Island (Feldman, 1995; Shultz, 1996; Roth, 1997). Also on-going is a long-term study of nesting Brown Pelicans on the Channel Islands, monitored since the late 1960s by California Department of Fish and Game (Gress et al 1990; Gress and Martin, 1998).

Loons migrating through the Southern California Bight during the Spring of 1976-1978 were censused from Goleta Point, and at-sea from 1989-1990 (Russell and Lehman, 1994). Breeding colonies of Brandt's Cormorants and Double-crested cormorants in southern California (both coastal and on the Channel Islands) were aerially surveyed each year since 1991 as part of a statewide monitoring program of these species (Carter et al., 1996; McChesney et al., 1998). A study of the southern breeding limits of Tufted Puffins and Rhinoceros Auklets at San Miguel Island was conducted in 1991 and 1994 (McChesney et al., 1995). The breeding biology of Brandt's Cormorants at San Nicolas Island was studied from 1992-1994 (McChesney et al., 1997). Distribution of Xantus' Murrelets at-sea in the Southern California Bight was studied during the breeding and post-breeding periods in 1995-1997 (Whitworth et al., 1997). Black-footed Albatross (*Diomedes nigripes*) were radio-tracked in the non-breeding season off southern California (Hyrenbach, 1998), and California Least Tern (*Sterna antillarum*) preferred foraging habitat was studied in and around San Diego Bay (Robinette and Baird, 1998).

The California Department of Parks and Recreation Natural Heritages Section survey covered 24 different state beaches, parks and preserves in the southern California region, including Point Mugu State Preserve, Malibu Lagoon State Beach, Bolsa Chica State Beach, Huntington State Beach and California Least Tern Nature Preserve, Los Peñasquitos Marsh Nature Preserve, and Tijuana Estuary Nature Preserve (Jaques and Strong, 1996).

A survey of Snowy Plovers (*Charadrius alexandrinus*) in state-managed coastal areas in Orange and San Diego Counties in winter and spring 1995 contains a list of other marine and coastal birds observed during surveys: this list includes several seabird species, and covers such coastal areas as Bolsa Chica, Buena Vista, Batiquitos and San Elijo Lagoons, Huntington Beach, Silver Strand State Beach and Tijuana Estuary (Powell, 1996).

San Diego Bay is the second largest expanse of bay water along the California coast, second only to San Francisco Bay, and is utilized by more than 135 bird species, including seabirds. Several studies of this area have been conducted under the auspices of the U.S. Fish and Wildlife Service's Coastal Ecosystem Program, and by the U.S. Navy. A year-long survey of waterbird species distribution and abundance on central and southern San Diego Bay was conducted in 1993-94 (Manning, 1995), and on north and central San Diego Bay in 1993 (Mock et al., 1994). The shoreline was not included in either of the aforementioned surveys. The first report provides species accounts for the bay, abundance data where available, and includes maps describing occurrence, high-use areas and spatial distributions for all species observed. Additionally, a year-long weekly census of water-associated birds within the Western Salt Works, adjacent tidal mudflats, and along a portion of the southwestern shoreline of southern San Diego Bay was conducted in 1993-1994 (Stadtlander and Konecny, 1994). This report provides species accounts and distribution and abundance by season for several species, including several seabirds, with data represented both in tables and maps. A two-year survey of nesting Black Skimmers (*Rhynchops niger*), Caspian (*Sterna caspia*), Elegant (*S. elegans*), Gull-

billed (*S. nilotica*), California Least, Royal (*S. maxima*) and Forster's Terns (*S. forsteri*) at the Western Salt Works was conducted in 1993-94 (Konecny, 1995). This report contains maps of nesting distribution of each species. This report also documents a nesting colony of Double-crested Cormorants on an abandoned dredging barge anchored within the Western Salt Works.

Black Skimmers nesting in Upper Newport Bay and the Bolsa Chica Ecological Reserve have been studied (Taylor, 1998). These two sites represent some of the largest colonies of Black Skimmers in the state.

Several species (Elegant, Royal and Caspian terns and Black Skimmers) nest within the Port of Los Angeles and are monitored for the City of Los Angeles by a local consultant (Kathy Keane, Keane Biological Consulting, Long Beach, CA, pers. comm.).

The California Environmental Resources Evaluation System (CERES) has compiled a database called the California Wetlands Information System (accessible via the internet: <http://ceres.ca.gov>) which contains profiles of nearly every wetland in the state. The southern California Wetlands Inventory covers every coastal wetland from Santa Barbara County to the Mexico border, including Mugu Lagoon, Bolsa Chica Wetlands, Upper Newport Bay, Batiquitos Lagoon, Los Penasquitos Lagoon, Mission and San Diego Bays, to the Tijuana Estuary. Each profile contains detailed information on key contacts, ownership, land use designation and on-site use, hydrology, water quality, habitat and species accounts, including seabirds. Species accounts are not broken down by season and do not comment on abundance, but do cite references, most of them unpublished reports.

Shorebirds

The Point Reyes Bird Observatory coordinated a large-scale effort to census shorebirds of the entire Pacific Flyway: annual surveys took place in the fall, winter and spring from 1988-1992 (Stenzel et al., 1989; Page et al., 1992), and censused areas in the southern California region included Mugu and Malibu Lagoons, Seal Beach, Bolsa Chica, Upper Newport Bay, Batiquitos Lagoon, Mission and San Diego Bays, as well as numerous river

mouths, lagoons and beaches. These surveys identified Mugu Lagoon as harboring up to 30,000 shorebirds in spring. This survey effort is by far the most comprehensive of its kind for California, and the report tabulates species abundance by census location and season. PRBO is continuing annual surveys during at least one season in most of these census areas.

A survey of Snowy Plovers (*Charadrius alexandrinus*) in state-managed coastal areas in Orange and San Diego Counties in winter and spring 1995 contains a list of other marine and coastal birds observed during surveys: this list includes several shorebird species, and covered such coastal areas as Bolsa Chica, Buena Vista, Batiquitos and San Elijo Lagoons, Huntington Beach, Silver Strand State Beach and Tijuana estuary (Powell, 1996).

The California Department of Parks and Recreation Natural Heritages Section survey (Jaques and Strong, 1996) covered 24 different state beaches, parks and preserves in the southern California region, including Point Mugu State Preserve, Malibu Lagoon State Beach, Bolsa Chica State Beach, Huntington State Beach and California Least Tern Nature Preserve, Los Penasquitos Marsh Nature Preserve, and Tijuana Estuary Nature Preserve.

San Diego Bay is the second largest expanse of bay waters along the California coast, second only to San Francisco Bay, and is utilized by more than 135 bird species, including shorebirds. In the southern portion of the bay is an extensive tidal mudflat and several large salt evaporation ponds (Western Salt Works). In 1993-1994, as part of the U.S. Fish and Wildlife Service's Coastal Ecosystem Program, a weekly census was conducted of water-associated birds within the Western Salt Works, adjacent tidal mudflats, and along a portion of the southwestern bay shoreline (Stadtlander and Konecny, 1994). This report provides species accounts and distribution and abundance by season for several species, including several shorebirds, with data represented both in tables and maps.

Currently, several agencies (USFWS, U.S. Navy) are involved in developing a San Diego Bay Integrated Natural Resources Management Plan, which contains comprehensive studies on

shorebirds (Mitch Perdue, U.S. Navy, pers. comm.).

The California Environmental Resources Evaluation System (CERES) has compiled a database called the California Wetlands Information System (accessible via the internet: <http://ceres.ca.gov>) which contains profiles of nearly every wetland in the state. The southern California Wetlands Inventory covers every coastal wetland from Santa Barbara County to the Mexico border, including Mugu Lagoon, Bolsa Chica Wetlands, Upper Newport Bay, Batiquitos Lagoon, Los Penasquitos Lagoon, Mission and San Diego Bays, to the Tijuana Estuary. Each profile contains detailed information on key contacts, ownership, land use designation and on-site use, hydrology, water quality, habitat and species accounts, including shorebirds. Species accounts are not broken down by season and do not comment on abundance, but do cite references, most of them unpublished reports.

Waterfowl and Wading Birds

San Diego Bay is the second largest expanse of bay waters along the California coast, second only to San Francisco Bay, and is utilized by more than 135 bird species, including waterfowl and wading birds. As part of the U.S. Fish and Wildlife Service's Coastal Ecosystem Program, a year-long survey of waterbird species distribution and abundance on central and southern San Diego Bay was conducted in 1993-94 by the U.S. Fish and Wildlife Service (Manning, 1995), and on north and central San Diego Bay in 1993 (Mock et al., 1994). The shoreline was not included in either survey. The first report provides species accounts for the North and Central bay, provides abundance data where available, and includes maps describing occurrence, high-use areas and spatial distributions for all species observed. Also in 1993-1994, as part of the U.S. Fish and Wildlife Service's Coastal Ecosystem Program, a weekly census was conducted of water-associated birds within the Western Salt Works, adjacent tidal mudflats, and along a portion of the southwestern bay shoreline (Stadtlander and Konecny, 1994). This report provides species accounts and distribution and abundance by season for several

species, including several waterfowl and waterbird species, with data represented both in tables and maps.

Currently, several agencies (USFWS, U.S. Navy) are involved in developing a San Diego Bay Integrated Natural Resources Management Plan, which has involved comprehensive studies of waterfowl (Mitch Perdue, U.S. Navy, pers. comm.).

The California Department of Parks and Recreation Natural Heritages Section survey covered 24 different state beaches, parks and preserves in the southern California region, including Point Mugu State Preserve, Malibu Lagoon State Beach, Bolsa Chica State Beach, Huntington State Beach and California Least Tern Nature Preserve, Los Penasquitos Marsh Nature Preserve, and Tijuana Estuary Nature Preserve (Jaques and Strong, 1996). It describes in detail the seasonal occurrence of waterfowl and wading birds in these areas.

A survey of Snowy Plovers (*Charadrius alexandrinus*) in state-managed coastal areas in Orange and San Diego Counties in Winter and Spring 1995 contains a list of other marine and coastal birds observed during surveys: this list includes several waterfowl and wading bird species, and covered such coastal areas as Bolsa Chica, Buena Vista, Batiquitos and San Eligo Lagoons, Huntington Beach, Silver Strand State Beach and Tijuana Estuary (Powell, 1996).

The California Environmental Resources Evaluation System (CERES) has compiled a database called the California Wetlands Information System (accessible via the internet: <http://ceres.ca.gov>) which contains profiles of nearly every wetland in the state. The southern California Wetlands Inventory covers every coastal wetland from Santa Barbara County to the Mexico border, including Mugu Lagoon, Bolsa Chica Wetlands, Upper Newport Bay, Batiquitos Lagoon, Los Penasquitos Lagoon, Mission and San Diego Bays, to the Tijuana Estuary. Each profile contains detailed information on key contacts, ownership, land use designation and on-site use, hydrology, water quality, habitat and species accounts, including waterfowl and wading birds. Species accounts are not broken down by season and do not comment on abundance, but do cite

references, most of them obscure internal reports, which could be obtained if necessary.

There is no systematic monitoring of heron/egret rookeries by any one organization or agency in southern California (John Kelly, Audubon Canyon Ranch, pers. comm.).

Pinnipeds

The primary agencies/organizations monitoring pinnipeds on the Channel Islands are Hubbs–Sea World Research Institute (HSWRI) and the National Marine Fisheries Service (both Northwest and Southwest Fisheries Science Centers) (P. Yochem, HSWRI, pers. comm.). Five pinniped species occur on the Channel Islands, with four species breeding there. San Miguel Island is the only island that supports all five species. San Nicolas Island supports large breeding colonies of Pacific harbor seals (*Phoca vitulina richardsii*), northern elephant seals (*Mirounga angustirostris*) and California sea lions (*Zalophus californianus*). Trends in distribution and abundance of pinnipeds in the Channel Islands have been summarized and numerous species-specific studies have also been conducted; in general, it is thought that California sea lions, Pacific harbor seals, northern elephant seals and northern fur seals (*Callorhinus ursinus*) may be more abundant on the Channel Islands than they ever were (Stewart et al., 1993).

The history of the northern elephant seal in California has been reviewed several times, e.g. (Cooper and Stewart, 1983; Stewart et al., 1994). Northern elephant seals breed on several of the Channel Islands, primarily on San Miguel and San Nicolas, but there are small colonies also on San Clemente, Santa Barbara and Santa Rosa Islands (Stewart et al., 1994). As of 1991, the San Miguel Island rookery produced almost half the world's Northern elephant seal pups that year. Elephant seal colonies on San Miguel and San Nicolas Islands were surveyed weekly during the breeding season (December–March) from 1981–1991, and live pups were counted on Santa Barbara, Santa Rosa, San Clemente and Santa Cruz islands in late February of each year from 1979–1991 (Stewart, 1992). Elephant seal rookeries were surveyed on San Miguel Island in 1985–95, San Nicolas Island in 1988–1995, Santa Rosa Island in 1990–95 and Santa Barbara Island in 1993–1995

using aerial photographs of rookeries (Lowry et al., 1996). This paper lists numbers of different age classes of elephant seals counted on different dates on each island. Several studies of Northern elephant seal foraging and migratory behavior using telemetry instrumentation have been conducted, all on elephant seals from San Miguel Island (DeLong and Stewart 1991; DeLong et al., 1992; Stewart and DeLong 1993; Stewart and DeLong 1994; Stewart and DeLong 1995). The 1995 study documented “double migrations” of northern elephant seals: elephant seals undergo extensive migrations up into the north Pacific Ocean and Gulf of Alaska twice each year, after breeding and after molt. They are the only vertebrate known to do so. Effects of the 1982/83 El Niño/Southern Oscillation event on northern elephant seals at San Miguel and San Nicholas Islands were studied: adult elephant seals were in poorer physical condition due to decreased/ altered prey availability and there was higher pup mortality in these years (Stewart and Yochem, 1991).

The Southern California Bight, including mainland and Channel Islands haul-out sites, is estimated to support approximately 5300 harbor seals (Brown et al., 1997). A comprehensive census of Pacific harbor seals in California was conducted from 1983 to 1995 (Hanan, 1996) and included a five-year tagging study in southern California to allow for estimation of what portion of the population was actually observed during aerial surveys. Harbor seals breed on all of the Channel Islands with the exception of Santa Barbara Island, with the largest colony occurring on San Miguel Island. Harbor seals on San Miguel Island were counted each year in late spring from 1973–1983 (Stewart et al., 1988): this paper also reviews abundance on the island from 1927–1986. Distribution and abundance of harbor seals on San Miguel Island was studied year-round in 1978–1980 (Stewart, 1981a): this study found that maximum numbers of harbor seals were hauled out in June during the molting period, and minimum numbers hauled out mid-winter. Harbor seal abundance on San Nicolas Island was studied from February 1980–September 1982 (Stewart and Yochem, 1984). A telemetry study of harbor seals on San Miguel Island during the fall of 1982

documented haul-out patterns and site fidelity of harbor seals, demonstrating that harbor seals, while faithful to one or maybe two hauling out sites, do exhibit intraseasonal movement between the islands, and that hauling out during the day versus at night differs between individuals (Yochem et al., 1987).

The status of California sea lions was reviewed in 1992 (Lowry et al., 1992). The Channel Islands (primarily San Nicolas and San Miguel; also Santa Barbara and San Clemente Islands) support the northernmost breeding colonies of California sea lions, though births have been known to occur as far north as the Farallon Islands (Pierotti et al., 1977). Peak abundance of California sea lions in the Southern California Bight occurs during the summer breeding season, when the majority of adults are present. In 1994, an estimated 81,000 California sea lions were present at Channel Island rookeries (Brown et al., 1997). Most recently, counts of California sea lions on San Nicolas Island obtained from aerial color photographs and ground counts were compared: aerial counts were more accurate than ground counts in areas of the island in which natural terrain obstructed views (Lowry, 1999).

Older studies of California sea lions include a survey of abundance on San Nicolas Island from February 1980–September 1982 (Stewart and Yochem, 1984). At-sea distribution of California sea lions in the Southern California Bight was evaluated in aerial surveys conducted over three years from 1975–1978 (Bonnell and Ford, 1987): this paper contains maps of seasonal sea lion distribution. California sea lion foraging habits were studied using radio telemetry in 1985 as part of a study comparing the foraging characteristics of California sea lions and northern fur seals breeding on San Miguel Island (Antonelis et al., 1990). This study revealed that the two species segregated during foraging. Effects of the 1982/83 El Niño event on California sea lions on San Miguel, San Nicholas, Santa Barbara, and San Clemente Islands were studied: births declined from 1983–86, and pup weights were lower, changes in both parameters indicating that the population probably experienced reduced prey availability (DeLong et al., 1991).

Northern fur seals are relative newcomers to the Channel Islands: the first breeding population was discovered in 1968 on San Miguel Island, and there is no confirmed evidence that they bred on the Channel Islands prior to the early 1960s (Stewart and DeLong, 1993). San Miguel Island remains the only Northern fur seal rookery in the Channel Islands, and is the southern-most breeding colony of the Northern fur seal in its present range. Northern fur seals are monitored primarily by the NMFS/National Marine Mammal Laboratory (Melin et al., 1996; Melin and DeLong, 1997). The San Miguel Island population is designated as one of five separate stocks of northern fur seals in the Northern Fur Seal Conservation Plan (National Marine Mammal Laboratory 1993). The conservation plan includes a map summarizing 16 years of recorded sightings of northern fur seals in the northwest Pacific, including off the California coast. A recently published book on the ecology and behavior of the Northern fur seal estimated the 1992 San Miguel population to be approximately 8200 animals, and includes a map of the breeding sites on the island (Gentry, 1998). Northern fur seal foraging habits were studied using radio telemetry in 1985 as part of a study comparing the foraging characteristics of northern fur seals and California sea lions breeding on San Miguel Island (Antonelis et al., 1990); this study found that the two species segregated during foraging.

While historically, Steller sea lions (*Eumatopius jubatus*) occurred and bred on the Channel Islands, the last known pup born there (on San Miguel) was in 1982, and no Steller sea lions have been seen on the Channel Islands since 1984 (Stewart and DeLong, 1993).

Guadalupe fur seals (*Arctocephalus townsendi*) are not known to breed on the Channel Islands, but occasionally adult or juvenile males are observed in the summer, usually at San Nicolas or San Miguel Islands (Stewart, 1981; Stewart et al., 1993). It is presumed that these animals migrate northward from their main rookery on Isla de Guadalupe off Baja California. Observations of interactions between Guadalupe fur seals and California sea lions at rookeries on the Channel Islands suggest that Guadalupe fur seals are dominant over California sea lions, and therefore

could potentially gain space at pinniped rookeries on the Channel Islands if the Mexican population continues to expand (Stewart et al., 1987). This paper also summarizes sightings of Guadalupe fur seals in California waters since 1949.

The California Department of Parks and Recreation Natural Heritages Section sponsored a comprehensive seasonal survey of wildlife occurring in all coastal California State Parks in 1991 (Jaques and Strong, 1996). This survey covered 24 different mainland state beaches, parks and preserves in the southern California region, including Point Mugu State Preserve, Malibu Lagoon State Beach, Bolsa Chica State Beach, Huntington State Beach and California Least Tern Nature Preserve, Los Penasquitos Marsh Nature Preserve, and Tijuana Estuary Nature Preserve. It describes in detail the seasonal occurrence of pinnipeds in these areas.

Other important southern California mainland sites for pinnipeds include offshore rocks at Point Loma and La Jolla in the San Diego area for harbor seals.

Distribution and Abundance of Species of Concern

In this section, data concerning marine bird and mammal species that are federally- or state-listed as threatened or endangered, or are known to occur in low numbers in the state, and/or breed exclusively in the state, are reviewed. The order in which species are reviewed in no way correlates with status. This section covers all federal and state-listed threatened and endangered birds known to occur along the California coastline (except for the Bald Eagle) and most of the state-listed marine/coastal bird Species of Special Concern. It also covers the Steller sea lion, but does not cover any of the cetaceans, the southern sea otter, or any of the sea turtles: please see previous sections for information on these species.

California Least Tern (Sterna antillarum browni)

The California Least Tern was federally- and state-listed as endangered in 1970. Annual popu-

lation censuses have been conducted since 1973 and are coordinated by the California Department of Fish and Game's Wildlife Management Division. Intense management, primarily in the form of protection and enhancement of nesting areas, has resulted in impressive growth of the California breeding population, from a low of an estimated 600 breeding pairs in 1970 to an estimated 3330-3392 breeding pairs in 1996. As of 1996, California Least Terns nest at 35 sites along the California coast (Caffrey, 1998), primarily in the south. In 1996, 58 percent of the total population nested at only 7 sites (one site in Alameda County, the rest in Los Angeles and San Diego Counties).

These birds nest on open, sandy, flat areas along the coast, of which very little is "natural" habitat, e.g. alongside airport runways, within industrial port areas, and on popular southern California beaches (Fancher, 1992). They are therefore extremely vulnerable to human disturbance and human-related activities. They also nest adjacent to river mouths, so are vulnerable to industrial accidents upriver. Least Terns occur along the California coast primarily in the spring and summer, and are generally not present in the state in late fall/winter.

This species has benefitted greatly from efforts to maintain, enhance and protect pre-existing nesting areas, as well as establish new areas. In addition, terns have returned to former nesting areas after several years' absence, and the use of decoys has been successful in attracting terns back to these previously used, or to new, areas (Caffrey, 1998).

A survey of California state parks, beaches and preserves along the coast in 1991 documented Least Terns nesting at several sites, most of them protected from disturbance by fencing, e.g. Oceano Dunes, McGrath Beach, Huntington Beach, Bolsa Chica, San Elijo Beach (Jaques and Strong, 1996). A two-year survey of nesting California Least Terns at the Western Salt Works in south San Diego Bay was conducted in 1993-94 (Konecny, 1995). This report contains maps of nesting distribution for this species. Foraging habits of California Least Terns in San Diego Bay were studied over 4 successive breeding seasons during the early 1990s (Robinette and Baird, 1998).

Marbled Murrelet (Brachyramphus marmoratus)

The Marbled Murrelet was federally-listed as threatened under the Endangered Species Act in 1992, and state-listed as threatened in 1992. It is believed to have declined by over 95 percent from historic levels due to a combination of nesting habitat destruction, food-web collapses, gill-net entanglement, and oil spills.

The status and distribution of the Marbled Murrelet in California from 1892–1987 was reviewed (Carter and Erickson, 1992). The first reliable records of at-sea distribution of Marbled Murrelets in California were obtained in 1979 and 1980 (Sowls et al., 1980). At-sea surveys specific for Marbled Murrelets commenced in 1989 and have covered the California coastline from Bodega Bay north to the Oregon border in the summers of 1994 and 1995 (Strong et al., 1997), from Point Lobos north to the Oregon border in April–October 1989–1993 (Ralph and Miller, 1995) and in the Año Nuevo area in the summers since 1995 (Becker et al., 1997). The Año Nuevo area is believed to be the southern limit of this species' breeding range (with nesting occurring in the old-growth forest of the Waddell Creek watershed), and at-sea distribution and abundance of Marbled Murrelets in this area has been studied (Ainley et al., 1995). In 1997, a radio-telemetry study of at-sea movements of Marbled Murrelets in the Año Nuevo area was conducted (Burkett et al., 1998). Two radio-telemetered birds ranged 224 km north and 181 km south of Año Nuevo. At-sea Marbled Murrelet surveys have not been conducted south of Point Lobos. Results of most studies suggest that this species occur exclusively in near-shore waters from 200 m to 12 km offshore.

Strong's (1997) population estimate of between 3100 and 4800 Marbled Murrelets between the Oregon border and Point Arena in 1994–1995 was lower than Ralph and Miller's (Ralph and Miller, 1995) estimate of 5600 birds based on their 1989–1993 surveys. While a comparison of this data suggests that there has been a 15–45 percent population decline between 1989 and 1995, it is more likely that differences in population estimates are due to substantial differences in sampling methodologies.

It is believed that Marbled Murrelets forage at sea within relatively small areas in close proximity to nesting grounds in old-growth coniferous forest. What little old-growth habitat remains along coastal California occurs in patches, and this has resulted in what are believed to be three distinct, isolated Marbled Murrelet populations in California: one centered around northern Humboldt County and Del Norte counties, a second off south-central Humboldt County, and a third near Año Nuevo. These regions are critical Marbled Murrelet marine habitat.

Essentially their year-round range comprises the off-shore areas adjacent to their nesting areas in Humboldt/Del Norte Counties and San Mateo/Santa Cruz Counties. In the fall/winter (post-breeding season) their range may be slightly larger, but does not extend further south than Morro Bay. A recent study documents a seasonal change in distribution of Marbled Murrelets at-sea relative to the coastal nearshore habitat along the northern California coast (Strong, 1998): a shift in relative abundance occurs between late July and mid-August, with bird abundance decreasing off sandy shorelines and increasing off rocky shorelines.

California Brown Pelican (Pelecanus occidentalis californicus)

Brown pelican populations in California declined severely in the 1960s and 1970s due to DDT contamination of the Southern California Bight and consequent eggshell thinning and breeding failure in this species (Gress, 1995). It was federally-listed as endangered in 1970, and the California subspecies (*Pelecanus occidentalis californicus*) was state-listed as endangered in 1971. A California Brown Pelican Recovery Plan was produced by the U.S. Fish and Wildlife Service in 1983 (Gress and Anderson, 1983). California Brown pelican numbers have increased from lows prior to 1975, to an estimated 100,000 birds present in California in October 1980 (Briggs et al., 1983), and an ever-widening dispersal range northward into Oregon and Washington (Deborah Jaques, Crescent Coastal Research, pers. comm.). Despite the banning of DDT use and production in the United States, however, breeding success remains low (Carter et al., 1995).

The Brown Pelican nests at only two sites in California, on Anacapa and Santa Barbara Islands. Censuses of the breeding population on the Channel Islands are conducted annually by the National Park Service in cooperation with the California Department of Fish and Game: results of breeding success and population status of Brown Pelicans in southern California are available for 1988-1989 (Gress et al., 1990), for 1991 and 1992 (Ingram, 1992; Ingram and Carter, 1997), and for 1997 (Gress and Martin, 1998). The 1992 report summarizes the breeding success of California Brown Pelicans in Channel Islands National Park between 1969 and 1992. Results of 1993-1997 surveys will be reported later this year (Paige Martin, Channel Islands National Park, pers. comm.). Aerial surveys for Brown Pelicans along the entire California coastline are currently being conducted under contract to CDFG/OSPR (D. Jaques, Crescent Coastal Research, pers. comm.). Important communal roosting sites for non-breeding brown pelicans during the summer and fall in central California are Pismo Beach, Diablo Canyon, Año Nuevo Island and Southeast Farallon Island (Jaques and Anderson, 1988); a roost at Moss Landing in Monterey Bay was believed to be the largest in the United States until it was abandoned in 1989 due to excessive human disturbance. This report contains a map depicting 32 important roost sites for the entire coast of California. A survey of marine wildlife distribution and abundance in California state parks, preserves, and beaches along the coast in 1991 documented important roosting sites for Brown Pelicans at Tijuana Estuary, Malibu Lagoon, Santa Clara Estuary, Morro Bay, Point Lobos, Salinas River, Moss Landing, Pajaro River, Año Nuevo, and Lake Earl/Lake Talawa (Jaques and Strong, 1996). Brown pelican use of a roost site at Mugu Lagoon in southern California was studied from 1991-1993 (Jaques et al., 1996): this study included aerial surveys of roost sites at other locations in the Southern California Bight (Marina Del Rey, Malibu, Ventura, Mussel Shoals, and Santa Barbara harbor).

Brown pelicans occur year-round in southern California from Santa Barbara south, and are at their highest population level from November to May (with influx of immature birds from Mexico)

(Small, 1994). In northern California (from Santa Barbara north) pelicans are present primarily from July through December, with lowest numbers occurring in February and gradually increasing through May/June. Brown pelicans have been observed as far north as Castle Rock National Wildlife Refuge in Del Norte County in the late fall and early winter (Jaques and Strong, 1998).

Elegant Terns (Sterna elegans)

The Elegant Tern is state-listed as a Species of Special Concern. As of 1980, only one breeding colony existed in California, in San Diego Bay, which represented the northern limit of its breeding range (Sowls et al., 1980). As of 1998, there are three nesting colonies of Elegant Terns in the state: at the Salt Works in southern San Diego Bay, monitored by the U.S. Fish and Wildlife Service (Mark Pavelka, USFWS, pers. comm.), at Bolsa Chica Ecological Reserve in Huntington Beach, and just this year, in the Port of Los Angeles (Kathy Keane, Keane Biological Consulting, Long Beach, CA, pers. comm.). The 1999 Elegant Tern census in south San Diego Bay counted approximately 150 nesting attempts with only five chicks surviving to near fledging. Approximately 3500 pairs moved from Bolsa Chica to nest in the Port of Los Angeles.

Xantus' Murrelet (Synthliboramphus hypoleucus)

There are believed to be only 2000-5000 breeding Xantus' Murrelets in California, on the Channel Islands (Carter et al., 1997), and this represents a significant portion of the world's population of this species (Carter et al., 1995). During the non-breeding season they range along the entire Pacific coast. At-sea distribution of radio-marked birds from Santa Barbara Island was studied via aerial transects during the breeding and dispersal periods of 1995-1997 (Whitworth et al., 1997). This study found that Xantus' Murrelets ranged much farther from the nesting colony during the breeding season than previously believed, and that they are at increased risk of being adversely impacted by an oil spill, as they frequently range within 10 km of offshore oil platforms in the Santa Barbara Channel, and shipping lanes have shifted nearer

to Santa Barbara Island in recent years. Post-breeding dispersal occurred in May/June, primarily northward from Point Conception, usually within 40 km of the coastline, but a few birds ranged as far offshore as 100 km. The pelagic distribution of Xantus' Murrelets off northern California and southern Oregon was studied via strip-transects between 1986 and 1995 (Karnovsky et al., 1995): during spring/summer, murrelets were inshore with highest densities west of the Farallones. In fall/winter, the highest densities of murrelets were further south and offshore, between Point Sur and Point Buchon.

Channel Islands National Park has monitored Xantus' Murrelets breeding within the park since 1985: the largest breeding population of Xantus' Murrelets in the United States is on Santa Barbara Island. The latest report of the on-going monitoring program covers censuses in 1992 (Ingram and Carter, 1997), and a report covering censuses since then is nearing completion (Paige Martin, Channel Islands Nat'l Park, pers. comm.) These reports contain detailed maps of parts of the nesting colonies of Xantus' Murrelets, and document reproductive success for these portions of the overall breeding population. A study of reproductive performance and nesting habitat selection of this colony was conducted in 1997 (Roth et al., 1998).

Ashy Storm-Petrel (Oceanodroma homochroa)

The Ashy Storm-Petrel is a California endemic: it is estimated that there are only 5000 pairs worldwide (Carter et al., 1995; Ainley and Hunt, 1991), with 80 percent of the entire world population nesting in California on the Farallon Islands and possibly the entire world population congregating in Monterey Bay in the fall (Ainley et al., 1994). Size and trends of the population on Southeast Farallon Island was studied based upon data collected in 1971, 1972 and 1992 (Sydeman et al., 1998). In 1992, the population was estimated to be approximately 4284 birds, of which almost 2000 were presumed to be breeding adults. Compared to the data from the early 1970s, the authors concluded that there had been an overall population decline of 34 percent over the last two decades. The authors noted that oceanographic conditions in 1992 may have influenced colony attendance.

California Gulls (Larus californicus)

While this species is not endangered in terms of overall population size, there is only one breeding colony of California Gulls on the coast of California (Ryan and Hanson, 1998). It was established in 1980 in a salt pond in south San Francisco Bay with 12 pairs of breeding birds. As of 1997, there were 5067 nests counted at several salt ponds in this area. Predation by red foxes (an introduced species) has been heavy. Currently, the San Francisco Bay Bird Observatory (SFBBO) under contract to the USFWS, monitors the California gull colony in south San Francisco Bay (Tom Ryan, SFBBO, pers. comm.).

California Clapper Rail (Rallus longirostris obsoletus)

The California Clapper Rail is state and federally listed as endangered, and until very recently was on the verge of extinction. While it once ranged from Humboldt to Morro Bay, by the early 1980s all but one pair of breeding Clapper Rails were confined to San Francisco Bay, with the one pair outside of the Bay breeding in Elkhorn Slough in Monterey County. The entire population reached an all-time low in 1991 of 500 birds (Harding-Smith, 1993). In 1997-98, the population estimate of California Clapper Rails was 685 for south San Francisco Bay (San Francisco Bay National Wildlife Refuge, 1998). Numbers in northern San Francisco Bay (north of the Golden Gate) as of the 1992 breeding season were estimated to be between 260 and 422 pairs (Evens and Collins, 1992). Population censuses in San Francisco Bay have been conducted since 1970, and annual winter high-tide surveys of south San Francisco Bay have been conducted since 1988 (Harding-Smith, 1993). This latter report summarizes surveys of south San Francisco Bay and of parts of San Pablo Bay for the years 1989-1993, and includes maps detailing abundance and distribution of California Clapper Rails. The Don Edwards National Wildlife Refuge oversees Clapper Rail work primarily in the south bay, whereas Avocet Research, an environmental consulting firm oversees work in the north bay (Jules Evens, Avocet Research, pers. comm.).

California Black Rail (Laterallus jamaicensis coturniculus)

The California Black Rail is a state-listed threatened species. The bulk of the western North American population (>80 percent) is restricted to the San Francisco Bay Area (Evens et al., 1991): as of spring/summer censuses conducted in 1986-88, most Black Rails in the state nest in northern San Francisco Bay, primarily around San Pablo Bay but also in pristine (i.e. unrestricted tidal flow) marshes around Suisun Bay (Evens et al., 1989; Nur et al., 1997). The 1989 report contains detailed maps depicting distribution; the 1997 report updates counts in selected areas originally censused for the 1989 report. There are also small breeding populations in Tomales Bay, Bolinas Lagoon and Morro Bay (Nur et al., 1997).

Western Snowy Plover (Charadrius alexandrinus nivosus)

Western Snowy Plovers nest on sandy shorelines and salt evaporation ponds, and have disappeared from many former nesting sites along the coast. The species was federally-listed as threatened in 1993 and is state-listed as a Species of Special Concern. In California, most breeding birds are concentrated from San Francisco Bay southward. Surveys to estimate the breeding population of Snowy Plovers in the western United States were performed in 1988 and 1989 (Page et al., 1991). This study counted lower numbers of breeding plovers on the California coast, particularly at Humboldt Bay, along the Mendocino coastline, in San Francisco Bay, at San Miguel and San Nicolas Islands, in northern San Diego County and in San Diego Bay. Numbers were higher at Morro Bay, along the coast between Morro Bay and Point Conception, in Oxnard and on Santa Rosa Island. Snowy Plovers were observed breeding on Santa Rosa, San Miguel and San Nicolas Islands. This report estimated a total of 1900 snowy plovers on the entire western U.S. coast, with greater numbers occurring in the interior.

A survey of California state parks, preserves and beaches on the California coast in 1991 notes that the California Department of Parks and Recreation (CDPR) has jurisdiction over most of

the areas still used by Snowy Plovers for nesting, and summarizes which agencies/organizations are monitoring snowy plover (Jaques and Strong, 1996). Pont Reyes Bird Observatory is the primary organization involved, with efforts focused primarily in the Monterey Bay area; CDPR monitors plovers on state-managed beaches; CDFG and CDPR sponsored surveys in Humboldt and Del Norte Counties in 1993 and 1996; and the National Biological Survey has been involved with snowy plover monitoring in San Diego County.

The San Francisco Bay Bird Observatory censuses Snowy Plovers during the breeding season in South San Francisco Bay (Tom Ryan, SFBBO, pers. comm.). A two-year survey of nesting Western Snowy Plovers at the Western Salt Works in South San Diego Bay was conducted in 1993-94 (Konecny, 1995). This report contains maps of nesting distribution for this species. PRBO monitors nesting populations of snowy plovers on San Miguel and Santa Rosa Islands (Ingram, 1992; Ingram and Carter, 1997). Snowy Plovers are counted once or twice monthly year-round on 86 beaches (covering approximately 240 km) from Bodega Bay to Año Nuevo by the Gulf of the Farallones National Marine Sanctuary's Beach Watch program (Roletto et al., 1998). A survey of state-managed lands in Orange and San Diego Counties in winter and spring 1995 found Snowy Plovers breeding at three coastal sites in these counties: Bolsa Chica Lagoon, Silver Strand State Beach and Tijuana Estuary, and wintering at nine different sites (Powell, 1996). This report noted that there are no recent reports of Snowy Plovers nesting in Los Angeles County.

Aleutian Canada Goose (Branta canadensis leucopareia)

The Aleutian Canada Goose was federally listed as endangered in 1967 when, after it was thought to have been driven to extinction by the introduction of foxes near nesting colonies, a remnant breeding population was discovered on Buldir Island in the Aleutian Islands chain in 1962. Intensive management of breeding colonies, a hunting ban on critical staging grounds, and captive breeding and release programs have

allowed steady and impressive growth of the population. The species was downlisted to threatened in 1991, and is currently a candidate for delisting. In 1996, the population was estimated at 23500 birds (Jaques and Strong, 1996).

The entire world population uses the far northern California region as a stopover site during fall migration, with important roost sites at Lake Earl and Lake Talawa (Jaques and Strong, 1996), Castle Rock (Jaques and Strong, 1998), and Prince Island (Fisher, 1995).

White-faced Ibis (Plegadis chihi)

The White-faced Ibis is a Species of Special Concern in California, and is a candidate for federal listing. A recent review of the White-faced Ibis's winter distribution described several coastal sites from the San Francisco Bay south to the Mexican border where these birds are seen in low numbers in winter (Shuford et al., 1996) (they primarily overwinter at inland sites). Their numbers in California during the winter have increased dramatically since the 1970s.

Steller Sea Lion (Eumatopius jubatus)

The Steller sea lion was federally listed as threatened in 1990 under an emergency ruling by the National Marine Fisheries Service when there had been a major and rapid decline in the Alaska population, with an overall decline in the total U.S. population of 78 percent between 1960 and 1988 (Kinsinger, 1995). A Steller sea lion Recovery Plan was published in 1992 (National Marine Fisheries Service, 1992). This plan identifies four major rookeries and haulouts in California: at St. George Reef, Sugarloaf Rock, the Farallon Islands and Año Nuevo Island. Año Nuevo is the largest Steller sea lion rookery in California, and is at present the southernmost rookery for this species, though Stellers did breed on San Miguel Island until 1981. Summer counts of adults and juveniles have declined over the last 60 years at all major rookeries in California, with the exception of Sugarloaf. In 1983 the total California Steller sea lion population was estimated to be 3000 animals (Dohl et al., 1986): the Steller sea lion recovery plan estimated the California Steller sea lion population to be approximately 2000–2500 (ex-

cluding pups) between 1980 and 1990 (National Marine Fisheries Service, 1992). Overall, the California population is declining, and possibly shifting northward in its distribution.

3

Species Sensitivity to Petroleum

Marine wildlife species vary in terms of their susceptibility to oiling by virtue of differences in their biology, ecology and behavior. Seabirds are probably at greater risk for suffering the negative impacts of oil spills than most other marine wildlife species; their susceptibility has been thoroughly and concisely reviewed (Holmes, 1984; Leighton et al., 1985a), and their susceptibility has led them to be considered primary bioindicators of pollution in the marine environment (Camphuysen and Van Franeker, 1992; Furness and Camphuysen, 1997). However, seabirds vary in their susceptibility to oiling: species such as the murre, auklets, puffins, guillemots, loons, grebes and sea ducks, which spend a large portion of their time on the sea surface making foraging dives, are far more likely to be oiled compared to a soaring bird that rarely touches the water (e.g. terns, albatross). This was exemplified in the *Exxon Valdez* oil spill, when proportionately larger number of loons, grebes, guillemots, murre and murrelets were affected in the immediate aftermath of the spill versus other more abundant and more aerial species (Piatt and Lensink, 1989; Piatt et al., 1990). The *Exxon Valdez* spill also resulted in the death of approximately 10 percent of the Bald Eagle population in the Prince William Sound (Bowman, 1993), serving to illustrate that oil spills have direct and negative impacts on a variety of wildlife inhabiting the marine environment.

Similarly, sea otters (*Enhydra lutris*) are far more susceptible to the immediate affects of an oil spill than other marine mammals, as their ability to thermoregulate is wholly dependent upon the integrity of their fur rather than on a blubber layer, as for the pinnipeds, and oil contamination destroys the thermal properties of a sea otter's pelage (Costa and Kooyman, 1982; Siniff et al., 1982; Davis et al., 1988). Additionally, compared to all other marine mammals, sea otters spend a very large portion of their day grooming their coats to maintain the insulative properties of the fur, and therefore are at much higher risk for the toxic effects of acute ingestion of petroleum products. Again, this was exemplified by the *Exxon Valdez* oil spill's toll on sea otters versus other marine mammal species. In the interest of time and space, the susceptibility of sea otters to oiling won't be covered further in this document, as it is universally recognized that their sensitivity to oiling is exquisite. Suffice it to say that in an attempt to model the impact on the southern sea otter of an oil spill on the scale of the *Exxon Valdez* incident occurring in the vicinity of the Monterey Peninsula, an estimated 90 percent of the total population would be exposed, with at least 50 percent of the population dying immediately (Brody et al., 1996). This level of devastation to the population is thought to be a function of both their physiology and their limited distribution.

Species susceptibility to the negative impacts of oil spills can be a far more subtle thing than immediate mortality and other obvious health-related effects. Biologists have long recognized changes in a given species' biology and ecology that correlate with the occurrence of oil spills, and have found that species vary in the degree to which they are affected by an oil spill by virtue of variation in foraging behavior, migration patterns, nesting habits, flocking behavior, and distribution. In fact, almost 20 years ago, the U.S. Fish and Wildlife Service evaluated the relative vulnerability of bird populations to oil by determining what it termed the 'Oil Vulnerability Index' (OVI) for 176 species of birds using Arctic marine habitats (King and Sanger, 1979). The authors based the index on 20 factors that affect bird survival, such as breeding range size, migration length, roosting, foraging and flocking habits, and mortality risk factors. High OVIs (maximum = 100) correlated with high susceptibility to oiling: for example, birds in southeast Alaska with OVIs >61 included Pelagic Cormorants (*Phalacrocorax pelagicus*), Oldsquaw (*Clangula hyemalis*), scoters (*Melanitta sp.*), Black oystercatchers (*Haematopus bachmani*), Northern Phalaropes (*Phalaropus lobatus*), Common Murres (*Uria aalge*), Pigeon Guillemots (*Cepphus columba*) and Marbled Murrelets (*Brachyramphus marmoratus*). These species scored high because of their ranging, foraging and breeding habits and characteristics which placed them at high risk for oiling. In contrast, species in southeast Alaska with low OVIs included Great Blue Herons (*Ardea herodias*), Canada Geese (*Branta canadensis*), Killdeer (*Charadrius vociferus*), Spotted and Least Sandpipers (*Actitis macularia* and *Calidris minutilla*), Bonaparte's Gulls (*Larus philadelphia*) and Common Ravens (*Corvus corax*). These species spend very little time on or in the water, and therefore are at low risk for oiling.

Researchers documented profound effects on avian community structure in Prince William Sound in the aftermath of the *Exxon Valdez* oil spill (Wiens et al., 1996): species richness and species diversity were much reduced shortly after the spill, but recovered quickly, suggesting that seabird communities appear to be resilient to severe but short-term perturbations like oil spills, perhaps because they move over a regional scale.

A model evaluating the sensitivity of colonially-breeding seabirds to oil spills looked at various oil spill scenarios and how they might affect mortality and population recovery of guillemots (*Cepphus sp.*) and kittiwakes (*Rissa sp.*) (Ford et al., 1982). This model suggested that guillemot mortality would be greatest following an inshore spill near breeding islands, while kittiwakes would be less affected by nearshore spills and more impacted by offshore spills. This model also predicted that low-level chronic oil pollution (rather than one-time perturbations) affecting the food supply could result in total reproductive failure of the guillemot colony if there was a 40 percent reduction in the food supply. A more recent simulation model was formulated to predict the mortality and recovery of seabird populations after an oil spill, and takes into account a large number of variables, including number of birds present, variations in oil slick avoidance behavior, seasonal changes in bird behavior, age of birds, and r- versus k-selected strategies (Seip et al., 1991).

Some studies have even documented the positive effect of an oil spill on some aspects of a species' ecology. For example, pre-spill and post-spill surveys of seabird species in certain locations within Prince William Sound showed that the *Exxon Valdez* oil spill caused a profound decline in the number of Pigeon Guillemots (*Cepphus columba*) present, but actually an increase in the number of Black-legged Kittiwakes (*Rissa tridactyla*) (Murphy et al., 1997). This study also documented no appreciable effect on several other species. Predatory and scavenging species like Bald Eagles (*Haliaeetus leucocephalus*), Pomarine Jaegers (*Stercorarius pomarinus*) and Northwestern Crows (*Corvus caurinus*) actually experienced positive effects of the *Exxon Valdez* spill, presumably due to an increase in foraging opportunities (Day et al., 1997). These kinds of studies serve to illustrate the variation in species sensitivity to oil spills.

Oil spills and oil contamination of the marine environment have been shown to have a direct effect on the breeding success of seabirds, either by directly affecting nesting habitat or behavior, or by altering the preybase to the point that birds are unable to come into adequate body condition

for breeding, and/or chick provisioning is inadequate to fledge chicks. These effects vary depending on the ecology of the species.

For example, the breeding success of Black Oystercatchers (*Haematopus bachmani*) on oiled islands in Prince William Sound versus unoiled islands during the 1989 and 1991 breeding seasons was evaluated (Andres, 1997). Direct mortality of Black Oystercatchers in Prince William Sound after the *Exxon Valdez* spill was almost negligible. However, fewer pairs occupied or maintained nests on oiled islands right after the spill in 1989 compared to 1991, while there was no difference between years on the unoiled island. Feeding rates on oiled islands were also much lower, as was the rate of disappearance of chicks from nests in 1989. The author concluded that breeding of Black Oystercatchers was disrupted during 1989 and 1990 but had recovered by 1991, and that disruption was probably attributable to reduced prey abundance, disturbance from clean-up operations causing nest abandonment, and decreased survivability of chicks coming into contact with oil on beaches.

In an experiment on the sublethal effects of crude oil on Leach's Storm-petrels (*Oceanodroma leucorhoa*), it was shown that a single sublethal exposure, either internal or external, of one member of a breeding pair of Leach's Storm-petrel resulted in decreased hatching success and/or survival of their chicks (Butler et al., 1988). This effect was even more dramatic when both birds in a pair were oiled. Egg losses were due primarily to nest abandonment by the adults. This study also determined that external exposure of adults had a more severe impact on chick survival than did internal exposure. Transfer of oil from oily adults to chicks during brooding resulted in matting of the down and therefore loss of the insulative properties of down. Interestingly enough, there was no mortality among adults experimentally exposed either internally or externally in this study.

In a similar experiment conducted earlier, one or both adults of free-ranging breeding pairs of Leach's Storm-Petrels were dosed orally once with crude oil (Trivelpiece et al., 1984). When adults were dosed while brooding young chicks (2-3 days old), chick survival was reduced sub-

stantially, especially when both adults were dosed, primarily due to poor weight gain. This was determined not to be due to transfer of oil to chicks from adults, as chicks dosed with oil did not exhibit poor weight gain. Instead, the authors believed that poor chick survival was related to the impaired ability of oil-dosed adults to provision their young.

The percentage of adult Yellow-billed Loons (*Gavia adamsii*) present in the Colville River delta in Alaska that were nesting in 1989 was found to be much reduced compared to the percentage of total population nesting prior to March 1989, when the *Exxon Valdez* spill occurred in southern Alaska (42 percent in 1989 compared to 76 percent in 1983 and 79 percent in 1984) (Field et al., 1993). The Colville River delta is on the North Slope and was unaffected by the *Exxon Valdez* spill, and while the authors were not able to prove that Colville loons were in Prince William Sound during or soon after the spill, the authors felt that the magnitude of the change in productivity was compatible with an anthropogenic impact on the population, like the *Exxon Valdez* spill. The authors speculated that direct mortality of Colville River loons migrating through Prince William Sound could have altered the age structure of the population, or that their ability to reproduce on a physiologic level was adversely affected by exposure to oil.

In a study of South Polar Skua (*Catharacta maccormicki*) breeding biology, researchers documented the profound effects of an oil spill on a colony nesting near Palmer Station, Antarctica (Eppley and Rubega, 1990). All chicks died. The authors ruled out starvation, toxicity, hypothermia and abandonment as causes for chick mortality, and therefore hypothesized that the normal foraging behavior of adults was disrupted due to external oiling, resulting in prolonged periods of nest inattendance (but not abandonment) and therefore lack of nest defense with consequent predation of chicks by conspecifics. Also of interest in this study were the observations made on the effects on other seabird species in the area, both positive and negative: Adelie Penguins and Blue-eyed Shags suffered mortality related to their diving behavior while foraging. On the other hand, scavenging species like Giant Petrels

actually experienced positive effects because scavenging for dead birds released them from the usual time constraints of distant foraging, and it is possible that post-fledging survival rates in this species were better after the spill.

Oil spills in the marine environment have also been shown to have sublethal yet negative impacts on non-marine bird species. Time spent foraging at stop-over points by migratory Semipalmated Plovers (*Charadrius semipalmatus*) and Sanderlings (*Calidris alba*) in an area impacted by an oil spill was found to be significantly reduced compared to foraging time at non-oiled beaches, primarily due to interruptions by clean-up personnel and vehicles (Burger, 1997). Reduced foraging time further compounds the already significant level of stress these species experience during migration. Time devoted to preening increased significantly as percent oiling of plumage increased, further reducing foraging time during a migratory stopover.

In a study of foraging habitat use by wading birds before and after an oil spill, researchers found that twice as many birds used freshwater, non-oiled sites after the spill than before, and likewise, fewer birds used estuaries that had been immersed in oil (Maccarone and Brzorad, 1995). The authors believed this change in foraging habitat use was probably related to major changes in the prey populations for wading birds, e.g. fish, shrimp, clams. Not surprisingly, Snowy Egrets (*Egretta thula*) in the area delayed egg-laying in the year of the spills, and their fledgling success declined greatly. This study clearly demonstrated that a spill can have far-reaching negative effects on birds apart from the impact of direct oiling and toxicity.

While rare, there are reports in the literature of negligible effects of oiling on survival of birds. For example, Purple Sandpipers (*Calidris maritima*) appeared not to suffer ill effects of oiling, at least in terms of weight and survival after one year: body mass and return rates were identical for oiled vs. non-oiled birds (n=18) (Dierschke, 1994).

Sandhill Cranes (*Grus canadensis*) were used as an experimental model for the endangered Whooping Crane (*G. americana*) to evaluate the potential impact of crude oil exposure on Gruidae

species (Fleming et al., 1982). In the experiment, cranes were orally dosed daily with Ixtoc I crude oil in quantities believed to exceed what would be ingested by cranes at an oil spill site. Internal oil exposure caused neither mortality, nor significant hematologic or serum chemistry changes. The authors concluded that crude oil was not toxic to cranes, and suggested that external oiling and ingestion of refined petroleum products were likely more toxic than acute ingestion of crude oil products.

The few reports in the literature addressing the sensitivity of cetacean species to oiling suggest that cetaceans are far less susceptible to oiling than marine birds and presumably pinnipeds. In experiments evaluating the response of bottlenose dolphins (*Tursiops truncatus*) to the presence of an oil slick or sheen on water in a captive setting, dolphins avoided the oil (Geraci et al., 1983; Smith et al., 1983; St Aubin et al., 1985). While it appeared that dolphins could “see” sheen on the water surface, aversive behavior was only seen after animals first came into contact with it. The importance of visual cues was corroborated when dolphins were less likely or able to avoid oil at night. The dolphins’ reactions to thin sheens were erratic and suggested that the sheen was not detectable acoustically or visually, and it did not produce a strong tactile response. A dolphin’s ability to detect sheen was also related to the thickness of the slick, as well as the composition of the oil, e.g. dolphins could detect 6 mm thickness of crude, residual and refined motor oils, and 17 mm thick slicks of diesel fuel, but could not detect 6 mm thick slicks of leaded gasoline or transparent mineral oil.

Despite this experimental data, oiling of cetaceans has been documented, most notably after the *Exxon Valdez* spill, when orca (*Orcinus orca*), gray whales (*Eschrichtius robustus*), Dall’s porpoises (*Phocoenoides dalli*) and harbor porpoises (*Phocoena phocoena*) were all observed either surfacing within slicks or with oil on their skin in the immediate aftermath of the spill (Harvey and Dahlheim, 1994; Loughlin, 1994a; Matkin et al., 1994; Zimmerman et al., 1994). A model designed to quantify the probability of interactions between migrating bowhead (*Balaena mysticetus*) and gray whales and potential oil spills in Alaska predicted that 0.1–2 percent of the

bowhead population would be oiled during a spill in the Beaufort Sea, which was deemed an insignificant portion of the Bowhead population (Jayko et al., 1990).

Documentation of oiling and species-specific sensitivity to oiling in pinnipeds has received little attention in the scientific literature, other than reports on the effects of the *Exxon Valdez* on pinnipeds. Harbor seals (*Phoca vitulina*) and Steller sea lions (*Eumatopius jubatus*) were observed oiled and swimming in oil or resting on oil-covered substrate in Prince William Sound after the *Exxon Valdez* (Calkins et al., 1994; Lowry et al., 1994; Zimmerman et al., 1994). The frequency of oiling of grey seal pups (*Halichoerus grypus*) on a breeding ground in Norway was determined to be approximately 30-50 percent between 1985-1989 (Ekker et al., 1992).

Likewise, oiling of sea turtles has received little attention, despite the contention of one group that sea turtles are particularly vulnerable to spilled oil since they surface to breathe and feed on objects floating at the sea surface (van Vleet and Pauly, 1987). Crude oil tanker discharge is thought to have a significant effect upon marine turtle populations in the eastern Gulf of Mexico (van Vleet and Pauly, 1987), and observations of increased strandings of sea turtles along the coast of the Gulf of Mexico in conjunction with increased explosive platform-removal activity suggests that this is another aspect of the petroleum industry that has potentially negative impacts on marine wildlife (Klima et al., 1989; Gitschlag and Herczeg, 1995).

Studies of the impact of the *Exxon Valdez* on river otter (*Lutra canadensis*) populations in Prince William Sound, Alaska demonstrated that river otters significantly changed their diet and habitat selection as a result of the spill, and in some cases these changes were not evident until a year after the spill (Bowyer et al., 1994; Bowyer et al., 1995).

4

Oil Spill Response— Initial Efforts and Events

The purpose of this first section on oil spill response is to highlight the most current, cutting-edge techniques for preventing marine birds and mammals from entering oil-contaminated areas (“hazing”); for searching waters and shores in an oil spill area for carcasses and live animals (“search and collection”) and for transporting live oiled animals to rehabilitation facilities (“capture”). Most references are relatively recent (less than 15 years old), and are meant to supplement available books and guides describing well-established methods in all these areas.

Hazing

Birds

There are relatively few publications or reports on techniques for specifically hazing marine wildlife away from oil spill areas (USDA, 1997; USDA, 1997a; USDA, 1997b). One of these publications describes the application of bird hazing methods originally designed for deterring birds from agricultural crops to hazing birds away from oil spills (USDA, 1997). The Canadian Wildlife Service has tested the efficacy of a sound-emitting device called the Breco Buoy™ in hazing wildlife away from oil spills (USEPA, 1998): the device was found to be effective in rapidly decreasing the number of birds present within 50 m–1 km

radius of the buoy in field tests. This same device was tested on non-molting birds (primarily Scaup, *Aythya sp.*, and Surf Scoters, *Melanitta perspicillata*) in San Francisco Bay, and found to be ineffective at scaring birds out of the immediate area (Whisson and Takekawa, 1998).

Most bird hazing techniques have been developed and tested for reducing bird predation on crops and on fish at aquaculture facilities, and are reviewed (Mott and Boyd, 1995). Cormorant and heron predation at fish farms can be quite extensive and result in significant economic losses, and has therefore prompted studies of ways to reduce hunting by these birds. A study of the effectiveness of nylon mesh barriers, flashing lights, pyrotechnics and Scarey man™ (an inflatable mannikin) for reducing heron predation suggested that nylon mesh barriers erected along the walls of the tanks physically prevented access to fish, and firing pyrotechnics (both exploding and whistling projectiles) daily for 14 consecutive days significantly reduced fish predation by frightening herons (Andelt et al., 1997). Bright flashing lights were effective in pushing birds to unlit areas of the farm, but were thought to be a deterrent only because they made it difficult for the birds to see prey, not because the lights were frightening. The Scarey Man™ was only minimally effective, as birds quickly habituated to its presence; however, another study also evaluating the effectiveness of an electronically controlled

Scarey Man™ showed a greater than 85 percent reduction in the depredating cormorant (*Phalacrocorax sp.*) population at a fish farm (Stickley et al., 1995), and the deterrent effect lasted for 2 weeks. In another experiment, these same researchers investigated the effectiveness of pre-recorded alarm-distress calls for scaring herons from aquaculture facilities, and found that birds quickly habituated to the calls, so that calls were only minimally effective as a deterrent technique (Andelt and Hopper, 1996). A cover net was ineffective at reducing cormorant predation on herring and flounder caught in a pound net (Cornelisse and Christensen, 1993).

Note that for the most part these methods did not deter birds from landing, but rather scared them away after arrival. Such hazing techniques would be of minimal benefit in preventing oiling of wildlife, as even a single landing/diving in an oiled area would result in oil contamination.

Similar and other techniques for deterring birds from agricultural fields, orchards, fish farms or urban areas have been tested: effigies were effective at reducing goose grazing in agricultural fields (Fuchs, 1996), and black plastic flags placed in wheat fields were highly effective at preventing waterfowl from grazing in agricultural fields as long as there were adjacent un-flagged areas for the birds to use as an alternative (Mason and Clark, 1994; Lane and Nakamura, 1996). Alarmed-geese calls were ineffective at causing Canada Geese (*Branta canadensis*) to leave urban areas, whereas screamer shells were highly effective, and geese did not appear to habituate to the sound over time (Aguilera et al., 1991). Balloons with or without eyespots were somewhat effective in causing doves to avoid fields in which balloons were placed as long as non-balloon areas were also accessible, as otherwise doves quickly habituated (Nakamura et al., 1995).

Perhaps most apropos to an oil spill situation (since the study involved a natural habitat), an experiment evaluating the effectiveness of white plastic flags at preventing overgrazing by Snow Geese (*Chen caerulescens*) in coastal salt marshes showed flags to be highly effective visual deterrents as long as adjacent un-flagged areas were available to the geese (Mason, 1995). These investigators also noted that the effectiveness

diminished as the time for migration approached, presumably because birds were becoming more bold (or careless) as they sought increasingly scarce food resources.

Methyl anthranilate is a naturally-occurring compound used as a food flavor and fragrance additive, and which happens to have a non-toxic, non-lethal repellent effect on birds when sprayed on pasture, added to fresh water, or mixed in feed. When added to fresh water pools, it successfully prevented both Mallards (*Anas platyrhynchos*) and Ring-billed (*Larus delawarensis*) and Herring Gulls (*L. argentatus*) from entering the water in both laboratory and field tests (Belant et al., 1995), and has been shown to be effective at preventing starlings (*Sturnus vulgaris*) from drinking water from dump ponds near mines containing cyanide (Clark and Shah, 1993). To our knowledge there has been no testing of the performance of methyl anthranilate in sea water, and few studies of its disposition in the environment and/or effects on non-target organisms (Clark et al., 1993; Aronov and Clark, 1996).

Falconry, i.e. flying a trained falcon over an area to scare birds out of an area, has been used as a bird-hazing technique. While this is an expensive method (it requires a trained falcon and falconer), it has been cost-effective at airports for reducing the risk of bird-strikes by planes (Erickson et al., 1990). While not effective over the long-term at preventing formation of nesting colonies of gulls in undesirable locations, it does result in immediate dispersal of birds from the area over which the falcon flies, and in that sense, may be useful in an oil spill situation for birds that would normally fly off to avoid a predator (shorebirds, gulls and terns, some waterfowl), though would not be effective for species that would normally dive to avoid predation.

Various visual and physical barriers placed above ground over seabird nesting areas (e.g. brightly colored string suspended above ground between poles, chicken-wire fencing, arrays of guy wires attached to center poles) were variably successful at excluding gull predators from nesting colonies (Maxson et al., 1996). Elevated nylon string, which was highly visible, was most effective.

A by-product of studies that have looked at the disturbance effect of aircraft flying over waterfowl is the finding that overflights with low-flying planes do cause a majority of birds (at least waterfowl) to fly off the water (Ward et al., 1999).

Marine Mammals

Various methods used to deter pinnipeds (California sea lions, *Zalophus californianus*, and harbor seals, *Phoca vitulina*, in particular) from predating on fish at salmon locks, fish farms, or near commercial fishing boats and gear (e.g. nets, lines) have been reviewed (Mate and Harvey, 1987; Brown et al., 1997). Underwater firecrackers are effective on a short-term basis, but not over the long-term, as animals become habituated to the noise. Attempts to evade firecrackers underwater causes sea lions to dive and surface in a more erratic and unpredictable manner. Likewise, above-water cracker shells produce a startling noise, but seals and sea lions quickly learn to ignore it.

The use of noise to scare marine mammals away from fishing gear has been reviewed (Richardson et al., 1995): various underwater sound-emitting devices, pyrotechnics, underwater playback of recorded predator (e.g. killer whale, *Orcinus orca*) vocalizations, and even banging on iron pipes submerged in water have been used to variable effect to scare pinnipeds and cetaceans away from nets. Variability in behavioral responses to various sounds is attributed both to physical factors (noise characteristics, attenuation rate, background noise) and also to differences in sensitivity of different individuals or of the same individual at different times. Also, tolerance, habituation and even sensitization have all been documented.

Acoustical harassment devices (AHDs) produce high-amplitude, irritating "white noise" underwater, usually in pulse tones in the 11-17 kHz range. They have been used effectively as deterrents to keep marine mammals away from gill-nets for both depredation and conservation purposes (Lien et al., 1992; Gearin et al., 1996; Kraus et al., 1997): in fact, instructions for the construction of these devices have been published for commercial fisherman (Fullilove, 1994), and

they are now being commercially manufactured for that purpose (Johnston and Woodley, 1998). Acoustical deterrent devices (ADDs) have lower acoustical power, emitting higher-decibel intermittent sounds in a unidirectional array: they have been effective at temporarily deterring marine mammals from a given area by serving as an alarm. AHDs and ADDs can be effective at hazing marine mammals initially, but can lose effectiveness if animals become habituated to the noise. Habituation potential depends on whether the AHDs and ADDs are used continually, and on the acoustical power of the sound they emit (the greater the acoustical power, the less habituation, as the more powerful AHDs can actually cause discomfort to the pinniped or cetacean).

In addition to the potential for habituation or tolerance, AHDs or ADDs have presented a few potential drawbacks for use as hazing devices. In some cases, ADDs have served as a "dinner bell" for habituated pinnipeds when used at locks or during deployment of fishing gear from boats (Dawson, 1994). Also, the mechanism underlying the deterrent effect of alarms is not always clear: the results of one study suggested that fewer harbor porpoises were caught in alarmed nets either because porpoises avoided alarmed nets and/or because their principal prey species (herring) also avoided alarmed nets (Kraus et al., 1997): if the latter mechanism is correct, this would be of little use in an oil spill situation. Also of considerable importance is the potential for noise devices to actually injure or permanently damage the auditory capabilities of marine mammals. Hearing impairment in marine mammals due to underwater sound-emitting devices or to explosives has not been documented (Richardson et al., 1995), but also has scarcely been investigated. A study of the effects of an ADD on harbor porpoises, a non-target marine mammal, showed them exhibiting marked avoidance of areas in which ADDs were activated, suggesting that ADDs could have a profound effect on the behavior of marine mammal species other than the target "nuisance" animals (Olesiuk et al., 1996).

Search and Collection

Search and collection protocols specific to oil spill situations have been described in detail, e.g. (Holcomb, 1991; Clumpner, 1995; Holcomb, 1995). Partly in response to the consensus that regular beached-animal surveys are of extreme value in monitoring marine wildlife populations and environmental catastrophes, the Gulf of the Farallones National Marine Sanctuary produced a guide for the identification of beached bird, mammal, shark and turtle carcasses found on the Pacific coast of North America (Ainley et al., 1994a).

Several recent reports have been written on improving methods for accurately assessing marine wildlife mortality via beached carcass surveys and/or carcass recovery. Carcass persistence rates and detection probabilities for King Eiders (*Somateria mollissima*) oiled in a spill in Alaska in 1996 were modeled (Fowler and Flint, 1997), and a mark-recapture technique for beached seabird surveys was conducted to determine how long a carcass remains on a beach (Good et al., 1998). This kind of information allows for a more accurate determination of total mortality in a die-off event determined via sequential surveys of a given section of coastline. After a devastating spill off the coast of France in 1978 (the AMOCO Cadiz spill), a carcass drift experiment was conducted two weeks after the spill in order to establish an approximate "finding and reporting" rate for casualties (Jones et al., 1978). In this study, 30 percent of the carcasses dropped 7.5 and 15 km from the spill area had been found within three weeks. A statistical analysis of 45 oil spills showed no valid correlation between spill volume and numbers of dead seabirds; in fact, the data analyzed in this study showed that there is a wide variance in mortality in spills of all sizes, and that there is no justification for any overall mortality estimate based on actual carcass counts (Burger, 1993). A study of three methods (line transect, circular quadrat, and complete count) for estimating density of dead birds (in this case, waterfowl) was conducted (Philibert et al., 1993): investigators determined the circular quadrat method to be an easy and good estimator of density of dead birds, preferable to the statistical complexity of the line

transect method, and less time-consuming than the complete search. This study has limited applicability to search and collection on beaches and shorelines, however, as the study was conducted in pastureland, where vegetative cover significantly interfered with detectability of carcasses. In a study of sea turtle strandings that could be attributed to the flounder fishery in North Carolina, strandings of moribund or dead turtles on beaches were found to be a poor estimate of total at-sea mortality related to the fishery (Epperly et al., 1996). The investigators surmised that few injured/dead turtles wash ashore due to the tendency for turtle carcasses to sink, at which point the disposition of the carcass depends on the near-bottom currents (and in the case of the Carolina coast in the summer, these currents are primarily offshore).

In an attempt to determine the important factors in deposition of carcasses on shore after a large die-off, several simulation studies have been conducted using both dummy and real carcasses. Wooden drift blocks were used in an experiment to simulate the movement of oiled seabird carcasses onto beaches off Vancouver Island, British Columbia (Hlady and Burger, 1993): blocks released close to shore (within 1-2 km) were recovered at a much higher rate than blocks released 35-116 km offshore, and tidal flow was found to have little effect, whereas wind and current did. Fewer blocks were recovered from rocky shores versus sand or gravel beaches, and many blocks were found tangled in jetsam, suggesting that carcasses can be difficult to find once washed ashore. In a study evaluating the effects of wind on recovery of oiled seabirds, wooden blocks simulating dead birds were dropped from boats or airplanes during either an on-shore or off-shore wind, and then beaches searched for washed-up blocks: not surprisingly, 61 percent of blocks dropped during the on-shore wind were recovered compared to only 0.7 percent of blocks dropped during the off-shore wind recovered (Flint and Fowler, 1998). The investigators concluded that wind was the dominant factor influencing drift of blocks in that vicinity, and that local currents also influenced deposition of blocks on specific beaches. An experiment in which sea otter carcasses recovered in the aftermath of the *Exxon Valdez* spill were marked and

released and their subsequent recovery rate was measured resulted in recovery of five of the 25 carcasses, representing only 20 percent of the experimental group (DeGange et al., 1994). Various field experiments were conducted to evaluate the degree or effect of carcass loss, scavenging, and incomplete search on deriving an estimate of total numbers of birds killed by the *Exxon Valdez* oil spill (Ford et al., 1996; Piatt and Ford, 1996).

Of possible relevance to search and collection of live birds during oil spills is a recently published paper on the utility of using far infrared thermal imaging to locate birds (Boonstra et al., 1995). The investigators attributed the highly variable results in detecting various birds in different habitats to the variation among species in the insulative property of nests and feathers. They surmised that thermal imaging could be useful in assessing nest occupancy in cavity or burrow-nesting birds or detecting activity in open spaces, but not in detecting ground nests of waterfowl or in detecting perched owls (birds with highly insulative plumage). Clearly, in oil spill situations in which the insulative property of feathers is severely decreased by oiling, and in which debilitated birds may be down on the water or on shorelines, thermal infrared imaging could be of potential value in locating live birds.

Capture Techniques

In this section, we review recent papers and reports that specifically address techniques for the capture of marine birds and mammals. While there are numerous papers and books on capturing and/or trapping hundreds of wildlife species, it is not the purpose of this document to review these methods so much as it is to highlight recent advances in the capture of species that would potentially be affected by an oil spill in California.

Birds

Several recent papers describe methods for capturing birds (seabirds, waterfowl) on or in water. The use of above-water mist nets set up on floating poles has been used to capture Marbled

Murrelets (*Brachyramphus marmorata*) (Kaiser et al., 1995) and Surf Scoters (*Melanitta perspicillata*) (Lesage et al., 1997). Submerged nets (mist, gill) have been successfully used to capture diving birds such as grebes (Breault and Cheng, 1990) and Surf Scoters (Lesage et al., 1997): dip nets have also been used to capture diving grebes as well as several duck species and a coot (Jehl and Yochem, 1987). A net gun was found to be most successful for the capture of Marbled Murrelets in one study (Quinlan and Hughes, 1992); dip nets, gill nets and spot-lighting were not found to be effective. This study also emphasized the importance of wearing gloves by bird handlers so that the natural water repellancy of the Murrelets' plumage was not disrupted. An in-water corral trap that took advantage of the natural feeding and fleeing behavior of ducks was used to trap canvasbacks (*Aythya valiseneria*) (Haramis et al., 1987).

Night-lighting with pole-netting was used to capture Double-crested Cormorants (*Phalacrocorax auritus*) on the water after flushing them from roost sites in trees (King et al., 1994), and night-lighting has been used to capture Common Eiders (*Somateria mollissima*) (Snow et al., 1990). A night-lighting technique for capturing Xantus' Murrelets (*Synthliboramphus hypoleucas*) in southern California was recently used with great success (Whitworth et al., 1997).

Several papers describe techniques for capturing ground-dwelling, usually nesting, birds. A noosing pole was used to capture ground-nesting Great Cormorants (*Phalacrocorax carbo*) (Hogan, 1985). A remote-controlled syringe that injects an immobilizing agent (ketamine) intramuscularly has been used to successfully capture nesting penguins, gannets and cormorants (Wilson and Wilson, 1989). Noosing poles and stationary nest traps were successful in the capture of nesting Brown Noddies (*Anous stolidus*) and Bridled Terns (*Sterna anaethetus*) (Chardine and Morris, 1987). A corral-type trap modified for easy transport has been used to capture large numbers of urban geese (Costanzo et al., 1995).

Mammals

Methods for the physical capture of marine mammals on- and off-shore have been developed.

Harbor seals, by nature wary, have been successfully trapped from haul-out sites by the deployment of a large capture net from a boat just as seals enter the water to flee (Jeffries et al., 1993). With this method, seals are not actually caught in the net in the water, but instead are prevented from fleeing the haul-out site underwater, and can thus be “corralled” closer to shore, then entangled as the net is pulled onto shore. Harbor seals were removed from the net and restrained with a hoop net over their heads.

The capture of sea otters has been well worked out and described (Bayha and Hill, 1990; Bodkin and Weltz, 1990; Britton et al., 1990; Hander, 1990; Benz and Britton, 1995). Presently, the methods used most often to capture sea otters are the dip net, the tangle net, and the Wilson Trap.

5

Oil Spill Response— Rehabilitation

Detection of Petroleum Products on or in Wildlife

In this section, methods for the detection of petroleum (i.e. petrogenic polynuclear aromatic hydrocarbons, or petPAHs) on fur or feathers or in tissues of marine vertebrates (mammals, birds, fish) or invertebrates will be reviewed. Some papers discussing detection of polyaromatic hydrocarbons in general will also be discussed, though the applicability of these techniques for detection of petPAHs is not known in many cases.

Direct Measures of Petroleum Product Exposure

The industry standard for detection of petPAHs in tissues of marine organisms is gas chromatography with either mass spectrometry (GC/MS) or flame ionization detection (GC/FID), and procedures for detection of petPAHs by these methods are described or reviewed in several recent papers (Hellou, 1996; Isigigur et al., 1996; Short et al., 1996; Baumard and Budzinski, 1997; Means, 1998; Picer, 1998). It has been argued that GC/FID is not as advantageous a method as GC/MS for quantification of petPAHs, because it is less accurate, or requires many more (hence, expensive) purification steps to achieve the level of accuracy readily achieved with GC/MS (Baumard and Budzinski, 1997). High-perfor-

mance liquid chromatography (HPLC) is also used for rapid and cost-effective petroleum analysis, but is less accurate in terms of specific compound identification.

Gas chromatography with either MS or FID has been used to detect and/or quantify experimental and natural petroleum exposure in many species of benthic invertebrates (bivalves, polychaetes, crustaceans), fish, marine mammals, marine turtles, and marine birds (Engelhardt et al., 1977; Hall et al., 1983; Kerley et al., 1985; van Vleet and Pauly, 1987; Hellou et al., 1991; Krahn et al., 1992; Law and Whinnett, 1992; Al-Yakoob et al., 1993; Krahn et al., 1993; Thompson et al., 1993; Frost et al., 1994; Loughlin, 1994; Mulcahy and Ballachey, 1994; Van Der Oost, 1994; Yu et al., 1995; Hellou and Warren, 1997; Maruya et al., 1997; Zhou et al., 1997). Additionally, GC/MS has been used to detect and/or quantify natural petroleum exposure in a terrestrial mammal, the kangaroo rat (Kaplan et al., 1996). High performance liquid chromatography has been used to detect PAHs in invertebrates and fish, in and on southern sea lions (*Otaria byronia*) and in harbor seal (*Phoca vitulina*) bile (Frost et al., 1994; Krahn et al., 1993; Van Der Oost et al., 1994; Marsili et al., 1997; Thompson et al., 1993). Analyzed tissues have included muscle, adipose, blood, bile, fur, and feathers.

In general, all crude oils are mixtures of the same hydrocarbon and non-hydrocarbon com-

pounds, but vary in the percent composition of these compounds. Natural weathering of oil in the environment also results in highly variable compositions. Hence, there is no one single method that can quantify all petPAHs potentially present in or on an animal in the aftermath of an oil spill, due to the complexity of the hydrocarbon composition and variability of the weathering process. However, several recent studies have attempted to fine-tune the petPAH detection process. The importance and methodology of compound-specific analysis of not only parent PAHs, but of alkylated and heterocyclic PAHs as well, was recently emphasized and described (Means, 1998): alkylated and heterocyclic PAHs are the predominant forms of PAHs in oil and coal products, and can be missed if tissues are tested only for the 16 traditionally-studied, parent PAHs listed as priority pollutants by the Environmental Protection Agency (EPA) and World Health Organization (WHO). This study notes that different members of the isomeric alkylated petPAHs exhibit differential toxicity and diffusion and degradation rates, further emphasizing the importance of compound-specific analysis.

A study of the natural exposure of terrestrial mammals (kangaroo rats) to crude oil after an oil well blow-out showed the incorporation of "polycyclic biomarkers" ("biomarkers" because they originate from the sterol and hopanoid moieties of the lipid fraction of decaying organisms) into the rats' livers (Kaplan et al., 1996). These polycyclic biomarkers are 4-ring steranes and 3 to 5-ring terpanes which are not present in living tissues, and so their detection is direct evidence of petroleum exposure.

Quantitative analyses of trace levels of specific petPAHs in biological samples present numerous difficulties. Methods for reducing the accidental loss of petPAH analytes during the many complicated steps in the analysis procedure (e.g. extraction, purification and quantification) have been developed, and primarily involve the integration of several surrogate internal standards into the GC/MS analysis, preferably at least one internal standard per aromaticity class (Baumard and Budzinski, 1997). Detection by GC/FID of petPAHs in muscle tissue of Atlantic salmon experimentally exposed to the water-soluble

fractions of Flotta North Sea light crude oil was greatly improved by first performing alkaline digestion of the salmon tissue followed by steam distillation (Isigigur et al., 1996). Likewise, saponification and hexane partitioning of contaminated oyster tissue followed by adsorption chromatography and gel permeation chromatography to clean up extracts was found to improve accuracy of PAH detection by HPLC and GC/MS (Thompson et al., 1993).

Additional methods for direct detection of petroleum products in tissues include assaying DNA for PAH adducts: competitive ELISAs using antisera that recognize specific PAH-DNA adducts have been used in several epidemiologic studies evaluating genotoxicity in people working in the petroleum industry (Mumford et al., 1996). This same immunoassay technique has been used to demonstrate PAH-DNA adducts in beluga whales (*Delphinaptera leuca*) (Mathieu et al., 1997). A radio-labelling technique was used to detect PAH-DNA adducts in eel (Van Der Oost et al., 1994).

A detection assay for use in the field has been developed (Mazet et al., 1997): an immunoassay originally developed for detection of petroleum products in soil and water was adapted and validated for detecting the presence of oil on the external coat (fur, feather, skin) of wildlife species. A similar test was used to detect crude oil on the pelts of river otters (*Lutra canadensis*) in Prince William Sound (Hecker et al., 1997). A crude non-mechanized method for detecting small amounts of oil on sea otters was tested after the *Exxon Valdez* spill: a known volume of clipped fur was mixed with a powerful solvent, and the color of the resulting supernatant was subjectively compared to several standards and judged to represent light, medium, heavy or no oiling (Hill et al., 1990). While the testing method did accurately detect petroleum products on the one oiled otter, the method was not statistically validated.

HPLC was used to measure PAHs on the fur and in the feces of southern sea lions (*Otaria byronia*) naturally exposed to high levels of petroleum products in a heavily polluted harbor (Marsili et al., 1997). This study noted that the PAH "fingerprint" obtained from a fur sample perhaps most accurately reflects the characteris-

tics of the contaminating petroleum product in the area, as fur is the first "tissue" to come in contact with the oil, and fur does not metabolize the oil to breakdown products.

In an experimental exposure study (both immersion and ingestion) involving ringed seals (*Phoca hispida*), differences in detectability of PAHs in various tissues were noted (Engelhardt et al., 1977). In the immersion experiment, PAHs were highest in urine and bile, less elevated in blood and plasma, and lower in tissues (lowest in lung) at 2 days post-immersion. Tissue sampling in the ingestion study was limited to samples that could be collected from live animals either by venipuncture or biopsy: PAHs were highest in blood, and higher in liver and blubber compared to muscle. This study illuminates the importance of selecting appropriate tissues for PAH analysis.

Methods used to detect exposure to benzene in petroleum industry workers were reviewed and updated (Kok et al., 1997): this study noted that while detection of urinary phenol (a major metabolite of benzene) is the most common method for biological monitoring of benzene exposure, it is unreliable, especially for low levels of exposure. Trans, trans-Muconic acid (ttMA) in urine was the most practical and reliable biomarker for monitoring low level exposure. We were unable to find any papers applying the principles of urinary metabolite analysis as an indicator of petroleum exposure in animals. Part of the difficulty lies in the fact that species differ in their liver function and detoxifying enzyme profile, and therefore most likely produce different metabolites or levels of metabolites.

Indirect Measures of Petroleum Product Exposure

Methods to detect petroleum exposure via indirect indices, i.e. by induction of detoxifying enzymes, damage to DNA, changes in blood parameters, etc. have been evaluated. These methods are useful both for assessing acute exposure as well as detecting sublethal chronic exposure.

Detecting the induction and activity of detoxifying, mixed function oxidase (MFO) enzymes (especially the cytochrome P450s, but also

ethoxyresorufin O-deethylase or EROD, aryl hydrocarbon hydroxylase or AHH) is a standard method for assaying for exposure to environmental contaminants. Genes that code for these detoxifying enzymes are turned on when PAHs bind to the Ah (aryl hydrocarbon) receptor on the cell membrane, triggering intracellular events that lead to transcription of genes like the CYP1A gene, which codes for the cytochrome P450s.

While most of the research utilizing these systems in bioassays for environmental contaminant exposure has focused on halogenated hydrocarbons like PCBs and dioxins, these bioassays have been used to detect petroleum exposure in marine organisms to varying success. Cod larvae were shown to respond to experimental oil exposure with increased cytochrome P450 synthesis (Goksoyr and Solberg, 1987). Expression of CYP1A in intertidal fish collected from or caged at reference sites and sites oiled by the *Exxon Valdez* was measured (Woodin et al., 1997): CYP1A activity was much higher in livers of fish from oiled sites versus un-oiled reference sites. A study evaluating fish and invertebrates near and far from oil-drilling platforms in the Gulf of Mexico found that hydrocarbon contamination of the environment (as measured by sediment contamination) was not high enough to induce CYP1A1 activity in fish, AHH activity in invertebrates or EROD activity in a cell bioassay (McDonald et al., 1996); it was conjectured that sediment samples would have to be contaminated at a level greater than 3000 ng/mg before detectable levels of enzyme activity would be detectable. This study also demonstrated significant species-specific variation in basal CYP1A1-dependent enzyme levels. The mixed function oxidase activity of several seabird species (Herring Gulls, *Larus argentatus*, Atlantic Puffins, *Fratercula arctica*, Guillemots, *Cepphus sp.* and Leach's Storm-petrels, *Oceanodroma leucorhoa*) in response to exposure to petroleum products was evaluated (Lee et al., 1985; Peakall et al, 1987; Peakall et al, 1989). Hepatic enzymes were found to be a sensitive but short lived biological indicator of exposure to crude oil: within 72 hours of a single oral dose of Prudhoe Bay crude oil, hepatic enzyme activity had decreased to approximately 50 percent of the measured activity at 24 hours

(Peakall et al., 1987; Peakall et al., 1989). Cytochrome P450-associated monooxygenase activity in liver samples of Western Sandpipers (*Calidris mauri*) naturally exposed to oilfield brine discharges was evaluated and shown to not correlate with contaminant burdens (Rattner et al., 1995): however, the level of contamination in these birds was found to be quite low. Activity of EROD in hepatic microsomes and primary hepatocyte cultures from wild Double-crested Cormorant (*Phalacrocorax auritus*) embryos collected from different sites in California and Oregon was measured (Davis et al., 1997). Activities varied widely between individuals and between geographic location, and were not correlated with level or character of environmental contamination. However, this study is useful in that it illustrates the potential for use of these techniques in evaluating petroleum exposure.

A technique for measuring dioxin (a PAH) exposure by measuring Ah (aryl hydrocarbon) receptor-mediated luciferase gene expression was developed as an alternative to the EROD induction assay (Aarts et al., 1993), and is being modified for application to petroleum PAH exposure in marine wildlife (M. Ziccardi, pers. comm).

Techniques for evaluating induction of detoxifying enzymes as a measure of contaminant exposure in marine mammals are being applied with increasing frequency, as the biochemistry of xenobiotic metabolism becomes better described in these species. These enzyme systems have been described to varying extents in several cetacean and pinniped species (Addison, 1984; Goksoyr, 1986; Goksoyr, 1988; Watanabe, 1989; Goksoyr, 1992; White, 1994; Mattson et al., 1998; Wolkers et al., 1998). Induction of mixed function oxidases as a measure of exposure specifically to petroleum products has been studied in ringed seals (Engelhardt, 1982), and harbor seals (Addison et al., 1986).

Measuring PAH metabolites in bile from fish exposed to petroleum products has also been evaluated. Trout exposed to fuel oil accumulated conjugated metabolites of petPAHs in their bile (Hellou and Payne, 1987). Bile from eel exposed to known levels of environmental PAH contamination of sediments were analyzed for PAH metabolites (Van Der Oost et al., 1994). Bile fluorescence

in carp experimentally exposed to crude oil and diesel fuels was correlated with the induction of mixed function oxidases as well as with the liver's potential to bioactivate promutagens to mutagens, and even of the formation of PAH-DNA adducts, and thereby validated as a method for detection of petroleum product exposure in fish (Britvic et al., 1993). So far, measuring petPAHs in bile has only occurred in fish, as sampling bile from live mammals requires surgery, and many bird species do not have gall bladders.

Several investigators have examined the effect of petroleum exposure on blood parameters (cell counts, serum chemistry, inflammatory response components), and in turn how those blood changes can be used as indicators of petroleum exposure. Changes in acute phase proteins and cytokines (e.g. elevated IL-6, haptoglobin and creatine kinase) have been correlated with probable petroleum exposure in river otters (Duffy et al., 1993; Duffy et al., 1994; Duffy et al., 1994a). It has been suggested that haptoglobin may also be an indicator of petroleum exposure in seabirds as well (Prichard et al., 1997). Hemolytic anemia, often presenting as a Heinz-body anemia, is considered a hallmark of acute petroleum toxicity (Leighton et al., 1983): detecting hemolytic anemia in an animal suspected of having ingested a petroleum product would be indirect evidence of exposure. Hemosiderosis, or the excessive deposition of hemosiderin in the tissues of vertebrates, usually as a result of excessive destruction of red blood cells, was assessed in oiled and rehabilitated Common Murres (*Uria aalge*) (Khan and Nag, 1993). Severity of hemosiderosis was found to correlate with length of time since oil exposure. The authors surmised that hemosiderosis was a useful indicator of hemorrhage/anemia following oil exposure, and to some extent, was a measure of severity of exposure.

Red blood cell damage is thought to be so predictable that an in-vitro assay that detects oxidative damage to red blood cells by petroleum PAHs has been developed, and can be used to assess the comparative toxicity of petroleum oils in different mammalian and avian species (Couillard and Leighton, 1993).

Another indirect measure of exposure to petroleum is the measurement of genotoxicity. In

this method, flow cytometry (which measures relative DNA quantities per cell) is used to detect changes in nuclear DNA that result from breakage of chromosomes induced by clastogenic (i.e. capable of inducing disruption or breakage) agents, and petPAHs are known clastogens. Such changes result in a higher coefficient of variation (CV) in DNA content, and the CV can be compared among groups. For example, a study of tissues from mink exposed experimentally to crude and fuel oils showed genotoxic effects in spleen-derived cells, and in blood collected from free-ranging sea otters (*Enhydra lutris*) from the Exxon Valdez spill area (Bickham et al., 1998). In fact, this study also showed possibly heritable changes in genome size in mink experimentally exposed to oil. The method was first described for use in detecting petroleum exposure in wildlife in 1988 (McBee and Bickham, 1988) and the method has been used to demonstrate genotoxic effects in Black-crowned Night Herons (*Nycticorax nycticorax*) from areas heavily contaminated by petrochemicals (Custer et al., 1994). Another study applied these techniques to aquatic turtles affected by radiation damage (Bickham et al., 1988), suggesting that the use of flow cytometry to assess exposure to contaminants is applicable to reptiles (i.e. sea turtles).

Another method used to quantify petroleum PAH DNA adducts is the 32P-postlabelling method, in which radioactivity is incorporated into DNA adducts via phosphorylation with 32P, and the radioactivity measured. This results in a highly sensitive technique for detecting genotoxic activity of petroleum PAHs. This technique has been used to detect PAH-DNA adducts in the livers of beluga whales (*Delphinaptera leucas*) living in the St. Lawrence River (Ray et al., 1991), and more recently to detect DNA adducts in the skin of mice exposed externally to various petroleum distillate fractions (Booth et al., 1998).

Other genetics-based methods for detecting petroleum exposure in marine organisms include a short-term, semi-automatic bacterial genotoxicity assay called the SOS Chromotest, which is based on the error-prone DNA repair pathway of *Escherichia coli*, detects DNA-damaging agents in water, sediment or soil samples, but can also be used to detect genotoxic substances in

biological samples such as urine, feces, and tissue extracts. The SOS Chromotest was used to positively detect chromosomal damage in tissues of mussels and clams collected from a bay in Quebec known to be heavily contaminated by PAHs (White et al., 1997). The advantages of this bioassay are that results can be obtained in a single work day and sterility of the sample is usually not required.

Minisatellite DNA, which are tandemly-repeated sequence elements of DNA, may function as sensitive biomarkers for heritable mutations induced by exposure to environmental toxins like petPAHs. A study of germ-line minisatellite DNA in Herring Gulls (*Larus argentatus*) from heavily-polluted areas (pollutants not specified) showed elevated mutation rates, suggesting that pollutant exposure was linked to genetic damage (Yauk and Quinn, 1998).

Of note is the fact that the human HPRT mutant lymphocyte assay, which detects somatic cell mutations in the *hpert* gene and is most commonly used to detect genetic damage due to exposure to environmental contaminants, has been adapted for use with California sea lion (*Zalophus californianus*) cells (Hastings et al., 1998). Though it has not yet been used to detect petroleum exposure, it will likely be applied in this manner in the future.

The possibility of measuring porphyrins and their metabolic reaction products in wildlife as indicators of exposure to environmental contaminants has been raised as well (Duffy et al., 1995).

Medical Effects of Oil on Marine Wildlife

Review

Exposure to petroleum products is toxic to wildlife, depending upon mode of exposure, duration of exposure, characteristics of the product (e.g. crude vs. refined, fresh vs. weathered), species sensitivity, age and health status of the individual, and numerous other variables. It is beyond the scope of this document to thoroughly review every paper published on the toxic effects of oil on wildlife. Rather, the purpose of this section is

to briefly summarize the effects of oil on wildlife (primarily seabirds and sea otters) and then review research published since 1990. This is followed by a bibliography of papers on the toxic effects of oil on wildlife.

The effects of oil on wildlife was recently and thoroughly reviewed (Jessup and Leighton, 1996). Most research conducted on the effects of oil on wildlife has focused on birds and sea otters, and a few have even addressed the effects of oil contamination on polar bears (Hurst and Oritsland, 1982; Hurst et al., 1991). Birds exposed to petroleum products exhibit a number of pathologic conditions and lesions as a consequence of exposure (Hartung, 1966; Hartung, 1967; Szaro, 1979; Lambert, 1982; Pattee, 1982; Fry, 1985; Leighton, 1985; Leighton, 1985b; Leighton, 1986; Fry, 1987; Peakall et al., 1987a; Hughes et al., 1990; Khan, 1991; Khan and Nag, 1993; Jenssen, 1994; Lusimbo and Leighton, 1996). Upon clinical presentation, oiled birds are often hypothermic, lethargic to comatose, hypoglycemic, hypoproteinemic, and/or anemic. Animals may be in respiratory distress, seizing, or have diarrhea, often bloody. Corneal ulceration and chemical burns of feathered and non-feathered skin and mucous membranes are common. In addition to anemia (characterized by anisocytosis, poikilocytosis, reticulocytosis, and Heinz body formation, likely due to oxidative damage to red blood cells), hypoproteinemia and hypoglycemia, and other hematologic and serum chemistry abnormalities are common. Depending on how long the bird has been exposed to oil, the bird may show weight loss. Histopathologic lesions that have been reported in the literature associated with oiling include aspiration pneumonia, ulcerative gastroenteritis, anemia, hemosiderosis, hepatic necrosis and/or lipidosis, pancreatitis and/or acute exocrine pancreatic insufficiency, renal tubular necrosis, salt gland hypertrophy, adrenocortical hyperplasia and adrenal necrosis, thymic atrophy and atrophy of the Bursa of Fabricius. Other effects include impaired growth.

Effects in sea otters include many of these same clinical signs and histopathologic lesions, including hypothermia, increased metabolic rate, gastrointestinal hemorrhage and ulceration, congestion and/or necrosis of the liver, kidneys,

brain and lungs, chemical burns to the interdigital webbing of the hind feet, and corneal and mucous membrane burns (Costa and Kooyman, 1982; Davis et al., 1988; Williams et al., 1988; Geraci and Williams, 1990; Lipscomb et al., 1993; Williams et al., 1995; Williams et al., 1995a). Studies of the clinical effects of oil exposure on pinnipeds and cetaceans have been reviewed (Engelhardt, 1985; Loughlin, 1994; Williams and Davis, 1995). Documented clinical and histopathologic effects in pinnipeds include ambulatory difficulty, thermoregulatory imbalance, conjunctivitis and corneal edema, gastrointestinal irritation, and liver and renal tubular necrosis (Davis and Anderson, 1976; Geraci and Smith, 1976; Engelhardt et al., 1977; Engelhardt, 1985; Geraci and St. Aubin, 1988).

There is little information regarding the medical effects of oil exposure on sea turtles. Juvenile loggerhead sea turtles experimentally exposed externally to South Louisiana crude oil (with probable unintended ingestion) exhibited multiple skin lesions including epidermal dysplasia and acute inflammatory infiltrates (Lutcavage et al., 1995).

It is important to remember that in most of these studies, a direct link between described lesions and oil exposure is not made, and that many of these lesions may be related to captivity stress or other underlying factors. Also, some studies show little to no signs of toxicity with petroleum exposure: for example, in a controlled experiment in which captive mallards (*Anas platyrhynchos*) and ferrets were administered weathered *Exxon Valdez* crude oil (WEVC) either acutely or dietarily, WEVC was found to be non-toxic to birds at doses of >5 g/kg body weight or 50,000 ppm in the diet (Stubblefield et al., 1993). This is considered practically non-toxic by U.S. EPA standards. In an assessment of the potential long-term toxicological effects of the *Exxon Valdez* spill on wildlife, the author concluded that there was little chance of long-term sublethal effects of oil exposure on wildlife (Hartung, 1995).

Recent research on the effects of oil on marine wildlife can be broadly categorized as falling under the following topics: Effects on the immune system, effects on plumage, and effects on hematology.

Effects on the Immune System

An area of wildlife toxicology receiving quite a bit of attention is the immunopathology of pollutant exposure. Most research on marine wildlife toxicology is focused on the effects of the halogenated hydrocarbons (PCBs, DDT, dioxins), but the effects of petroleum products on immune function is garnering increasing attention, and much of what is being learned about the effects of PCBs on immune function may well prove to be applicable to oil toxicity studies.

Marine wildlife ecotoxicology has taken this turn in part because of the recent rise in large-scale disease outbreaks in marine mammals. Necropsies of bottlenose dolphins (*Tursiops truncatus*) that stranded along the Atlantic coast in 1987-1988 and along the Gulf of Mexico in 1990 and 1992, and of dying striped dolphins (*Stenella coeruleoalba*) in the Mediterranean Sea, showed numerous opportunistic infections indicative of immune dysfunction. In a study examining the relationship between contaminant exposure and immune suppression in free-ranging bottlenose dolphins from the Atlantic coast, whole blood concentrations of PCBs and DDT were negatively correlated with the degree of peripheral blood lymphocyte responses in vitro (Lahvis et al., 1995): lymphocyte responses to the mitogen concanavalin A and phytohemagglutinin were reduced in animals with higher levels of PCBs and DDT, supporting the idea that these contaminants reduce immunocompetence in this species. In an experiment involving captive harbor seals (*Phoca vitulina*) fed herring from the heavily polluted Baltic Sea, seals fed organochlorine-contaminated fish exhibited high tissue contaminant levels and much reduced lymphocyte responses to mitogens and rabies and tetanus toxoid antigens (de Swart et al., 1995; de Swart et al., 1996). After 2 years on the experimental diets, seals fed contaminated fish exhibited impaired T-cell mediated immune responses. Interestingly, humoral immunity seemed unaffected by contaminant exposure.

Research on the immune function of wildlife species is predicated on knowledge of the components of the immune system. Recent studies describing leukocyte physiology, and cytokines

and/or the genetic encoding of these proteins, such as interleukin-2 in orca (*Orcinus orca*) (Ness et al., 1998), interleukin-6 in harbor seals (*Phoca vitulina*), orca and southern sea otters (*Enhydra lutris*) (King et al., 1996), and MHC-1 in harbor seals (*Phoca vitulina*) (Zhong et al., 1998) have been conducted. Effects of petroleum product exposure on seabird immunology was recently reviewed (Briggs et al., 1996).

Effects of oiling on river otters were studied in the aftermath of the *Exxon Valdez* spill. River otters inhabiting oiled areas of Prince William Sound exhibited elevated levels of blood haptoglobin (an acute-phase protein) and interleukin-6 up to 2 years after the spill, compared to river otters in un-oiled areas (Duffy et al., 1993; Duffy et al., 1994) but showed evidence of recovery within 3 years of the spill (Duffy et al., 1994a).

Effects on Plumage

Oil on feathers severely reduces a bird's ability to float and thermoregulate, as the physical presence of oil on feathers disrupts the normal architecture of the feather, allowing water to "leak" through the plumage to the skin. Studies of the effect of oiling on thermoregulation and metabolism in birds were some of the more common studies conducted early on, and research continues. For example, Common Eiders (*Somateria mollissima*) were found to be more susceptible to the negative thermoregulatory effects of crude oil-dispersant mixtures on their plumage than mallards, and both species were more susceptible to crude oil-dispersant mixtures than to crude oil alone (Jenssen and Ekker, 1991). The authors felt that the species difference in susceptibility was probably due to specific differences in plumage structure, e.g. birds possessing air-filled plumage with high insulative properties, like Common Eiders, are more vulnerable than species with plumage that doesn't offer as much resistance to heat loss. This study also found that the metabolic rate of the mallards was higher 2-3 days after oiling vs. 2-3 hours after oiling, presumably because at that point, the birds had preened the oil deeper into their feathers, exacerbating the problem.

Another recent study evaluated the differential “wettability” of molt vs. non-molt feathers from ducks and geese encountering surface-active organic pollutants like petroleum products and other oils (Stephenson, 1997): this study found that the contour plumage of molting Lesser Scaup (*Aythya affinis*) are more easily penetrated than non-molting plumage.

Effects on Hematology

Hemolytic anemia, the hallmark of oil toxicity in seabirds first characterized in the early 1980s (Leighton et al., 1983), continues to be demonstrated in studies of the effects of oil on seabirds. In a bunker C fuel oil spill in Japan, White-winged Scoters (*Melanitta fusca*), Black Scoters (*Melanitta nigra*) and Oldsquaw (*Clangula hyemalis*) exhibited regenerative anemia on day 12 after exposure (Yamato et al., 1996). The hematology of oiled and rehabilitated birds has been compared to non-oiled, control birds (Newman et al., 1997): rehabilitated birds showed significantly lower hemoglobin, creatine kinase, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase, calcium, total protein and globulin, while white blood cell count and calcium concentrations were significantly higher in rehabilitated birds compared to control birds.

River otters inhabiting oiled areas of Prince William Sound exhibited elevated serum levels of the enzymes aspartate aminotransferase, alanine aminotransferase and creatine kinase up to 2 years after the spill compared to river otters in un-oiled areas (Duffy et al., 1994).

Juvenile loggerhead sea turtles (*Caretta caretta*) experimentally exposed to South Louisiana crude oil exhibited anemia (reduced red blood cell counts and red blood cell polychromasia, indicative of a regenerative response) and elevated white blood cell counts (Lutcavage et al., 1995).

Breeding Magellanic Penguins lightly oiled in an accidental spill off Argentina exhibited reduced body mass and lower levels of reproductive hormones (testosterone, dihydrotestosterone, estradiol and luteinizing hormone) and higher corticosterone than non-oiled birds (Fowler et al., 1995), and this was correlated with reduced reproductive success on colony.

Bibliography of Effects of Oil on Wildlife

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Rehabilitation

In this section, techniques for ameliorating the toxic effects of oil on wildlife are reviewed, specifically: removing oil from fur and feathers; anesthetizing marine birds, turtles and mammals; evaluating capture and captivity stress; diseases and disease diagnosis in these species; and new medical procedures. For the most part, papers published since 1990 are reviewed. The reader is also referred to several excellent books, and reports and proceedings which go into great detail on the medical management and rehabilitation of marine species, such as Williams, 1985; Harrison and Harrison, 1986; Dierauf, 1990; Williams, 1990; Williams, 1993; Ritchie et al., 1994; and Williams and Davis, 1995.

Removing Oil from Fur and Feathers

Methods for thoroughly removing oil from bird feathers and evaluating waterproofness of plumage were tested as early as 1973, (e.g. Naviaux and Pittman, 1973; Jenssen and Ekker, 1988) and continue. Most recently, a method for objectively evaluating the efficacy of various types of surfactants for removing petroleum products from feathers was developed and used to test commercially-available surfactants (Bryndza et al., 1995). These investigators formulated a contaminating "oil" comprised of 13 polycyclic aromatic hydrocarbons, which were chosen based on the fact that they represented the types of compounds present in light petroleum mixtures such as diesel fuel and light crude oils. By using an "oil" for which all components and relative concentrations of these components were known, the investigators could accurately measure these components on feathers post-cleaning, allowing for an objective evaluation of surfactant efficiency. Plucked contour feathers from Snow Geese (*Chen caerulescens*) were oiled and then cleaned with several different commercially available surfactants in both hard and soft water. In general, the shampoos and liquid dishwashing detergents were most effective, with Dawn dishwashing detergent being the most effective of the surfactants tested in the study. Five percent solutions of Dawn were no more effective than 2 percent solutions in removing hydrocarbon mixtures from feathers.

Researchers evaluated the impact of water temperature on core body temperature of North American river otters during simulated oil spill recovery washing protocols using internal radiotelemetry temperature sensors (Stoskopf et al., 1997). They found that washing otters in warm water (38.4 degrees C) allowed otters to maintain a stable core temperature, whereas washing otters in cold water (24 degrees C) caused core temperature to drop at 0.1 degrees C/min during the wash procedures. However, otters rinsed in warm water experienced core temperatures decreasing at the same rate as during the cold water procedures, but the decline didn't begin until the rinsing stage, and core temperature never dropped below 35 degrees C. The investigators attributed this drop to a failure to completely dry the washed otter's fur after rinsing.

Anesthesia

Pinnipeds: Several papers have been published in the scientific literature regarding anesthesia in seals and sea lions. California sea lions (*Zalophus californianus*) have been successfully immobilized with a variety of both injectable and inhalational anesthetic agents. Detomidine (at 40-55 ug/kg) combined with ketamine (at 2-4.3 mg/kg) was used to induce 4 adult male California sea lions (Heard and Beusse, 1993); anesthesia was maintained with isoflurane gas via endotracheal tube. Recovery from anesthesia was smooth. This induction/maintenance combination was qualitatively considered to be very effective in immobilizing adult male California sea lions, with detomidine at 40 ug/kg and ketamine at 3.0-4.0 mg/kg being the most effective dosages. Apnea (breath-holding) was overcome by twisting the ears of the sea lions. Electrocardiographs obtained on each animal revealed similar patterns, with small R and deep S waves. Heart rate varied from 52-90 bpm, and respiratory rate varied from 12-28 bpm. Oxygen saturation as obtained via pulse oximetry ranged from 89-99 percent. Yohimbine was used at 80 ug/kg IM to reverse the detomidine, and seemed to hasten recovery in one sea lion.

California sea lion pups (n=115) were successfully immobilized with the inhalational agent isoflurane alone (no injectable anesthetic agents given), administered via mask and then endotracheal tube (Heath et al., 1997). Sea lion pups showed more rapid anesthetic induction and recovery compared to domestic animals anesthetized with isoflurane alone. Adult and newborn California sea lions (n=30) were anesthetized using the inhalational agent halothane only (Work et al., 1993): induction times and recovery times were longer than with isoflurane, which is generally true with halothane versus isoflurane in all species.

Adult Steller's sea lions (*Eumatopius jubatus*) (n=56) were administered tiletamine/zolazepam via remotely delivered darts at dosages of 1.6-3.3 mg/kg and then maintained on the inhalational agent isoflurane delivered via an endotracheal tube (Heath et al., 1996). The authors felt that tiletamine/zolazepam provided a large degree of chemical restraint which potentiated the anes-

thetic period, and that isoflurane provided complete anesthetic control, minimized the need for injectable drugs, provided an excellent recovery, and was safe. Three animals died of anesthetic complications. Adult female Juan Fernandez fur seals (*Arctocephalus philippii*) (n=22) were chemically immobilized with a combination of ketamine (2.16-6.76 mg/kg) and diazepam (0.04-0.28 mg/kg) injected intramuscularly or intravenously after the animal was captured and physically restrained (Sepulveda et al., 1994). Induction time averaged 15 minutes and recovery time averaged 47 minutes with intramuscular delivery, and 0.6 minutes and 26 minutes, respectively, in animals injected intravenously. Not all immobilizations were complete, and two animals died. The authors concluded that intravenous ketamine/diazepam combinations resulted in rapid induction and better degrees of immobilization compared to intramuscular administration, but that IV administration resulted in significant tachycardia and hyperthermia compared to the IM route. The authors hypothesized that this may have had more to do with the fact that animals were in an agitated/excited state when initially injected, rather than a calm or resting state, as would be achievable if drugs were remotely delivered rather than hand-injected.

Several cyclohexamine-based drug combinations (e.g. ketamine or tiletamine with either a benzodiazepine or an alpha-2 agonist) were tested on adult female Southern elephant seals (*Mirounga leonina*) (n=75) (Woods et al., 1994). Drugs were delivered by remote injection, and all animals received atropine along with the immobilizing agents in order to decrease respiratory secretions. All combinations proved effective in immobilizing Southern elephant seals, and exhibited advantages and disadvantages. For example, seals given the ketamine/xylazine combination were more sedated and had better analgesia and skeletal muscle relaxation than animals immobilized with the other combinations. Three of the animals receiving tiletamine/zolazepam showed hallucinatory behavior during recovery. Some of the animals receiving ketamine/diazepam exhibited prolonged apnea and upper respiratory tract obstruction. The authors concluded that for researchers or managers with little experience anesthetizing elephant

seals, tiletamine/zolazepam offered advantages in preparation, predictability and dosage over the other combinations. These same authors published results of a study evaluating various antagonists of cyclohexamine-based drug combinations, e.g. 4-aminopyridine, yohimbine, doxapram, and sarmazenil (Woods et al., 1995). The antagonist 4-aminopyridine usually induced shaking and actually prolonged the time until recovery. Yohimbine at 0.06 mg/kg was effective in reversing ketamine/xylazine anesthesia. Doxapram was preferable to sarmazenil in reversing ketamine/diazepam anesthesia. Doxapram was ineffective in reversing tiletamine/zolazepam anesthesia, and sarmazenil was partially effective. However, the authors concluded that antagonism of the cyclohexamine/benzodiazepene combinations were not indicated due to the normal rapid onset and recovery from these combinations without antagonists. Two animals became blind during administration of ketamine/diazepam with sarmazenil reversing, and ketamine/diazepam with 4-aminopyridine reversing. The authors could not explain the onset of blindness in this study. These same authors published results of a study about the use of medetomidine, ketamine and atipamezole to chemically immobilize southern elephant seals, comparing their results with the use of other cyclohexamine-based combinations (Woods et al., 1996). They found that medetomidine alone did not give sufficient restraint, and the addition of atipamezole had little effect on the level or duration of restraint. They concluded that ketamine and medetomidine offered few advantages over ketamine and xylazine.

Juvenile southern elephant seals (<3 yrs old) (n=32) were immobilized with intravenous ketamine at estimated dosages of 2-3.0 mg/kg and diazepam at 0.05-0.2 mg/kg (Slip and Woods, 1996). Seals were manually restrained while receiving injections. Drug dose did not correlate with prolonged apnea. The authors concluded that manual restraint and intravenous injection of drugs provides a safer, faster and more predictable method of immobilization than intramuscular injections.

Juvenile Pacific harbor seals (*Phoca vitulina richardsii*) have been successfully anesthetized

with the injectable agent propofol, as well as with propofol in combination with isoflurane (Gulland et al., 1999).

While Weddell seals do not range off the California coast, the following study is included in this review because it evaluates the use of a single injectable immobilizing agent in a phocid. Tiletamine/zolazepam (1:1 ratio, Zoletil) at a dosage of 0.29-1.08 mg/kg IM was used to immobilize Weddell seals via a hand-held syringe, with mean time to immobilization of approximately 15 minutes, and a duration of full immobilization of approximately 23 minutes (Phelan and Green, 1992). The mean dose for fully immobilized seals was $0.78 + 0.14$ mg/kg. The authors observed a range of degrees of immobilization, from full immobilization to only light sedation. The mortality rate for the study group was 10 percent (3/30 animals): mortality was attributed to prolonged apnea with no response to respiratory stimulants (doxapram hydrochloride). Several animals required intravenous doses of tiletamine/zolazepam (50-100 mg) to achieve/maintain full immobilization. Doxapram hydrochloride was used to counteract apnea in several animals. Hypersalivation was not observed.

Sea otters: The *Exxon Valdez* oil spill afforded veterinarians with the opportunity to evaluate the efficacy of several injectable immobilizing agents in sea otters (*Enhydra lutris*). Several agents were used to aid treatment of *Exxon Valdez* otters, including butorphanol, fentanyl, meperidine and oxymorphone, used alone or in combination with acepromazine, azaperone and diazepam (Sawyer and Williams, 1990). Naloxone was always used to reverse the opioids. Based on experiences gained during the *Exxon Valdez* spill, the injectable anesthetic of choice was fentanyl (0.09-0.22 mg/kg) used in combination with azaperone (0.5 mg/kg) or acepromazine (0.05 mg/kg) or diazepam (0.2-0.5 mg/kg) (Sawyer and Williams, 1996; Sawyer and Williams, 1990). These findings corroborated an earlier published study reporting on the efficacy of fentanyl (0.05-0.11 mg/kg) and azaperone (0.11-0.45 mg/kg) for producing neuroleptanalgesia in sea otters (Williams et al., 1981). The combinations used during the *Exxon Valdez* spill provided up to 2.5 hours of immobilization, which provided adequate time for clean-

ing and treating otters. The fentanyl was effectively reversed with naloxone. Of note is the fact that isoflurane anesthesia used to immobilize two sea otters resulted in the death of both animals: the authors hypothesized that the isoflurane solubilized petroleum residues present in the upper respiratory tracts of the animals, leading to increased inhalation and absorption of these products. In a study evaluating the efficacy of meperidine, diazepam, xylazine, azaperone, fentanyl, ketamine and nalbuphine for short term sedation (not anesthesia) of adult male Alaskan sea otters, meperidine (11-13.2 mg/kg) in combination with diazepam (0.22-0.55 mg/kg) proved to be the safest and most reliable because it was reversible and did not result in residual lethargy (Joseph et al., 1987).

River otters: Translocation programs for North American river otters (*Lutra canadensis*) in North Carolina have allowed for detailed evaluations of methods for immobilizing river otters (Spelman et al., 1994; Spelman et al., 1997; Spelman et al., 1997a). Based on the authors' experience, tiletamine/zolazepam at 4 mg/kg administered intramuscularly is recommended for short-term anesthesia in otters, with flumazenil (at 1 mg/25 mg zolazepam) administered to partially antagonize the zolazepam after 20 minutes of anesthesia (Spelman et al., 1997a). Flumazenil shortened recovery time considerably. A combination of ketamine (10 mg/kg)/midazolam (0.25 mg/kg) or medetomidine (25ug/kg)/ketamine (2.5 mg/kg) administered intramuscularly was also effective for short anesthetic procedures (20-25 minutes) in river otters (Spelman et al., 1994). Atipamezole at 50-200 ug/kg reversed the medetomidine well and allowed for rapid recovery. Higher doses of medetomidine (50 ug/kg) in combination with ketamine are required for longer procedures. A combination of ketamine (at a mean dose of 17 mg/kg), xylazine and acepromazine administered intramuscularly was used to immobilize river otters (Hoover, 1985; Hoover and Jones, 1986). These studies reported on various physiologic parameters and ancillary monitoring of river otters during immobilization, such as rectal temperature, heart rate and electrocardiograms. Another study reported on post-anesthetic core body temperature fluctuations

after immobilization of river otters (Spelman et al., 1997).

Sea Turtles: Kemp's Ridley sea turtles (*Lepidochelys kempi*) (n=9) were successfully anesthetized with the inhalational agent isoflurane. Isoflurane anesthesia resulted in 7-minute inductions and recovery times of approximately 241 minutes (range: 1.5-7.5 hours) (Moon and Stabenau, 1996). The induction time was rapid, presumably because the authors intubated turtles while awake and performed positive pressure ventilation to induce. The prolonged recovery phase was characterized by hypoxemia, acidemia, hypercapnia and lactic acidosis, and was believed to be due either to ventilation/perfusion mismatch or intracardiac shunting. Despite the prolonged recovery, all turtles recovered from isoflurane anesthesia without apparent adverse effects within 24 hours. Green sea turtles (*Chelonia mydas*) were anesthetized with either pentobarbital or thiopental injected intravenously into the dorsal cervical sinus, or ketamine injected intramuscularly, intraperitoneally, or intravenously (Wood et al., 1982). Pentobarbital at 10 mg/kg IV as an initial dose with subsequent supplemental doses of 5 mg/kg at 15-30 minute intervals up to a total dose of 25 mg/kg provided good anesthesia. Induction and recovery times can be long with pentobarbital, however. Thiopental at 20 mg/kg IV provides more rapid induction and recovery compared to pentobarbital, but was ineffective in inducing anesthesia 10 percent of the time. Supplemental dosing with thiopental is not recommended due to the narrow therapeutic margin with this drug compared to pentobarbital. Ketamine was most effective when administered intraperitoneally at fairly high doses (up to 71 mg/kg). Induction is rapid, duration of anesthesia is short, and recovery time is rapid with ketamine IP.

Birds: Very few published papers specifically address anesthesia of marine/estuarine birds. In general, the body of knowledge on the use of inhalant and injectable anesthetics for avian patients can be applied to wild birds, including pelagic species. For example, the use of the injectable anesthetic agent propofol in birds is gaining increasing attention (e.g. Fitzgerald and Cooper, 1990; Lukasik et al., 1997) and will likely

prove to be an excellent alternative to inhalant anesthetics when the use of gas anesthesia is contraindicated. Also, the use of pulse oximetry for monitoring the anesthetized bird was reviewed, and found to be unsatisfactory for routine use on birds because of motion artifact (Schmitt et al., 1998). Of perhaps more specific relevance to the rehabilitation of oiled birds is a paper on the response of Bald Eagles to gas anesthesia (Aguilar et al., 1995): Bald Eagles have been found to develop cardiac arrhythmias under isoflurane anesthesia.

Captivity Stress

In the last 10-15 years there has been increased attention paid to the impact of capture and captivity stress on animals, including marine animals. The nature of the stress response in bottlenose dolphins (*Tursiops truncatus*) was studied by examining the effects of handling and exogenous adrenocorticotropic hormones on adrenocortical hormones, white blood cells and on selected serum constituents influenced by exertional stress in dolphins (Thomson and Geraci, 1986). Captive dolphins were either subjected to a chase-capture corralling procedure prior to being restrained for 6 hours, or captured quickly (calm-capture) with as little herding as possible. Dolphins were also administered an adrenocorticotropic hormone (ACTH) stimulation test and blood samples collected subsequent to ACTH stimulation. Resting serum cortisol concentrations were determined to be 30-40 nmol/L, which is comparable to other mammalian species. A stress response was evoked even under the calmest conditions of capture achievable: by 1.5 hours post-capture, cortisol concentrations had peaked and stabilized at 80-120 nmol/L. This 4-fold increase in serum cortisol is comparable to the elevations seen in other free-ranging mammals under capture conditions. Cortisol increased 3 to 4-fold after ACTH administration, which was lower than expected: the authors surmised that this was most likely due to the fact that the adrenal cortex had already been maximally stimulated by capture and handling. Eosinophils appeared to be the best indicator leucocyte for the dolphin stress response: eosinophil counts decreased rapidly and significantly in stressed

dolphins. The authors noted that it was significant that the dolphins in this study, which had been held in captivity for many years and handled routinely, continued to exhibit such a significant stress response.

In a study of the effects of internal oil exposure on captive Rhinoceros auklets (*Cerorhinca monocerata*), investigators found that the auklets were more profoundly affected by capture and captivity than by ingestion of oil, at least as far as blood cell parameters were concerned (Newman et al., 1998a). Anemia developed in both oil-exposed and unexposed birds within 3 weeks of capture. In a study examining the effects of capture and blood-sampling stress on adrenal and reproductive hormone levels in free-ranging incubating Semipalmated Sandpipers (*Calidris pusilla*), researchers found that corticosterone levels increased dramatically within 30 minutes of capture, and in fact, doubled within 1 minute of handling and bleeding (Gratto Trevor et al., 1991). Changes in testosterone levels depended upon the level of testosterone prior to the onset of capture stress: birds with high levels showed a decrease, and birds with low levels showed an increase in testosterone with stress. Prolactin levels decreased within 15-30 minutes of handling in both sexes, and progesterone levels increased dramatically. Overall, handling time seemed to have no significant or consistent effect on degree of alterations of hormone levels. In another study evaluating the adrenocortical response to capture stress on two shorebird species, Semipalmated Sandpipers (*Calidris pusilla*) and Western Sandpipers (*Calidris mauri*), the highest levels of corticosterone were detected in autumn migrating birds compared to breeding and spring migrating birds (O'Reilly, 1997).

A study evaluating the stress response in domestic geese made use of chronically-catherized birds from which blood samples could be drawn from another room, eliminating the effect of the stress of human presence and handling on the stress response (LeMaho et al., 1992). They compared plasma catecholamines and plasma corticosterone between these geese and completely habituated, outwardly "unstressed" geese, and found that even in the habituated calm birds, serum catecholamines and corticosterone

were significantly elevated when compared to basal levels in the birds from which blood samples could be collected remotely. Based on their results, they concluded that even in the most outwardly calm animal, the stress of physical restraint and handling affects the stress response.

Adrenocortical response to capture stress was found to exhibit variation depending upon age in Leach's Storm Petrels (*Oceanodroma leucorhoa*): younger birds exhibited much more pronounced elevations in serum corticosterone in response to capture stress compared to breeding adults (O'Reilly, 1996). Herring gulls (*Larus argentatus*) held in captivity over 3 years showed lower serum IgG levels than their free-living counterparts (Braune et al., 1993); this same study measured immune responsiveness of captive gulls via various assays testing phagocytic, cell-mediated and humoral immune function. However, the paper is brief and gives scant detail on the methods for sampling both captive and free-ranging gulls, and therefore are difficult to evaluate.

The stress response of free-ranging Xantus' Murrelets (*Synthliboramphus hypoleucas*) subjected to three different restraint procedures, which varied in terms of time held in boxes before handling, showed that birds handled the soonest post-capture showed the least signs of capture stress (e.g. lower corticosterone levels, basophil counts and heterophil:lymphocyte ratios) compared to the birds held for longer periods of time (Newman et al., 1998). The researchers found that once the birds were held longer than 10 minutes, it didn't matter whether they were held an additional period of time in terms of stress parameters. Similarly, the stress response of free-ranging Common Diving Petrels (*Pelecanoides urinatrix*) captured at sea showed 4-fold elevations in plasma corticosterone within 30 minutes of capture (Smith et al., 1994). Interestingly, petrels caught during a winter storm, with high winds, heavy snow and zero visibility, exhibited significantly elevated corticosterone levels immediately after capture and no increase with time post-capture, indicating the birds were maximally stressed by the inclement weather conditions.

The acute captivity stress of wild loggerhead sea turtles (*Caretta caretta*) was evaluated utilizing plasma corticosterone concentrations (Gregory et

al., 1996): loggerhead turtles exhibited increased plasma corticosterone concentrations with capture, restraint and multiple blood sampling over a 6 hour period, with peaks in plasma corticosterone seen 3 hours after capture. The increase was over 7-fold after 30 minutes of restraint in some animals. Increases in plasma corticosterone was highly variable between individuals, however. Mean initial corticosterone concentrations of turtles captured by tangle net are among the lowest values reported for reptiles, and therefore represent a unique data set for free-swimming *Caretta caretta* and may be indicative of baseline levels of corticosterone in this species. Corticosterone levels were higher in summer vs. winter in small loggerheads, but not in large loggerheads. Plasma corticosterone levels in large females sampled during the breeding season did not show elevations at 1 hour post-capture, indicating that breeding adults are less susceptible to acute stressors.

A study of adrenal and hematological responses to stress in juvenile green turtles (*Chelonia mydas*) provides not only baseline adrenocortical, hematological, and plasma biochemical values for clinically healthy juvenile green turtles, but also found that juvenile turtles with green turtle fibropapillomas showed evidence of chronic stress and immunosuppression (Aguirre et al., 1995).

Diseases and Diagnostics

While we have included at the end of this section an extensive bibliography of papers on diseases of marine species, we thought it was important to describe more specifically results of recent research, information regarding emerging diseases of marine species, and development of diagnostic techniques for diseases in marine species. In this section we focus on studies published since 1990.

An immunoassay has been developed in order to detect marine caliciviruses (Ferris and Oxtoby, 1994). This test is apparently much more sensitive compared to other available tests (e.g. complement fixation, virus neutralization), and is easy and quick to perform. An immunoassay that is inexpensive and could be used in the field (i.e. does not require a special laboratory set-up) has also been developed to detect type C botulinum

toxin (*Clostridium botulinum*) in wild waterbirds (Rocke et al., 1998): when adequate volumes of blood (>1.0 ml) are available, this test is as sensitive and specific as the mouse bioassay for detection of botulism in bird blood contaminated with known quantities of botulinum toxin.

In order to better interpret data from pinnipeds for the purposes of modelling diving physiology, hematocrits were measured using two different techniques (Coulter counter vs. microcentrifugation) in seals under varying conditions (e.g. restrained vs. resting, pups vs. adults, etc.) (Castellini et al., 1996). The data showed that the Coulter counter hematocrit values were 4-15 percent higher than values obtained for microcentrifuged samples, hematocrits from restrained animals were higher than hematocrits from resting animals, adult hematocrits were higher than pup hematocrits, and hematocrit values declined over the course of isoflurane anesthesia. The results of this study suggest that laboratory methods, age of animal and handling methods significantly affect hematocrit values in pinnipeds.

Methods for successful ultrasonographic imaging of the reproductive tract of Kemp's ridley sea turtles (*Lepidochelys kempi*) using B-mode real-time scanners have recently been described (Rostal et al., 1990). This paper describes proper positioning of the turtle and scanner for optimal "windows" into the coelomic cavity.

A commercially available enzyme immunoassay (EIA) for detecting progesterone in horses was tested for its efficacy in accurately measuring progesterone in bottlenosed dolphin (*Tursiops truncatus*) serum compared to the more laborious and expensive radioimmunoassay (RIA) (Owen, 1990). Results of the comparative study suggest that the EIA is as accurate as the RIA in measuring serum progesterone in dolphins, meaning that quick detection of pregnancy is possible for dolphins brought into a rehabilitation center after an oil spill.

Special Procedures

There have been several publications describing new procedures and techniques pertinent to the clinical care of marine mammal and avian species

in the rehabilitation setting. For example, the efficacy of rectal fluid therapy for correction of dehydration in avian patients was evaluated experimentally (Ephrati and Lumeij, 1997): rectal catheters inserted through the coprodeum 6 cm into the intestine of pigeons were attached to infusion pumps and an oral rehydration solution was administered at a rate of 1.5 ml/hour (mean body weight was 436 g). This method of fluid administration was effective in 4 of 6 birds treated for dehydration, as indicated by the correction of blood parameters indicative of dehydration back to within normal limits.

There is a recent thorough and practical review of blood transfusions in avian patients which describes the costs and benefits of homologous and heterologous blood transfusions in birds, as well as various recommendations for when to consider giving a bird a transfusion (Shimmel et al., 1996), including recommendations for oiled seabirds. A recent paper critically evaluates three different heat sources for maintaining core body temperature in avian patients (Phalen et al., 1996): an overhead radiant heat source was found to be more effective in maintaining core body temperature in anesthetized doves compared to a warm-water heating blanket underneath the patient. Humidification and warming of anesthetic gases proved problematic for avian patients in this study. An excellent review was recently published on the application of protein electrophoresis in the diagnosis of infectious and metabolic diseases of birds (Cray and Tatum, 1998). Additionally, there have been a few reviews of special topics in avian therapeutics published recently (e.g. Jenkins, 1994; Spenser, 1994).

A bone biopsy technique proved efficacious for aging sea turtles (Klinger et al., 1997). Perhaps more importantly, it documents the successful capture, surgery, post-operative recovery and release to the wild of several loggerhead (*Caretta caretta*) and Kemp's ridley sea turtles (*Lepidochelys kempi*). Techniques for laparoscopy in green sea turtles (*Chelonia mydas*) for the purposes of sexing and evaluating organs have also been described (Wood et al., 1983). A technique for successfully recovering stomach contents from over 600 green, hawksbill (*Eretmochelys imbricata*), olive ridley

(*Lepidochelys olivacea*) and loggerhead sea turtles is described in a recent paper (Forbes and Limpus, 1993): this method could also be used to attempt to flush petroleum products out of the upper gastrointestinal tract of sea turtles. Various methods for resuscitation of sea turtles are reviewed, and an efficacious method for resuscitation is detailed in a recent paper (Stabenau et al., 1993). Surgical reconstruction of the carapace of a loggerhead sea turtle (Schoelkopf, 1992), and medical treatment for multiple foreign objects in a hawksbill turtle (Reidarson et al., 1994) have also been described.

A study evaluating the histologic response to five different suture materials in the body wall of rock doves showed that chromic catgut and polyglactin 910 suture material produced marked inflammatory reactions while polydioxanone, monofilament nylon and stainless steel produced minimal reactions (Bennett et al., 1997). For birds, the authors recommended polydioxanone for closures that require strong, slowly absorbable material causing little tissue reaction.

Husbandry and Therapeutics

There are several publications that provide detailed, general information on rehabilitating marine mammals, some of which focus specifically on oil spill rehabilitation (Thomas, 1990; Williams et al., 1990; Williams and Hymer, 1992; Gage et al., 1993; Smith et al., 1995). These papers contain a great deal of general information on housing, feeding, medical triage and common clinical problems. As well, there are a few papers which specifically address the issue of evaluating rehabilitated animals for release (e.g. Hoover et al., 1984; Haebler et al., 1990; Gales and Waples, 1993; Wells et al., 1998). Papers covering more specific topics relevant to marine mammals in captivity / rehabilitation include a study of food transit times in river otters (Davis et al., 1992), energy intake requirements of captive oystercatchers (*Haematopus sp.*) (Goede, 1993), and recommendations for handling fish being fed to fish-eating animals in captivity (Crissey, 1998).

There are several recent publications on a variety of methods for marking individual animals in captivity. A technique for identifying individual dolphins, which consists of identifying

characteristic markings by obtaining detailed photographs of the whole body by lifting the dolphin out of the water with a mechanical lift, is described (Kastelein and Dokter, 1988). The utility of Velcro™ leg tags for marking Herring (*Larus argentatus*) and Great Black-backed Gull (*Larus marinus*) chicks was evaluated (Cavanagh and Griffin, 1993). Tag loss was significant, but attributed to chick growth rather than removal by the chicks or tag failure, so the usefulness of such tags in a rehabilitation setting where birds are in captivity for (hopefully) no more than 2-3 weeks, such tags could be useful. Harbor seals (*Phoca vitulina*) have been marked with plastic cattle ear tags placed in the interdigital webbing of each hind flipper between the first and second digits (Jeffries et al., 1993). Visibility of tags was improved by attaching 20 cm vinyl streamers of various colors to the tag. This study comments on tag loss by brand of tag.

Determination of plumage waterproofing is the fundamental issue in assessing whether a seabird is ready for release. An objective method for assessing the water-repellancy of rehabilitated oiled seabirds was developed using gravimetry (measuring the weight of water) (Kerley et al., 1987). In this method, the weight of an experimentally oiled (with vegetable oil) penguin was measured when the bird was dry, the bird was allowed to swim in a pool for a specified period of time, and then the bird was re-weighed. Any weight gain was attributed to absorbed water in the plumage, and the bird was deemed non-waterproof. Oiled birds absorbed water at a rate of 4.29 g/min. Based on this study, the researchers concluded that a rehabilitated oiled jackass penguin (*Spheniscus demersus*) could be considered waterproof if it absorbed less than 30 grams of water after 5 minutes immersion, and recommended that penguins absorbing more than 50 grams of water in 5 minutes should be examined for contamination of plumage. The authors were careful to point out that different species of seabirds will differ in their water uptake while waterproof, as a function of body size and the nature of the plumage, and suggested that oiled bird rehabilitation centers develop these tests for those species of seabirds they routinely handle.

The efficacy of four different worming medications for the treatment of three common gas-

trointestinal parasites in Brown Pelicans (*Pelecanus occidentalis*) was evaluated (Grimes et al., 1989): albendazole and fenbendazole were found to be highly effective against all three parasites, and piperazine was found to be completely ineffective. In order to address the potential public health risk posed by wild birds, an evaluation of antimicrobial-resistant E.coli strains carried by migratory waterfowl and a gull species in Japan showed that all 524 E. coli strains isolated and tested were resistant to sulfadimethoxine (Tsubokura et al., 1995). In this study, drug-resistant strains occurred most frequently in Whistling Swans, followed by Black-tailed Gulls.

Lastly, the zoonotic risk of handling and treating marine mammal and bird species in captivity has been addressed in a few papers. Threats to public health from gulls has received quite a bit of attention, primarily due to the fact that gulls inhabit the urban environment and potentially contaminate water sources and recreational areas (Hatch, 1996). Potentially zoonotic organisms found in gulls include *Salmonella* spp., *Listeria* spp. and *Campylobacter* spp. (Quessy and Messier, 1992). In addition, a condition known as “seal finger” has been documented in people working with pinnipeds (e.g. Bergholt et al., 1989; Eadie et al., 1990; Denoncourt, 1991; Stadlander and Madoff, 1994; Baker et al., 1998).

Bibliography of Diseases of Marine Wildlife

The body of information in the scientific literature regarding diseases and parasites of marine species is vast, and varies significantly in content. Some reports simply note the occurrence of a disease in a single individual or a parasite in a given host (e.g. clinical reports or host records). Other papers describe in detail the pathophysiology of a specific disease in numerous marine species, or the life cycle of the host-parasite interaction, or the pathology associated with infection with that parasite. An in-depth review of all these papers is beyond the scope of this document. Instead, we have compiled annotated bibliographies of papers and reports describing the occurrence of diseases

and parasites in marine birds, mammals and turtles, as well as annotated bibliographies of papers and reports describing normal hematology and serum chemistries for many marine bird, mammal and reptile species. This bibliographies are indexed for easy cross-referencing and, hopefully, maximum utility to the reader. It is hoped that the reader uses these bibliographies both to locate specific papers of interest and to gain a sense for the body of knowledge in a given topic area.

Birds

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Cetaceans

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6

Oil Spill Response— Post-Release Survival

This chapter reviews what is known to date of the post-release survival of rehabilitated oiled wildlife, summarizes publications that describe techniques used to identify and track individual marine wildlife, and reviews papers that have evaluated the long-term health effects of various marking and tracking devices. At the end of this chapter, an annotated bibliography has been compiled. It contains older references about attachment and marking techniques, studies of the effects of tracking animals on animal behavior, and also numerous studies of marine bird and mammal biology, ecology and behavior that have been conducted using radiotelemetry. It also includes a few references to papers discussing statistical analysis of marked-recapture data and survival rate analysis.

Post-Release Survival Studies

Birds

There are a number of published accounts documenting the rehabilitation, release and post-release survival of oiled birds. While these papers vary in terms of species rehabilitated, rehabilitation techniques, follow-up time and methods, etc., there is a growing body of evidence that clearly indicates survival rates are increasing for rehabilitated animals after release. This is due to a better

understanding of the techniques and procedures used in the rehabilitation process.

International Bird Rescue Research Center (IBRRC) reported on the recovery (via returns of bands from hunter-kills) of six heavily-oiled and rehabilitated waterfowl from a 1991 spill: recoveries occurred during a period from 10 months to 3.9 years post-release, for an average of 2.7 years post-release (Russell, 1996). Based on the band data, it was determined that all of the birds had successfully migrated at least once before they were shot.

Approximately 10,000 African Penguins (*Spheniscus demersus*) affected by an oil spill after the *Apollo Sea* sank off the coast of South Africa were transported to a rehabilitation center in the immediate aftermath of the spill (Underhill et al., 1999). Of these 10,000, 5213 birds were released after cleaning, 4076 of which were marked with flipper bands. Of these 4076 marked birds, 2652 were re-sighted on breeding colonies over an 1800-km section of coastline within 2 years of their release, with the cumulative number of birds increasing steadily at the time of publication. Two years after the spill, over 50 percent of banded birds had been re-sighted, with 712 birds being re-sighted for the first time over 1 year after the spill. Similarly, 87 percent of African Penguins oiled, rehabilitated and released after a spill in July 1979 off the coast of South Africa were seen

back on colony by February 1980, and six birds had produced clutches (Randall et al., 1980). The rehabilitation of Little Penguins (*Eudyptula minor*) oiled off Northern Tasmania in 1995 correlated with reduced reproductive success of oiled-rehabilitated females compared to nests of non-oiled females or oiled-rehabilitated males in the first breeding season after the spill (Goldsworthy et al., 1998). However, during the subsequent breeding season, there was no difference in the reproductive success of oiled-rehabilitated Little Penguins compared to control birds. The pre-fledging body weights of chicks of oiled-rehabilitated parents were less than weights of chicks of non-oiled parents.

American coots (*Fulicula americana*) oiled during the 1995 Unocal-MetroLink spill in California were rehabilitated, and their survival and health status followed post-release (Anderson et al., in press; Newman et al., in press). This study demonstrated increased mortality for rehabilitated coots versus non-oiled, non-rehabilitated coots, and rehabilitated coots showed significantly higher white blood cell counts and serum calcium concentrations compared to control birds approximately two months post-release. However, there were no statistically significant differences in blood parameters between rehabilitated and control coots from day 81 through 140 of the study.

There are a few papers that dispute the positive effect of rehabilitation on the survival of oiled birds, or argue with the idea that oil contamination is detrimental to populations. Researchers evaluating the long-term survival of oiled, rehabilitated Brown Pelicans (*Pelecanus occidentalis*) concluded that rehabilitated Brown Pelicans experienced lower survival than control, non-oiled, non-rehabilitated Brown Pelicans (Anderson et al., 1996). A review of USFWS Bird Banding Laboratory records of banding recoveries from rehabilitated oiled birds released from 1969-1994 compared to non-oiled, non-rehabilitated birds suggested that the post-release survival of oiled seabirds was low (Sharp, 1996).

Using the rate of recovery of banded adult non-oiled, non-rehabilitated Guillemots (*Cephus sp.*) for comparison, researchers from the Netherlands estimated that approximately 78 percent of

rehabilitated and released adult oiled Guillemots did not survive during the first year after release and therefore estimated that 22 percent did survive the first year (Camphuysen et al., 1997). In another study, 50 percent of a banded population of Purple Sandpipers (*Calidris maritima*) in the German Bight was affected by an oil spill in 1991-1992: return rates of oiled and non-oiled birds the following winter were identical, and did not differ significantly compared to the previous year study (Dierschke, 1994). Analysis of historical data on recoveries of banded Guillemots, both oiled/rehabilitated and non-oiled/non-rehabilitated, in the United Kingdom showed an average post-release survival time of only 6-7 days (Wernham et al., 1997). Based on their data, survival rates for rehabilitated Guillemots were only 0.7-1.3 percent of the natural survival rates. This report did not go into detail on rehabilitation and release methods used.

Marine Mammals

Most published data on the post-release survival of rehabilitated marine mammals describes the survival of animals that were brought to rehabilitation centers for reasons other than oiling (e.g. emaciation, injury, disease). An exception is the post-release survival studies conducted on rehabilitated sea otters after the *Exxon Valdez* spill (see below). Nevertheless, information on the release of marine mammals that have been rehabilitated for whatever reason is pertinent to the issue of whether rehabilitation of oiled marine mammals is worthwhile, as it demonstrates that it is indeed possible to support and treat ill and injured wild marine mammals in captivity and then successfully reintroduce them to the wild.

As mentioned, sea otters (*Enhydra lutris*) oiled in the *Exxon Valdez* spill and rehabilitated were instrumented with radio transmitters and monitored after their release (Monnett et al., 1990). At the end of an 8-month tracking period, 12 of 45 otters were dead, 9 were missing, and one radio failed, and it was noted that these mortality and missing rates were much higher than those normally observed for non-oiled, non-rehabilitated sea otters in Prince William Sound.

Juvenile harbor seals (*Phoca vitulina*) rehabilitated by The Marine Mammal Center in California and released with flipper tags have been resighted at 14 days and at 4 months post-release (Webber and Allen, 1987). A harbor porpoise cared for at a rehabilitation facility for 13-months was fitted with a satellite-linked transmitter on its dorsal fin and tracked for 50 days post-release (Westgate et al., 1998), during which time it exhibited normal behavior comparable to that of wild, non-rehabilitated harbor porpoises in that area. On the other hand, the release of several bottlenose dolphins held in captivity for approximately 10 years was only partially successful, as a few of the animals had to be recaptured when they began losing weight (Gales and Waples, 1993). Radiotransmitters deployed in this study were VHF, and the authors made the point that longer-life, longer-range, satellite transmitters might possibly have yielded better data on post-release survival of individuals they lost track of soon after release.

In an experiment specifically designed to test the hypothesis that wild cetaceans could be successfully released back to the wild after a period of time in captivity, two bottlenose dolphins were caught, held for two years, and released back to the wild at their capture site (Wells et al., 1998). One of the animals was sighted 3 years after release at his capture site, and the other was seen approximately 5.75 years after release. Both dolphins appeared to be fully integrated into dolphin groups, exhibiting normal dolphin behavior.

Marking and Transmitter Attachment Techniques

Birds

Birds have been marked with leg bands (metal, color), passive integrated transponder (PIT) tags, and radio- and satellite-transmitters. In a study of PIT-tagged Common Terns (*Sterna hirundo*), an array of antennas was installed within the nesting colony to monitor the presence of PIT-tagged adults (Becker and Wendeln, 1997). This study also demonstrated a PIT tag loss of less than 2

percent per year, as long as PIT tags were placed along the carina on the breast and the injection site was closed with tissue glue. Metal leg band wear may differ between male and females, at least in Laughing Gulls (*Larus atricilla*) (Dolbeer and Belant, 1995), and bands were found to wear much more rapidly on Common Goldeneye (*Bucephala clangula*) compared to White-winged Scoters (*Melanitta fusca*) (DuWors et al., 1987). Loss of color bands was evaluated in a study of Roseate Terns (*Sterna dougallii*): the probability that a bird marked with three colored leg bands would still have them the next season was 0.87 (Spendelow et al., 1994).

The ability to consistently locate color-banded Herring Gulls (*Larus argentatus*) and Lesser Black-backed Gulls (*Larus fuscus*) on a mixed-species colony was evaluated: most searches resulted in the detection of 85-90 percent of surviving banded adults, while during a few searches >70 percent of banded birds were located (Calladine, 1997). Each search lasted until all color-banded birds present were thought to have been seen. The author surmised that the most efficient period for finding color-banded gulls was during incubation and early chick rearing.

Methods of attachment of radiotransmitters to birds have been examined across a wide variety of species. Transmitters have been attached to the backs of waterfowl using dental floss and glue (Wheeler, 1991), and with sutures and glue onto 1-day old Mallard (*Anas platyrhynchos*) ducklings (Mauser and Jarvis, 1991). Suture and glue methods were found to result in poor-retention of transmitters on Northern Shovelers (*Anas clypeata*), but may have been due to weight of the transmitter (8 g) (Zimmer, 1997). As well, suture and glue attachment of transmitters to the backs of captive Mallard showed poorer retention rates compared to harness attachments (Houston and Greenwood, 1993). Improvements in the method for attaching radiotransmitters to waterfowl is described in which radios are secured to the backs of Mallards with sutures and a subcutaneous stainless steel wire "anchor" (Pietz et al., 1995).

A method for attaching radiotransmitters to tail feathers which allows for easy removal and replacement of expired transmitters is described for use in owls (Reid et al., 1996).

Radiotransmitter backpacks have been attached to African (*Spheniscus demersus*) and Adelie Penguins (*Pygoscelis adeliae*) with cloth-backed tape (Wilson and Wilson, 1989). Adelie Penguins were found to peck less at black-colored transmitter packages than colored packages, which presumably results in longer wear of the “preferred” transmitters (Wilson et al., 1990). The hydrodynamic aspects of design and attachment of back-mounted radiotransmitters on penguins has been thoroughly analysed, and resulted in recommendations for design and attachment of a package that could reduce hydrodynamic drag by 65 percent compared to previous packs (Bannasch et al., 1994). Methods for attaching radio-transmitters to shorebirds were reviewed, and a method for attachment to sandpipers is clearly described (Warnock and Warnock, 1993). Presumably this method could be used for other shorebirds.

Intracoelomic placement of transmitters in birds has also been described, primarily in waterfowl (e.g. Olsen et al., 1992; Korschgen et al., 1996). One paper documents the loss of an intracoelomic transmitter in a Blue-winged Teal (*Anas discors*), probably by expulsion of the radio through the oviduct (Garrettson and Rohwer, 1996).

Marine Mammals

Sea otters (*Enhydra lutris*) have been marked with subcutaneous PIT tags, flipper tags and intraperitoneal radiotransmitters. PIT tag marking required that a tagged animal actually be captured in order to scan for the PIT tag (Thomas et al., 1987). Tag loss of up to 26 percent of Temple™ tags per year was observed (Siniff and Ralls, 1991). In the latter study, the authors concluded that sea otter tag-resight data was impractical for accurately estimating annual survival rates for these animals, given the myriad reasons for lack of tag sighting (e.g. tag loss, movement of animals out of study area, differential mortality patterns, etc.). Radiotransmitters have been attached to flipper-mounted tags in sea otters, and showed retention rates of greater than 263 days (Hatfield and Rathbun, 1996). A method for implantation of radiotransmitters into the abdominal cavity of sea otters has been described, and was found to give

long-term reliable information on otters with no negative effects on health (Ralls et al., 1989).

A study of the best method of attachment and design of satellite transmitters for use in small cetaceans was conducted, including an analysis of hydrodynamic flow around transmitters (Stewart et al., 1995). An acoustic transponder tag placed subcutaneously on the back was developed for tracking sperm whales (*Physeter macrocephalus*) underwater by sonar (Watkins et al., 1993). This method allowed for positive identification of individuals over a long period of time.

Sea Turtles

Turtles have been marked with plastic or metal tags attached to a flipper, and PIT tags. Loss of flipper tags has plagued sea turtle researchers in their efforts to conduct long-term studies of survival and reproduction, and appears to be affected by species, type of tag, method of attachment, location on body, and even the oceanic region inhabited by the turtle. One study evaluating retention of Monel™ flipper tags by loggerhead turtles (*Caretta caretta*) showed a loss of almost 20 percent of tags within 90 days, and therefore the authors concluded that this was not a reliable permanent marking method for loggerheads (Henwood, 1986). Another study demonstrated a loss of 96.1 percent of plastic Jumbo Riese™ tags from loggerheads over a three year period (Eckert and Eckert, 1989), and found that placing Monel™ tags upside-down on the foreflipper decreased abrasion injury to the carapace. Another study found that titanium tags attached to the axillary area was the most effective marking method for long-term monitoring of Flatback sea turtles (*Natator depressus*), but that overall, PIT tags performed better than flipper tags, with only an 8 percent loss after two years (Parmenter, 1993). A study of Black turtles (*Chelonia agassizi*) in Mexico found that plastic Allflex™ tags were better retained than Monel™ metal tags over the course of two breeding seasons (Alvarado et al., 1993). It appeared that significant levels of inflammation around metal tags resulted in their becoming uncinched.

The Effects of Band, Tag, and Transmitter Attachment

Birds

Patagial tags were found to negatively influence breeding behavior of male Ruddy Ducks (*Oxyura jamaicensis*), in that the time spent in courtship behavior was decreased, and time spent sleeping and preening was increased (Brua, 1998). Females with patagial tags spent an increased amount of time grooming. The presence of a patagial tag was determined to result in the death of an American White Pelican (*Pelecanus erythrorhynchos*) when the bird caught its bill underneath the tag (Chapman and Chapman, 1990).

Foot loss in a banded population of Spotted Sandpipers (*Actitis macularia*) was studied over 19 years and revealed that 2.6 percent of birds lost one foot in years following banding (Reed and Oring, 1993), and it was not always the foot on the banded leg. Survival rates of Canada Geese (*Branta canadensis*) with neck bands in addition to leg bands were significantly lower than survival of geese with leg bands only (Castelli and Trost, 1996).

Blue-winged Teal (*Anas discors*) females with intracoelomic transmitters showed more normal nesting effort and less nest abandonment than females with harness-attached backpacks (Garrettson and Rohwer, 1996). However, if females were captured while nesting or in the early chick-rearing period, implanted females were more likely to abandon than females with backpacks. No differences in daily survival rates were detected between the two groups.

It has been customary during telemetry studies of wintering waterfowl to exclude any mortality that occurs early-on in the post-release period for the purposes of survival analyses, because it is assumed that this mortality is related to the stress of capture and captivity. In response, investigators attempted to objectively evaluate the length of time in which female Northern Pintails (*Anas acuta*) were adversely affected by capture, handling, radiotransmitter attachment and release, and to identify factors which influence survival and flight quality post-release (Cox and Afton, 1998). Their data indicated that female

pintails went through a 4-day "adjustment" period after release during which they were 16 times more likely to die than later on in the study. The investigators suspected that capture myopathy contributed to early mortality.

Satellite transmitters attached to Whitefaced Ducks (*Dendrocygna viduata*) with harnesses did not adversely affect body mass, skin or feathers, but did result in increased preening time in ducks with backpacks compared to ducks without harnesses (Petrie et al., 1996). In another study, wild female Mallards (*Anas platyrhynchos*) fitted with harness-attached radiotransmitter backpacks showed lower return rates to the nest compared to ducks with surgically implanted intracoelomic transmitters (Dzus and Clark, 1996). Similarly, female Brant (*Branta bernicula*) with transmitters attached via harness returned to the breeding colony in subsequent years at a significantly reduced rate compared to females marked with colorbands only (Ward and Flint, 1995).

Radiotransmitters attached to the backs of Mallard ducklings either via sutures or implanted subcutaneously did not apparently result in adverse effects on thermoregulation (Bakken et al., 1996). Various-sized transmitters attached to the backs of female Mallards via sutures or harnesses had no negative effect on behavior or feathers and skin (Houston and Greenwood, 1993).

Radiotagging of adult nesting Common Terns (*Sterna hirundo*) (tagging method not described in English-language abstract) did not result in differential growth of chicks in the nest (Frank and Sudmann, 1993). While one adult in one pair hardly left the nest after being tagged, requiring provisioning by its mate, another tagged adult of another pair fed its chicks at a higher than average rate. In a preliminary study of foraging behavior of nesting male California Least Terns (*Sterna antillarum browni*), the presence of a radiotransmitter glued to the back profoundly negatively affected the nesting and foraging behavior of these individuals (Massey et al., 1988).

Common Murres (*Uria aalge*) implanted with intracoelomic radiotransmitters showed significantly impaired breeding behavior compared to

un-implanted birds, in terms of presence on colony, nesting status and chick provisioning (Meyers and Hatch, 1997). In another study of Common Murres, birds fitted with transmitters with internal aerals showed no deleterious effects in terms of nest attendance, length and number of absences from the colony and prey deliveries compared to non-instrumented birds, whereas birds with transmitters with external aerals spent less time at the colony and provisioned their chicks less (Wanless et al., 1988). Fortunately, this did not result in reduced fledging of chicks from the nest, as the non-telemetered mate compensated.

While attachment of transmitter-like devices to the backs of Royal Penguins (*Eudyptes schlegeli*) had no measurable impact on breeding, attachment of time-depth recorders (TDRs) had substantial impacts, including aborting the breeding effort for the season, increased water influx, and decreased fat levels (Hull, 1997). The authors surmised that this was probably related to increased drag of the TDRs, and that the reason the transmitters did not produce a similar effect was related to the size.

Marine Mammals

We did not find many papers specifically on the effects of marking or tracking devices on or in marine mammals. Of possible relevance is a study looking at possible effects of intraperitoneal transmitters on reproduction of river otters (*Lutra canadensis*): this study found no ill effects of an intraabdominal transmitter on any aspect of river otter reproduction (Reid et al., 1986). Female Antarctic fur seals (*Arctocephalus gazella*) carrying both radiotransmitters and TDRs exhibited longer foraging trips and nursing visits on-shore compared to females fitted with radiotransmitters only (Walker and Boveng, 1995).

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Index

A

Abbotts Lagoon 13
acepromazine 55
acoustical deterrent devices 39
Acoustical harassment devices 39
Actitis macularia 32, 87
acute phase proteins 46
Adelie Penguin 33, 86
adrenal glands 48
adrenocorticotrophic hormones 56
African Penguin 60, 83
age estimation 59
Ah receptor 95
Alameda County 25
Alcatraz Island 13, 15
Aleutian Canada Goose 11, 29, 101
American Avocet 10, 14, 75, 77
American coot 62, 74, 84, 96, 109
AMOCO Cadiz 40, 105
Anacapa 19, 27
Anas acuta 87
Anas clypeata 85
Anas discors 87
Anas platyrhynchos 38, 48, 50, 51, 52, 63, 85, 87
anemia 46, 48, 50, 102, 107, 117
anesthesia 53, 54, 55, 56, 95, 104, 108, 112, 117
Ano Nuevo Island 19, 27, 30, 93, 116
Ano Nuevo State Reserve 17, 18, 19, 109
Anous stolidus 41
Antarctic fur seal 88, 115
apnea 54, 55
Apollo Sea 83, 115
Arctocephalus gazella 88, 115
Arctocephalus philippii 54
Arctocephalus townsendi 6, 12, 15, 19, 24, 113
Ardea herodias 15, 18, 32, 74, 75
aryl hydrocarbon hydroxylase 45
Ashy Storm-Petrel 20

atipamezole 54, 117
atropine 54
Aythya valisineria 14
azaperone 55, 116

B

Balaena mysticetus 4, 34, 68, 69, 70, 82
Balaenoptera acuturostrata 4, 103
Balaenoptera borealis 5
Balaenoptera edeni 5
Balaenoptera musculus 5, 79
Balaenoptera physalus 5, 82
Bald Eagle 31, 56, 95
banding 80, 83, 84, 85, 87, 89, 99, 100, 113
Batiqitos Lagoon 20, 21, 22
Beach Watch programs 5, 13, 17, 112
beluga whale 44, 47, 67, 108, 116
benzene 45, 106
bioassays 45, 47, 58
biomarkers 44, 45, 47, 100, 106, 117
bittern 11
Black Oystercatcher 13, 17, 32, 33
Black Skimmer 15, 20, 21, 114
Black-crowned Night Heron 15, 18, 47
Black-necked Stilt 14
blood transfusions 59, 112
blue whale 5, 74, 75, 76, 79, 102
Blue-winged Teal 87
Bodega Bay 5, 10, 12, 13, 14, 15, 16, 17, 19, 26, 117
body temperature 50, 53, 55, 59, 110, 113, 114
Bolas Lagoon 9, 12, 13, 15, 16, 29
Bolsa Chica 20, 21, 22, 25, 27
Bonaparte's Gull 32
bottlenose dolphin
 5, 34, 49, 56, 58, 68, 69, 70, 71, 78, 79, 82, 85, 89,
 92, 98, 102, 107, 110, 113, 115
bowhead whale 4, 34, 68, 69, 70, 82
Brachyramphus marmoratus 26, 32

Brandt's Cormorant 3, 9, 12, 13, 17, 20, 63
 Brant 87
Branta canadensis 11, 14, 29, 32, 38, 62, 75, 81, 87
 Breco Buoy 37
 breeding grounds 16
 Bridled Tern 41, 89
 Brown Noddy 41
 Bryde's whale 5
Bucephala clangula 85
 burns 48
 butorphanol 55

C

caliciviruses 58, 63, 64, 66, 101
Calidris alba 34
Calidris maritima 34, 84
Calidris minutilla 32
 California Black Rail 29, 101
 California Brown Pelican
 17, 19, 26, 27, 60, 63, 74, 75, 81, 84, 103
 California Clapper Rail 28
 California Gull 13, 28, 61, 112
 California Least Tern 13, 20, 21, 22, 25, 87, 98, 101, 111
 California Least Tern Nature Preserve 20, 21, 22
 California sea lion
 6, 11, 15, 16, 17, 18, 19, 23, 24, 35, 39, 44, 47, 53, 63, 64,
 65, 66, 67, 77, 93, 96, 97, 98, 100, 102, 104, 107,
 108, 111, 113, 116, 117
 California Wetlands Information System 21
Callorhinus ursinus 6, 15, 23, 64, 66, 77, 96, 102
 Campylobacter 60, 63, 111
 Canada Goose 11, 14, 29, 32, 38, 62, 75, 81, 87, 95, 101
 Canvasback 14
 Cape Mendocino 11
 Cape San Martin 19
 capture
 7, 41, 42, 52, 56, 57, 58, 59, 80, 82, 85, 87, 89, 90,
 92, 96, 97, 99, 103, 106, 107, 110, 111, 114, 116
 carcasses 40, 61, 64, 67, 100, 102
Casmerodius albus 15, 18
 Caspian Tern 13, 20, 21, 62, 91
 Cassin's Auklet 12, 20, 76
 Castle Rock National Wildlife Refuge 9, 11, 30, 105
Cephus columba 13, 17, 20, 32
Cerorhinca monocerata 9, 20, 90
 cetacean
 4, 5, 34, 39, 46, 48, 67, 68, 70, 71, 78, 79, 85, 86,
 91, 96, 99, 102, 107, 114
 Channel Islands
 6, 7, 19, 20, 23, 24, 27, 28, 99, 100, 105, 113, 114
Charadrius alexandrinus 14, 18, 20, 21, 22, 29
Charadrius semipalmatus 34
Charadrius vociferus 14, 32
Chelonia mydas 8, 56, 58, 59, 72,
 73, 80, 82, 94, 95, 116, 117
Chen caerulescens 38, 108
 chronic oil pollution 32, 110
Clangula hyemalis 32, 50
 clastogens 47
 Common Diving Petrels 57, 113
 Common Goldeneye 85

Common Murre
 3, 9, 12, 13, 17, 32, 46, 51, 61, 62, 63, 80, 87,
 90, 91, 95, 97, 99, 102, 106, 108
 Common Raven 32
 Common Tern 63, 85, 87, 102
 corral traps 41
 corticosterone 52, 57, 82, 103
 cortisol 56, 81
Corvus corax 32
 Crescent City Harbor 10
 crude oil 33, 34, 43, 44, 46, 48, 49, 50, 51, 52, 53, 71,
 102, 104, 105, 106, 107, 108, 110, 112, 114, 117
 CYP1A 45, 108
 cytochrome P450 45, 103, 108, 115, 117
 cytokines 46, 49

D

Dall's porpoise 34
 Dawn 53
 DDT 26, 49
 Del Norte County 11, 27
Delphinaptera leuca 44, 47
Dendrocygna viduata 87, 90, 110
Dermochelys coriacea 8, 80, 101, 113
 detection
 40, 43, 44, 46, 58, 85, 97, 99, 101, 102, 103, 108, 114
 deterrence 38, 39, 108, 110, 115
 detomidine 53, 104
 detoxification 45, 46, 109
 Devil's Slide Rock 13
 diazepam 54, 55, 64
 diesel fuel 34, 46, 53
 DNA 44, 45, 46, 47, 63, 97, 99, 108, 109, 111, 115, 117
 Double Point 16
 Double-crested Cormorant 3, 9, 12, 19, 41, 46
 doxapram 54, 55
 Drakes Estero 13, 15, 16
 Duxbury Reef 16

E

E. coli 60
 Eel River 10, 11
 egret 11, 15, 18, 23, 75, 88, 106
Egretta thula 15, 34
 El Nino 7, 8, 100, 113
 Elegant Tern 27
 Elkhorn Slough 18, 19, 28, 110, 111, 117
 endangered 4, 6, 8, 25, 26, 28, 29, 71, 72, 100
Enhydra lutris
 6, 31, 47, 49, 55, 71, 72, 79, 82, 84, 91, 93, 96, 99,
 102, 112, 114, 115, 116
 eosinophils 56
Eretmochelys imbricata 73, 111
Eschrichtius robustus 5, 34, 70
 ethoxyresorufin O-deethylase 45, 46
Eubalaena glacialis 5, 69
Eudyptes schlegeli 88
Eudyptula monior 84
Eumatopius jubatus 11, 24, 30, 35, 53

Exxon Valdez

31, 32, 33, 34, 35, 40, 44, 45, 47, 48, 55, 66, 68, 70,
72, 84, 92, 96, 97, 98, 100, 101, 102, 104, 106, 107, 108,
109, 110, 112, 114, 116, 117

F

falconry 38, 101

Farallon Islands

5, 12, 13, 16, 17, 24, 7, 28, 30, 40, 95, 96,
111, 112, 113, 114

fentanyl 55

fibropapillomas 58, 72, 73, 95

fin whale 5, 82, 85

fish

34, 37, 38, 39, 43, 45, 46, 49, 59, 63, 95, 96, 97, 99,
103, 104, 105, 106, 107, 117

fisheries 4, 6, 8, 40, 99, 102, 105, 108

flame ionization detection 43, 44

fluid therapy 59, 101

flumazenil 55

Forster's Tern 21

Fort Funston 16

fuel oil 46, 47, 50, 52, 114

Fulicula americana 62, 84, 96

G

gas chromatography 43, 44

gastroenteritis 48

Gavia adamsii 33

genotoxicity 44, 46, 47

Giant Petrel 33

gillnet fisheries 4, 105

Golden Gate National Recreation Area 13, 117

Government Point 7

gravimetry 60

gray whale 5, 34, 70, 78, 98

Great Black-backed Gull 60

Great Blue Heron 15, 18, 32, 74, 75, 89

Great Egret 15, 18

grebes 13, 31, 41, 88

green sea turtles

8, 56, 58, 59, 72, 73, 80, 82, 94, 95, 116, 117

grey seal 35, 51, 64, 81, 95, 99, 101

Guadalupe fur seal 6, 12, 15, 16, 19, 24, 103, 113

Gulf of Mexico 45, 49, 68, 69, 79, 94, 99, 115

Gulf of the Farallons 12, 16

H

habituation 37, 38, 39, 57

Haematopus bachmani 13, 32

Half Moon Bay 9

Haliaeetus leucocephalus 95

Halichoerus grypus 35, 51, 64, 81, 95

halogenated hydrocarbons 45, 49

halothane 53

haptoglobin 46, 100

harbor porpoise

5, 34, 39, 66, 67, 69, 70, 78, 79, 82, 85, 92, 93, 96,
107, 110, 116

harbor seal

6, 11, 15, 16, 19, 23, 35, 39, 43, 46, 49, 54, 60, 64,
65, 66, 67, 68, 70, 77, 78, 81, 85, 95, 96, 98, 100,
102, 103, 106, 110, 113, 115, 117

haul-out sites 11, 18, 19, 24

hawksbill sea turtle 73, 111

hazing 37, 38, 39, 95, 101, 102, 107, 115, 116

hematocrit 58, 81

hematology 34, 48, 50, 61, 81, 82

hemolytic anemia 107

hemosiderosis 46, 48, 106

heron 11, 15, 18, 23, 37, 52, 63, 74, 75, 76, 77, 96, 106

Herring Gull

38, 45, 47, 50, 52, 60, 62, 80, 85, 98, 107, 110

high-performance liquid chromatography 43, 44

histopathology 48, 116

Humboldt Bay 9, 10, 11, 29, 96, 99, 100, 101, 105, 109

Humboldt County 8, 26

humpback whale 5, 67, 79, 91, 92, 107

Huntington Beach 20, 21, 22, 25, 27

hypoglycemia 48

hypoproteinemia 48

hypothermia 33, 48

I

immobilization 54, 55, 104, 112

immunity 49, 100

immunology 49, 57, 61, 81, 89, 97, 100

ingestion 31, 45, 48, 50, 52, 57, 107, 110

internal exposure 33

invertebrates 43, 45

isoflurane 53, 55, 56, 58, 95, 103, 104

J

Juan Fernandez fur seals 54, 78

K

Kemp's Ridley sea turtle

56, 58, 59, 73, 74, 82, 93, 94, 112

ketamine 41, 53, 54, 55, 56, 64, 104, 113, 117

kidneys 48

killdeer 14, 32

Killer Whale 34, 39, 49, 67, 106, 109

King Eider 40, 41, 51, 102

Kittiwake 90

L

Lake Earl 27, 30

Lake Talawa 27, 30

laparoscopy 59

Larus argentatus 45, 47, 50, 52, 60, 85, 98, 107, 110

Larus californicus 13, 28, 61

Larus delawarensis 38, 61, 63, 76, 111

Larus fuscus 85, 98

Larus marinus 60
Larus occidentalis 19
Larus philadelphia 32
Laterallus jamaicensis 29, 101
 Laughing Gull 62, 89
 Leach's Storm-Petrel 33, 45, 57
 Least Sandpiper 32
 leatherback sea turtle 8, 9, 73, 80, 101, 107, 113
Lepidochelys kempfi 56, 58, 59, 73, 74, 82, 93, 94, 112
Lepidochelys olivacea 8
 Lesser Black-backed Gull 85, 98
 lethargy 48, 55
 Limantour Estero 12, 13, 15
 Listeria 60, 63, 111
 Little penguin 84
 liver 48
 loggerhead sea turtle
 8, 48, 50, 57, 59, 72, 74, 80, 82, 86, 94, 103, 104,
 108, 112
 loon 20, 33, 61, 63, 88, 101
Lutra canadensis
 35, 44, 55, 71, 72, 79, 82, 88, 99, 100, 104, 113, 114
 lymphocytes 47, 49, 57, 104, 107

M

Mallard 38, 48, 50, 51, 52, 61, 63, 80, 85, 87, 108, 114
 Marbled Murrelet 26, 32, 41, 88, 89, 96, 98
 marking 59, 86, 88, 89, 92, 93, 99
 mass spectrometry 43, 44
 medetomidine 54, 55, 113, 117
Megaptera novaeangliae 5, 79, 91
Melanitta perspicillata 37, 41, 107
 meperidine 55
 Methyl anthranilate 96, 99
 methyl anthranilate 38
 midazolam 55
 migration 5, 10, 30, 32, 34, 38, 88, 105, 110, 112
 minke whale 4, 68, 78, 82, 92, 103
Mirounga angustirostris 6, 15, 23, 65, 67, 77, 81, 108
 Mission Bay 21
 mixed function oxidases 45, 46, 51, 52, 107, 110
 Monterey Bay
 9, 12, 16, 17, 18, 19, 27, 28, 29, 96, 113, 115
 Morro Bay 3, 11, 17, 18, 19, 26, 27, 28, 29, 117
 mortality
 7, 23, 32, 33, 34, 40, 55, 61, 62, 63, 66, 67, 68, 69,
 70, 71, 75, 84, 86, 87, 98, 101, 102, 105, 107
 molting 6, 11, 16, 50

N

naloxone 55
 Navy Outer Sea Test Range 4, 98
 nets 8, 26, 38, 39, 41, 42, 58, 66, 97, 99
 noise 39
 Northern elephant seal
 6, 11, 15, 16, 19, 23, 54, 64, 65, 67, 77, 80, 81, 82,
 93, 96, 99, 108, 112, 113, 114, 117

Northern fur seal
 6, 12, 15, 16, 17, 19, 23, 24, 54, 64, 66, 77, 78, 81,
 88, 96, 102, 103, 109, 113, 115
 Northern Phalarope 32
 Northern Pintail 87, 99
 Northern right whales 5, 69
 Northern Shoveler 85, 117
Nycticorax nycticorax 15, 18, 47

O

Oceanodroma homochroa 20
Oceanodroma leucorhoa 33, 45, 57
 oil spill models 31, 32, 34, 53, 76, 92, 101, 114
 Oldsquaw 32, 50
 olive ridley sea turtle 8, 9, 80, 82
 Orange County 20, 21, 22
Orcinus orca 34, 39, 49, 67, 106, 109
Otaria byronia 43
 oxymorphone 55
Oxyura jamaicensis 14, 87

P

pancreatitis 48
 Pelagic Cormorant 13, 17, 19, 32
Pelecanoides urinatrix 57, 113
Pelecanus erythrorhynchos 87
Pelecanus occidentalis 17, 19, 26, 60, 63, 74, 75, 81, 84
 penguins 41, 60, 61, 84, 86, 96, 102, 103, 105, 111, 116
 pentobarbital 56
 Pescadero 12, 14, 15, 17
 petroleum products
 31, 34, 44, 45, 46, 47, 48, 49, 50, 53, 59, 108
 phalaropes 14
Phalaropus lobatus 32
Phalacrocorax auritus 3, 9, 12, 19, 41, 46
Phalacrocorax pelagicus 13, 17, 32
Phalacrocorax penicillatus 3, 9, 20, 63
Phoca hispida 45, 101, 102
Phoca vitulina
 11, 15, 19, 23, 35, 39, 43, 49, 54, 60, 64, 65, 66, 67,
 70, 77, 78, 81, 85, 95, 100, 103, 106, 110, 113, 115, 117
Phocoena phocoena
 5, 34, 66, 67, 69, 70, 78, 79, 93, 96, 107, 11
Phocoenoides dalli 34
Physeter macrocephalus 5, 86
 Pigeon Guillemot 13, 17, 20, 32, 111
 Pigeon Point 7, 12, 17
 pinniped
 4, 5, 11, 15, 16, 17, 18, 19, 23, 25, 31, 34, 35, 39, 46, 48,
 51, 53, 58, 60, 64, 65, 66, 67, 71, 77, 81, 97, 99,
 100, 112, 113
 Pismo State Beach 17, 18, 19
 PIT tags 85, 86
Plegadis chihi 30
 pneumonia 48, 73
 Point Arena 26
 Point Buchon 28
 Point Conception 4, 5, 6, 7, 11, 17, 18, 19, 28, 29, 107
 Point Lobos State Reserve 17, 18, 19

- Point Mugu 21, 22, 25, 27, 105
 Point Reyes National Seashore
 3, 5, 10, 12, 13, 15, 16, 20, 21, 63, 96, 101, 108, 110,
 112, 113, 117, 118
 Point Sal 7
 Point St. George 10, 12
 polar bears 48, 105
 polynuclear aromatic hydrocarbons
 43, 44, 45, 46, 47, 96, 115
 Port of Los Angeles 21, 27
Porzana carolina 15
 Prairie Creek Redwoods State Park 10, 11
 predation 33, 37, 38, 39, 96, 99
 preening 34, 87
 prey 23, 33, 34, 37, 39, 88, 104, 108
 progesterone 57, 58, 110
 propofol 55, 56, 101, 103, 108
Ptychoramphus aleuticus 12, 20, 76
 pulse oximetry 56, 112
 Purple Sandpiper 34, 84
Pygoscelis adeliae 86
- ## R
- Rallus limicola* 15
Rallus longirostris 28
 Recovery Plan 26, 30, 103
Recurvirostra americana 10, 14, 75, 77
 Rhinoceros Auklet 9, 20, 90, 108
Rhynchops niger 15, 20
 right whale 5, 69, 91
 Ring-billed Gull 38, 61, 63, 76, 111
 ringed seal 45, 46, 64, 66, 101, 102, 108
 river otter 35, 44, 50, 53, 55, 59, 71, 72, 79, 82, 88, 92,
 97, 99, 100, 104, 111, 113, 114
 rookeries 11, 15, 16, 18, 23, 24, 30, 108
 Roseate Tern 85, 113
 Royal Penguin 88
 Royal Tern 21, 65, 75, 79, 88, 93
 Ruddy Duck 14, 87
 Russian River 9
- ## S
- Salmonella 60, 62, 63, 97, 111
 Salt Point State Park 10, 11
 San Clemente Island 23, 24
 San Diego Bay 8, 19, 20,
 21, 22, 27, 29, 73, 106, 108, 109, 111, 113, 114
 San Diego County
 8, 19, 20, 21, 22, 25, 27, 29, 68, 71, 73, 82, 92, 98,
 102, 104, 106, 107, 108, 109, 111, 113, 114, 117
 San Elijo Lagoon 20, 21, 25
 San Francisco Bay
 8, 12, 13, 14, 15, 16, 17, 20, 21, 22, 28, 29, 30, 37, 62,
 65, 95, 96, 101, 106, 107, 110, 112, 113, 115, 116
 San Francisco Estuary Institute 15, 117
 San Gabriel River 8
 San Luis Obispo County 19
 San Miguel Island
 19, 20, 23, 24, 29, 30, 64, 66, 77, 78, 109, 113
 San Nicolas Island 4, 7, 23, 24, 29, 66, 108, 113
 San Onofre 8
 San Pablo Bay 14, 28
 Sanderling 34, 98
 Sandhill Crane 51, 102
 Santa Barbara Channel 27
 Santa Barbara Island 19, 23, 27, 28, 112
 Santa Cruz Island 5, 13, 17, 18, 19, 23, 26, 97, 100
 Santa Rosa Island 19, 23, 29
 sarmazenil 54
 Scarey Man 37, 96
 Scaup 37, 50, 52
 scoter 13, 32, 100, 107
 sea turtles
 8, 40, 43, 47, 48, 50, 52, 56, 57, 58, 59, 72, 73, 74,
 80, 82, 86, 92, 93, 94, 95, 97, 100, 101, 102, 103, 104,
 106, 107, 108, 110, 111, 112, 113, 114, 115, 116, 117
 seal finger 60, 96, 113
 Seal Rock 11
 search 40, 41, 85, 104
 search and collection 40, 41
 sedation 55, 105
 sei whale 5
 Semi-palmated Plover 34
 serum chemistry 34, 46, 48, 61, 81, 82
 shorebirds
 3, 4, 10, 11, 13, 14, 15, 17, 18, 21, 22, 38, 57, 61, 75, 77, 86,
 90, 100, 106, 111, 113, 115
 Silver Strand State Beach 20, 21, 22
 slick 32, 34
 Snow Goose 38, 53, 63, 108
 Snowy Egret 15, 34
 Snowy Plover 14, 18, 20, 21, 22, 29, 106, 110, 111
Somateria mollissima 40, 41, 51
 Sonoma County 12
 Sora 15
 SOS Chromotest 47
 South Polar Skua 33
 Southern California Bight
 4, 6, 20, 23, 24, 26, 27, 66, 91, 97, 100, 103, 105, 112, 116
 Southern sea otter
 6, 7, 31, 40, 42, 44, 47, 48, 49, 51, 55, 61, 71, 72, 79,
 82, 84, 86, 91, 92, 93, 96, 97, 99, 100, 101, 102, 103,
 104, 105, 106, 107, 108, 109, 111, 112, 114, 115, 116
 species decline 7
 species diversity 32
 sperm whale 5, 68, 79, 82, 86
Spheniscus demersus 60, 83
 Spotted Sandpiper 32, 87, 111
 St. George Reef 11, 30
 state beaches 4, 10, 11, 12, 14, 15, 17, 18, 19, 21, 22, 25
 state parks 4, 10, 11, 25, 27, 29
 Steller sea lion
 6, 11, 19, 24, 30, 35, 53, 63, 64, 66, 78, 81, 93, 98,
 109, 116
Sterna anaethetus 41
Sterna antillarum 13, 25, 87
Sterna caspia 13, 20, 91
Sterna dougallii 85, 113
Sterna elegans 27
Sterna hirundo 63, 85, 87, 102
 stranding 8, 40, 63, 67, 68, 70, 71, 101, 103

stress 34, 48, 51, 52, 56, 57, 58, 87, 95, 97, 103, 110,
113, 115, 116
Sugarloaf Rock 30
Suisun Marsh 14
Surf Scoter 37, 41, 107
suture 59, 85, 96
Synthliboramphus hypoleucas 20, 57

T

tagging
6, 16, 23, 60, 76, 85, 86, 87, 89, 90, 98, 99, 101, 102,
104, 110, 111
tar balls 5, 13, 17
telazol 53, 54, 55
telemetry
23, 24, 26, 27, 44, 53, 84, 85, 86, 87, 88, 89, 90, 91, 92,
93, 94, 96, 98, 102, 104, 105, 108, 109,
110, 111, 113, 114,
115, 116, 117
testosterone 57
thermal imaging 41, 97
thermoregulation 31, 33, 41, 49, 51, 97, 99, 105
thiopental 56
threatened 6, 8, 26, 29, 30, 76
Tijuana Estuary 20, 21, 22, 27
Tomales Bay 9, 12, 13, 14, 15, 16, 17, 29, 106
Tufted Puffin 9, 20, 108
Tursiops truncatus
5, 34, 49, 56, 58, 68, 69, 70, 71, 78, 79, 82, 89, 92,
110, 113, 115
type C botulinum toxin 58

U

ulcers 48
Upper Newport Bay 21
Uria aalge 3, 12, 17, 32, 46, 51, 61, 62, 63, 80,
87, 91, 106

V

Virginia Rail 15

W

Waddell Creek 17, 26
wading birds 4, 11, 15, 18, 22, 34, 76, 108
waterproofing 53, 60
weathering 44, 47, 114
Western Gull 12, 13, 19, 63
Western Snowy Plover 29
White Pelican 61, 87
White-faced Duck 87, 90, 110
White-faced Ibis 30
Wilson Trap 42
worming 60

X

Xantus' Murrelet 20, 27, 28, 57
xenobiotic 46
xylazine 54, 55, 64

Y

Yellow-billed Loon 33
yohimbine 54

Z

Zalophus californianus
6, 11, 15, 18, 23, 39, 47, 53, 64, 65, 67, 77, 102,
104, 107, 108, 117
zoonoses 60