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NORTHWEST STRAITS OVERVIEW

A Science Gap Report

Prepared for the Northwest Straits Commission

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Background and Purpose of the Document

The Northwest Straits includes the open waters, nearshore areas and shorelines on the U.S. side of the Strait of Juan de Fuca and Strait of Georgia, and includes the waters of Puget Sound as far south as Port Susan. This area is rich in natural resources and contains valuable fish and wildlife habitats. It also provides an important passage for fish, larvae, ocean water and marine transportation from the Pacific Ocean to the populated areas of Puget Sound and the lower Fraser River basin in British Columbia.

Planning for resource conservation and protection of this area has been underway since the 1980s through the Puget Sound Water Quality Authority and other Washington state agencies and the National Oceanic and Atmospheric Administration, as well as the efforts of several Washington State and British Columbia-based non-governmental organizations. The work of the bipartisan Murray-Metcalf Commission in the late 1990s created the Northwest Straits Initiative, under the direction of the Northwest Straits Commission, to provide for better understanding of the system and conservation of the marine resources of the Northwest Straits.

The Northwest Straits falls under the jurisdiction of seven counties (Clallam, Jefferson, Whatcom, Skagit, San Juan, Island and Snohomish) and the state of Washington. Because the waters and habitats of the Straits are contiguous with Canadian waters, living resources and contaminants move freely across the international boundary. By working with the Canadians, the Northwest Straits Commission and the counties can better understand maximize the ecosystem and afford the best protection for the resources.

This draft document represents an initial attempt to compile available information about the status of resources and habitats of the Northwest Straits. It is not meant to serve as a comprehensive overview or a "State of the Straits" report. Rather, it was originally intended as a background piece, for participants of a one-day workshop, held in December 1999 in Everett, Washington, on data gaps and research needs for the Northwest Straits study area.

After reviewing this draft document, workshop participants made suggestions for updating and improving the draft text. Many of these have been incorporated into this revised report. Participants also identified major data gaps and information needs for their areas of interest. Gaps and needs were recorded, summarized and presented to the group at large. A further distillation of these points was drafted and distributed by Washington Sea Grant Program in February 2000. Copies of this document are available from the Northwest Straits Commission.

The limited timeframe for development of this draft necessitated that the authors rely heavily on published or readily available sources of information, with particular emphasis on other integrative papers. The draft's authors, Richard Strickland, Nancy Lerner, and editor, David G. Gordon, are especially indebted to the authors and contributors of the series of documents developed by NOAA for the planned Northwest Straits National Marine Sanctuary, and to the authors and contributors of *Marine Resources: A Citizen's Guide to the Northwest Straits*, published by the Center for Marine Conservation.

The work of the Northwest Straits Commission and the county-based marine resources committees focuses on conserving the resources and habitats of the region, using the benchmarks developed by the citizens commission as measurable goals. For this reason, the draft document has been organized into chapters that follow major resource groups, habitats and oceanographic features. Each chapter includes a characterization of the resource, followed by a discussion of that resource's current status. It concludes with a brief description of recognized data gaps and research needs. References for the entire text are gathered at the document's end.

I. OCEANOGRAPHY, WATER AND SEDIMENT QUALITY

CHARACTERIZATION OF THE RESOURCE

Basin

For purposes of this report, the Northwest Straits is defined as the study area presented in the Murray-Metcalf Citizens Advisory Commission Report (Washington Sea Grant, 1998). It includes U.S. waters of the Straits of Juan de Fuca and Georgia, U.S. waters surrounding the San Juan Islands, the Whidbey Basin, and northern portions of Puget Sound, and all associated embayments.

The Strait of Juan de Fuca constitutes the majority of the area and volume of water in the Northwest Straits. The Strait of Juan de Fuca is approximately 180 km long, 20-28 km wide, and 250 m deep at its entrance, decreasing gradually to the east (Mackas and Harrison 1997). Other morphological data on the Straits and Puget Sound are presented by Thompson (1994).

Circulation

Thompson (1994) summarized knowledge of the circulation in the Northwest Straits. Lower-salinity, warmer water originating from rivers flows oceanward at the surface, and higher-salinity, colder water originating from depths off the Washington coast flows landward along the bottom. These layers are intermixed to a degree that varies with time and location. The Strait of Juan de Fuca is considered a well-mixed estuary, while Puget Sound and the Strait of Georgia are considered partially-mixed.

The most intense mixing occurs along shallow sills, which occur in the Northwest Straits at Admiralty Inlet and in Rosario Strait and San Juan Channel. Because of this mixing, an estimated average of 52 percent of water flowing seaward at the southern end of Admiralty Inlet is "refluxed" back into the deep water of the central Sound rather than being discharged to the Strait of Juan de Fuca (Boss et al. 1998).

More than 80 percent of the water from Puget Sound and Strait of Georgia flows through the Strait (Mackas and Harrison 1997). Direction of net water movement within the Strait depends on depth. Net movement of cold oceanic deep water is to the east while net movement of fresher, warmer surface water is to the west (Mackas and Harrison 1997). Due to deep water, strong wind, and current mixing action, as well as seasonal strong contribution of riverine nutrients, the water of the Strait is well mixed, cold, and nutrient rich throughout the year (Mackas and Harrison 1997).

The Strait is a wind-dominated system, with currents changing dramatically within hours in response to both regional and larger scale oceanic winds. Strong seasonal storms contribute both freshwater and sediment to the Strait, which form large lenses of low salinity and high turbidity within nearshore along the majority of shoreline of the Strait. Winds from the south along the outer coast drive surface intrusions of ocean water into the Strait and can cause reversals of the more typical seaward surface estuarine transport (Thompson 1994).

Open-water habitat

Open waters are critical feeding habitats for adult fishes, birds, and mammals and their forage organisms, including forage fishes and the plankton of the food web. Phytoplankton is the predominant base of the food web. Phytoplankton biomass (chlorophyll) is monitored Sound-wide by the Washington Department of Ecology (WDOE) (Newton et al. 1997). Embayments off the main basin of the Straits are occasionally subject to poor circulation and nutrient loading, resulting in localized eutrophication and macroalgae blooms.

This habitat includes the little-studied microlayer, the upper 50 micrometers of the water surface. The microlayer is rich in organic chemicals and bacteria that metabolize this material, along with the eggs of such organisms as English sole, octopus, crab, shrimp, snails, urchins, and worms (NOAA in press B).

The neustonic zone (upper ~3 mm of the water column) is a highly productive habitat for phytoplankton and planktonic eggs (West 1997). The neuston is vulnerable to contamination by oil spills and terrestrial runoff as well as the deposition of airborne contaminants.

Physical properties such as tidal and wind-driven current speeds, wave exposure, and the strength of vertical mixing all significantly affect the quality of habitat for various open-water species. Waters protected from large waves and strong currents, such as bays and the lee of islands, for example, are important winter habitat for marine birds, waterfowl, and shorebirds (NOAA in press B).

The spatial pattern of phytoplankton production through the year is governed by the balance between vertical mixing of nutrients (which is strong over shallow sills) and vertical stratification (which is strong near river mouths and in quiet waters where solar heating creates a warm surface layer). There is strong circumstantial evidence that carnivores such as fish, birds, and mammals are abundant in areas where physical properties enhance plankton production. In addition, predators are observed to congregate at surface "fronts," where circulation causes waters to converge.

Two naturally occurring types of phytoplankton (*Heterosigma akashiwo* and *Chaetoceros* spp.) cause blooms that have caused serious mortalities of farmed salmon in net-pens in Puget Sound and the Northwest Straits in recent years (Connell and Jacobs 1998, Horner 1998).

Another naturally occurring phytoplankton species (*Alexandrium catenellum*) contaminates shellfish with natural toxins called saxitoxins and causes paralytic shellfish poisoning (PSP) in mammals that consume the shellfish. Blooms of this species and PSP have been observed in the Strait of Juan de Fuca for decades, and were observed in the Whidbey Basin in 1978 (Horner 1998, Determan 1998b).

Blooms of *Pseudo-nitzschia* spp. can contaminate shellfish with toxic domoic acid and cause Amnesic Shellfish Poisoning (ASP) in humans consuming the shellfish (Horner 1998). These species were detected in Port Angeles in 1992 and in Penn Cove in 1997 (Trainer et al. 1998). The origin of these species in local waters is uncertain.

The plankton is not monitored for the presence of toxic species. Instead, levels of PSP and ASP toxins in shellfish are monitored by the Washington Department of Health (Determan 1998b, Trainer et al. 1998; see also the *Invertebrates* section of this document).

Zooplankton, primarily copepods, constitute the principal food-web link between phytoplankton and higher trophic levels in open water (Harrison et al. 1994). These organisms grow and reproduce to increase in abundance during summer in response to increased food supplies. During winter many species migrate into deep water and cease feeding.

Because of its dynamic nature, the open-water habitat is more difficult to alter than shoreline habitats. Nevertheless, properties such as temperature, salinity, and current patterns can be altered by natural or anthropogenic changes in climate, river flow, and winds (BC/WA Marine Science Panel 1994).

Marine Water Quality

Plankton is concentrated by the formation of convergence zones, fronts, and slicks. The same processes also concentrate contaminants, probably making plankton more vulnerable to contamination (West 1997).

Chemical contamination of the water and microlayer can have biological impacts (White 1997a). The sea surface is a concentration point for chronic sea-surface pollution (CSSP), including pesticides, metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (West 1997).

Large quantities of water-borne contaminants, from sewage to toxic chemicals, are discharged from point sources in the Northwest Straits study area, such as in Bellingham Bay, Everett Harbor, and Fidalgo Bay (White 1997a). These contaminants may be of particular concern at large river mouths, where industrial facilities often are concentrated and where salmonids migrate.

Nonpoint pollution sources such as stormwater runoff from urban areas and failing shoreline septic systems in rural areas also contribute to contamination of the water column. According to the Washington Department of Health (WDOH), the average rate of failure of septic systems is 3.5 to 5 percent (White 1997b).

The Washington Department of Ecology (WDOE) has used 1990–1995 surveys to classify the sensitivity of the water column in various regions of Puget Sound to water quality degradation (PSWQAT 1998). Water quality can be compared by oxygen depletion in subsurface waters under conditions of strong vertical stratification. WDOE classifies stratification characteristics into four groups: persistent, seasonal, episodic, and weak (Newton et al. 1998).

Oxygen concentrations less than 5 mg/L are considered stressful and below 2 mg/L can be fatal to vulnerable fauna, such as juvenile salmon. Subsurface source water entering the Strait of Juan de Fuca from the Pacific Ocean is naturally low in oxygen (5.5–6.0 mg/L), enhancing the potential for oxygen stress in stratified locations. Dissolved oxygen (DO) concentrations <3 mg/L were measured at South Hood Canal, Penn Cove, and Discovery

Bay; and <5 mg/L were found at 19 additional stations during WDOE's 1996–97 surveys (Newton et al. 1998). Observations of low DO primarily occurred in late summer to early fall but in South Hood Canal occurred year-round and reached anoxia at times. Persistent stratification co-occurred with low DO concentrations.

WDOE also monitors dissolved nitrogen concentrations at the surface as an indicator of potential eutrophication that may occur in certain locales (PSWQAT 1998). Additions of nitrogen by humans could cause overgrowth of phytoplankton, which could aggravate already low dissolved-oxygen conditions. Areas of low surface nitrogen tend to be strongly stratified and have the potential for subsurface oxygen depletion. Occurrence of consecutive months with <0.01 mg/L surface dissolved inorganic nitrogen (nitrate+nitrite plus ammonium) in combination with stratification and other indicators was used to indicate stations potentially sensitive to eutrophication (Newton et al. 1998).

WDOE monitors the flow, temperature, oxygen and phosphorus content, and suspended solids in the Snohomish River Basin (PSWQAT 1998). River basin properties can affect both the habitat quality of water in the river estuary and the circulation patterns of water in Puget Sound as a whole. WDOE monitors fecal coliform bacterial concentrations in open waters of the Sound. Fecal coliform bacteria are indicators of sewage contamination and warn of the possible presence of human pathogens (PSWQAT 1998).

A new program called JEMS (Joint Effort to Monitor the Straits) has recently begun regular monitoring of temperature, salinity, oxygen, nutrient chemistry, and chlorophyll at three stations in the Strait of Juan de Fuca (J. Newton, WDOE pers. comm.)

Sediment Quality

Because most contaminants are poorly soluble in water, sediments are considered the primary sink for anthropogenic contaminants. They are also the primary source of contaminants that reach organisms (West 1997, PSWQAT 1998.

The biological impacts of sediment contamination have been evaluated by conducting bioasssays (using test organisms such as amphipods and sea urchin gametes), which are standardized on a national basis (Long et al. 1998). Additional tests, cytochrome P-450 and microbial bioluminescence, have also been used locally.

STATUS OF THE RESOURCE

Marine Water Quality

Sea surface temperature and salinity conditions in Puget Sound show fluctuations in response to climatic conditions, notably the El Niño Southern Oscillation cycle (Newton 1995). Surface waters are generally warmer and more saline during El Niño years, reflecting higher air temperatures and decreased river runoff. Salinity trends appeared reversed at a station in the southern Strait of Georgia, possibly because of the position of the Fraser River plume.

Dissolved oxygen concentrations are relatively low in deep water entering Puget Sound through Admiralty Inlet (Boss et al. 1998). Periodic intense intrusions of this water into central Puget Sound occur at neap tides during spring and late summer. If discharges of anthropogenic contaminants into the upper waters of the central Sound could be timed for periods of these intrusions, a greater fraction of the material would be dispersed into the Strait of Juan de Fuca rather than entrained into the reflux circulation.

In the Northwest Straits, Penn Cove and East Sound showed anoxic conditions based on 1990–1995 monitoring by WDOE (PSWQAT 1998); Dungenes Bay and Port Angeles Harbor have been cited as impaired due to low dissolved oxygen (WDOE, 1998). The Strait of Georgia and a cluster of sensitive stations in Saratoga Passage, Skagit Bay, and Port Susan showed some oxygen stress. Bellingham Bay and Port Gardner would appear to be sensitive to eutrophication based on physical and chemical characteristics, but did not show low oxygen values. The majority of the Puget Sound monitoring stations were either persistently (15 out of 38 stations)or seasonally (11 out of 38 stations) stratified during 1996–1997 (Newton et al. 1998).

Most waters of the Northwest Straits show relatively high levels of dissolved nitrogen at the surface, indicating a low potential for eutrophication (PSWQAT 1998). East Sound shows strong surface nitrogen depletion during summer. Penn Cove, Holmes Harbor, Sequim and Discovery Bays, Port Susan, Saratoga Passage, and Possession Sound show moderate depletion. During WDOE's 1996–1997 surveys, very high ammonium-N concentrations (>0.14 mg/L) were seen in the Northwest Straits of East Sound (Newton et al. 1998).

Most waters of the Northwest Straits show relatively low levels of fecal coliform bacterial contamination (PSWQAT 1998). Areas of high contamination (>43 org/100 mL) are found in Bellingham Bay and Port Gardner—the Nooksack and Snohomish Rivers are suspected as sources of this contamination. WDOE monitoring shows that fecal coliform contamination is widespread in rivers feeding Puget Sound. Moderate contamination (14–43 org/100 mL) was found at another site in Port Gardner and in the Strait of Georgia, perhaps originating from the Fraser River. Dungeness Bay also shows elevated fecal coliform counts seasonally. Fecal coliform bacteria counts (>14 organisms/100 mL) were found at 12 Puget Sound stations during WDOE's 1996-97 surveys (Newton et al. 1998). No stations in the Northwest Straits showed chronically persistent fecal contamination. Bellingham Bay showed wintertime highs in fecal counts.

For many years, concern has been expressed about the potential impacts of the City of Victoria's untreated sewage disposal into the Strait of Juan de Fuca (BC/WA Marine Science Panel 1994). Studies of currents (Crone et al. 1998) suggest that about 60 percent of floatable material released from the Victoria outfall is trapped within 10–20 km of the source (the Victoria Bight), and that the remaining 40 percent is spread widely on both sides of the Strait of Juan de Fuca and out to the Pacific. The results also suggest that relocating the outfall westward would significantly improve the dispersal of the effluent.

A study of 13 priority pollutant metals in seawater (Crecelius and Cullinan 1998) found no evident local contamination in the vicinity of the oil refineries at March Point and Cherry Point in the Northwest Straits, unlike a similar urban area of Commencement Bay. Portions of Port Angeles Harbor meet EPS Superfund criteria due to PCB contamination from a now-defunct pulp mill.

Concentrations of PCBs, PAHs, and metals orders of magnitude higher than U.S. Environmental Protection Agency water quality standards have been measured at the sea surface in Puget Sound (West 1997).

Certain areas in the Northwest Straits are susceptible to blooms of *Alexandrium*, the phytoplankton causing PSP. These sites include Sequim Bay, Discovery Bay, Kilisut Harbor, Drayton Harbor, and Birch Bay (PSWQAT 1998, Determan 1998b; see also Invertebrates). Strong PSP blooms also have been observed in the Strait of Juan de Fuca and the San Juan Islands, which are not routinely monitored.

A bloom of the diatom *Pseudo-nitzschia* , which can contaminate shellfish, was studied in Penn Cove in 1997 (Horner 1998, Trainer et al. 1998). Although the causes of such blooms are not well understood, the initiation of this bloom appeared to be related to high river runoff, wind and rain, and warm temperatures

Fresh Water Quality

WDOE monitoring of the Snohomish River Basin has shown some increasing nutrient loading since 1990, indicating the potential for causing eutrophication problems in the Whidbey Basin (PSWQAT 1998). Fecal coliform bacterial concentrations exceed water quality standards in the lower Skagit River and its estuary, and low DO conditions are present near the mouth of the south fork of the Skagit (Pickett 1998).

Monitoring by WDOE shows that the concentration of metals in rivers entering Puget Sound is generally quite low. Mercury exceeded the threshold at which chronic biological damage can occur in two of 12 measurements from the Stillaguamish River between 1994 and 1997 (PSWQAT 1998). Copper exceeded the concentration at which acute biological damage can occur once in 12 observations from the Stillaguamish River over the same period.

Some metal contamination from mining and pulp mill operations has been observed in the Quansam and Fraser Rivers, respectively, feeding the Strait of Georgia (PSWQAT 1998). Metal contamination conditions in the former river are worsening, while those in the latter are improving.

Sediment Quality

Monitoring indicates a relatively low degree and extent of sediment contamination in Puget Sound as a whole (PSWQAT 1998). WDOE's sediment management program has identified 49 contaminated sites in Puget Sound, almost all of which are in urban areas. Contaminants were undetectable in 70 percent of samples; the remaining 30 percent of samples came mostly from urban areas.

About 3,200 acres of Puget Sound have been found to have contaminant concentrations above the state's cleanup screening levels, representing 0.3 percent of the submerged surface area of the Sound (PSWQAT 1998). Because the Northwest Straits is less urbanized than the remainder of the Sound, it would be expected to be less contaminated than the rest of the Sound.

Locations with elevated concentrations of mercury, lead, PAHs, or PCBs in the Northwest Straits include Port Angeles Harbor and Port Gardner. Bellingham Bay also exhibits some sites classified as "contaminated" or "moderately contaminated" according to WDOE Sediment Management Standards (PSWQAT 1998). Areas of contaminated sediments are correlated with contaminant levels in fish tissues, health effects on fish, and potential effects on human health (PSWQAT 1998).

A comparison of bioassay results with other urbanized embayments showed that toxicity is not very severe or widespread in northern Puget Sound (Long and Dzinbal 1998). One hundred stations were sampled along most of the eastern shore of the Northwest Straits, from Everett Harbor to Point Roberts. Using an amphipod bioassay, 13 stations showed reduced survival as evidence of toxicity. Using a more rigorous statistical analysis, none of these areas in the Northwest Straits was classified as toxic.

Using sea urchin fertilization bioassays, 40.6 km^2 of sediments in the Northwest Straits (5.2 percent of the area sampled) were classified as toxic (Long and Dzinbal 1998). Fifteen of 100 stations showed toxicity: nine samples from Everett Harbor, two from Drayton Harbor, and one each from Port Susan, Fidalgo Bay, Padilla Bay, and Bellingham Bay. Toxicity was highest in Drayton Harbor and outer Everett Harbor.

Results from cytochrome and microbial bioluminescence tests also indicated highest toxicity in Everett Harbor, with toxicity also evident in Drayton Harbor and Bellingham Bay (Long and Dzinbal 1998). A multiagency pilot project is underway to plan and manage cleanup of contaminated sediments in Bellingham Bay (Stoner et al. 1998).

Results from toxicity bioassays are being combined with chemical and benthic community analyses to provide an overall synopsis of sediment quality in northern Puget Sound (Long and Dzinbal 1998).

DATA GAPS AND RESEARCH NEEDS

Salt Water Quality

Little is known about sea surface and pelagic habitats (Mumford 1997).

The water regime is not well thought out in the estuarine environment, particularly in embayments (Mumford 1997).

Evidence for chronic sea-surface pollution effects on living marine resources (especially eggs and larvae of stressed species) is compelling, and should be more closely and seriously assessed (West 1997).

Fresh Water Quality

Fecal coliform bacterial concentrations and low DO conditions can be brought within water quality standards in the lower Skagit River and its estuary if rigorous source control and monitoring are implemented (Pickett 1998).

Sediment Quality

Data needs have not been identified at this time.

Other

The relationships among physical properties that enhance plankton production predators and congregations of predators have received very little formal study. If higher animals tend to congregate consistently in favored areas, these patterns are poorly documented in the scientific literature.

Floating mats of kelp, green algae and other marine plants in the open-water habitat appears to be an important vector for dispersal of juvenile rockfish (NOAA in press A). Additional research in this area should be initiated.

II. NEARSHORE HABITATS

CHARACTERIZATION OF THE RESOURCE

The British Columbia/Washington Marine Science Panel (1994) identified habitat loss as the most serious threat to Puget Sound and the Straits of Georgia and Juan de Fuca, which include the Northwest Straits area. Habitat loss was given this priority because of: 1) the importance of habitat for the survival of valued species; 2) the current and projected rapid increase in the human population of the region and its effects on natural habitats; and 3) what the Panel considered the irreversibility of habitat alteration and loss.

Classification systems in common use assign Northwest Straits habitats into the categories presented in Table 1. The spatial extent of three of the prominent habitat types—eelgrass beds, kelp beds, and marine banks—are broadly depicted in maps from the Center for Marine Conservation (CMC 1998). However, specific knowledge of small-scale distributions of these habitats is spotty. In reality, many nearshore environments commonly contain heterogeneous subareas of hard- and soft-bottom and mixed substrate. For simplicity's sake, however, habitats are treated as idealized types in this document[1] .

Table 1. Categories of Habitats in the Northwest Straits Area (NOAA in press B, Levings and Thom 1994, Dethier 1990)

Habitat Category	Critical Habitats
Rocky-bottom intertidal & nearshore subtidal	Kelp beds Marine banks Rocky reefs Rock/gravel
Soft-bottom intertidal & nearshore subtidal	Eelgrass beds Emergent marshes Unvegetated (sand flats, mud flats) Intertidal algae Marsh/riparian Drift algae

General nearshore habitats

The importance of habitat for marine species is explained by West (1997). Submerged marine vegetation (SMV) habitats are of particular value under present conditions because many stressed resources rely on them (West 1997). SMV habitats include seagrasses, overstory and understory kelps, and turf algae. They support a high diversity and abundance of organisms, providing energy sources, refuge and foraging habitats, and attachment substrates. In addition, these habitats dissipate wave and current energy, stabilize sediments, and transfer energy to other habitats.

Both attached and adrift, kelp and eelgrass beds collectively support extremely complex nearshore assemblages of fish and plant life. They are considered critical habitats by local and national resource managers alike (Shaffer 1999).

The San Juan Islands and Strait of Juan de Fuca in the Northwest Straits have the highest proportion of vegetated shoreline in the Puget Sound Basin, with 87.7 percent of the shoreline vegetated compared to 72.3 percent of Puget Sound as a whole (Bailey et al. 1998). Green algae, covering 29.8 percent of the shoreline, was the most common vegetation in the San Juans and Straits according to this survey, followed closely by eelgrass and mixed algae (27.2 percent). Spit or berm vegetation was the least common vegetated habitat (10.5 percent) in the San Juans and Straits. In the Whidbey Basin, green algae and eelgrass were equally abundant, each covering 40.5 percent of the shoreline.

Armoring (bulkheading) can dramatically change the sediment transport and drift cells along shorelines, which in turn results in changes in and loss of critical baitfish habitat (Shaffer 1999).

Several species are believed to be vulnerable to "habitat-bottleneck" limits on their population abundance, in which reductions in nursery habitat area restrict their number of organisms that can complete their life cycle (West 1997). Examples of such species include Pacific herring, lingcod, rockfish, and Pacific cod.

The geographic location of various habitat types in relation to processes that control dispersal of larvae may also be relevant to their functions (West 1997). Thus, mitigation by relocation of habitat may not be a viable strategy in some situations.

The Washington Department of Natural Resources (WDNR) nearshore habitat program surveys shorelines to map the location and types of nearshore vegetation, producing maps and digital GIS data (PSWQAT 1998). For example, a 1995 update of the 1977 *Coastal Zone Atlas of Washington* for Whatcom County in the Northwest Straits area increased the area inventoried by more than 35 percent from the previous atlas. Data for Skagit and northern Island counties will be available soon.

Considerable effort has been invested in mapping habitats in Puget Sound and the Northwest Straits study area (Mumford 1997). Currently:

- The Washington Department of Transportation is using diver surveys and underwater videography to map eelgrass habitat.

- ShoreZone nearshore habitat mapping efforts now underway should complete the 2400 miles east of Cape Flattery in 15–20 years (Berry et al. 1998). Methods to simultaneously monitor trends in nearshore habitat health, are under study.

- Mapping of nearshore habitat in Whatcom, Skagit, and Island counties are completed and data is available on CD-ROMs.

Rocky-bottom habitats

Rocky reefs are submerged hard-bottom environments with sufficient physical complexity to provide shelter for territorial fish species, especially rockfishes (Pacunski and Palsson 1998). The majority of rocky bottom areas in Puget Sound are located in the Northwest Straits area (Pacunski and Palsson 1998, NOAA in press B). They are composed of solid rock or of gravel- to boulder-sized substrate and usually experience moderate to high wave and current energy.

Primary producers in rocky-bottom habitats include phytoplankton, benthic microalgae, and attached macroalgae (seaweeds, mainly bull [*Nereocystis luetkeana*] and giant [*Macrocystis integrifolia*] kelp) and surfgrass (*Phyllospadix* sp.). The invertebrate fauna are dominated by attached species such as barnacles, mussels, chitons, tube worms, seastars, anemones, as well as small crustaceans and annelids that find shelter in the interstices among attached organisms or between rocks. These invertebrates, in turn, are prey for small and large fish, which support bird and mammal populations.

Kelp provides both a food supply and physical refuge for animals (Shaffer 1998). Kelp beds support numerous prey species such as lingcod, kelp greenling, cabezon, and various rockfishes and perches, for recreational and commercial fisheries. Adult chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) also use kelp beds extensively for feeding and staging areas before heading into natal streams to spawn (Shaffer 1999). Birds and mammals also congregate in these habitats because of the prey abundance. Inventory of kelp beds from Copalis Beach to Port Townsend has been completed annually since 1989 and data are available from WDNR.

Marine banks are large, isolated areas of shallow (3–4.5 m) water in the eastern Strait of Juan de Fuca (NOAA in press B). These banks are highly productive and support unique flora and fauna through a range of habitats. They are considered critical feeding grounds for cetaceans, and also support robust populations of salmon and halibut.

The introduced kelp *Sargassum muticum* has become widespread in the Northwest Straits area over the last several decades (West 1997).

Soft-bottom habitats

Soft-bottom habitats are most vulnerable to human impacts because the physical substrate itself is amenable to alteration and because population centers often arise near these habitats. They generally experience low wave and current energies, are vegetated by rooted higher plants rather than attached macroalgae, and are populated by burrowing invertebrate infauna species (such as clams, ghost shrimp, and tube worms) and motile and sedentary epifauna species (such as nereid worms and oysters, respectively). Particularly important to the food web are the meiofauna such as harpacticoid copepods, which are prey for juvenile fish.

Sediment-dwelling organisms are being surveyed Sound-wide by WDOE to indicate the type and diversity of organisms in particular sediment habitats (such as sand; mixed sand, silt, and clay; and mud) in the absence of high levels of pollution (PSWQAT 1998).

Additional occasional surveys of soft-bottom fishes and macro-invertebrates are conducted by the Washington Department of Fish and Wildlife (WDFW) (Palsson pers. comm.). The initial results of these studies have identified numerous species that indicate specific environmental conditions. The absence of expected species is evidence of natural low-oxygen conditions at the head of Saratoga Passage, and is used to highlight areas potentially stressed by pollution.

Soft-bottom habitats trap and entrain spilled oil. In addition to the direct biological impacts of this oiling on the marsh itself, the trapping reduces the rate of oil weathering and provides a reservoir for re-oiling of the adjacent marine environment (White 1997a). Also, mobile fishing gear such as bottom trawls has been shown to alter certain types of soft-bottom habitats and communities in other parts of the world (Palsson pers. comm.). Such gear once was used throughout the Northwest Straits area but now are limited to otter trawling in waters deeper than 50 fathoms from Cape Flattery to Port Angeles and waters deeper than 30 feet in the San Juan Archipelago and the Strait of Georgia and adjacent waters. Some benthic impacts have been demonstrated in Puget Sound (WDFW 1985), but the extent of the impacts has not been recently examined with more advanced technology.

Shoreline armoring, meant to protect upland property, often increases the long-term erosion rate of the shoreline (Terich 1987, in White 1997a). These impacts may not be visible for several years, but may be difficult or impossible to repair once they become evident. Biological impacts of shoreline armoring include losses in food supply, migratory corridors, and foraging, spawning, and rearing habitat that can affect the entire food chain (White 1997a).

These habitats also are at risk from invasion of non-indigenous species, notably the cordgrass *Spartina* spp. and the green crab *Carcinus maenas* (CMC 1998). *Spartina* alters natural soft-bottom intertidal fish and shellfish habitats because it grows in dense colonies that trap sediments, changing the elevation of tideflats. It excludes native vegetation or turns unvegetated tideflats into vegetated ones (PSWQAT 1998).

<u>Eelgrass beds</u>

Eelgrass grows in muddy to pebbly substrate from the high subtidal to the high intertidal zone in protected to semi-protected areas (NOAA in press B). Eelgrass beds are considered the most critical habitat for supporting a wide variety of marine animals, either directly or indirectly (CMC 1998).

Eelgrass beds are the primary spawning habitat for Pacific herring, nursery areas for juvenile Dungeness crab (*Cancer magister*) and salmon, and critical winter habitat for black brant (*Branta bernicla*) and other waterfowl (NOAA in press B). Juvenile and adult crab (including gravid females) have been documented to depend on eelgrass beds in the Northwest Straits (Shaffer 1999).

Although seagrass beds are in decline in many areas, the Northwest Straits study area contains most of the significant eelgrass beds in Puget Sound, including Padilla Bay, the Snohomish Estuary, and southern Georgia Strait (NOAA in press A).

Both marshes and eelgrass beds are degraded by alterations of the nearshore environment through such actions as dredging and filling, diking, bulkheading and other forms of shoreline armoring, stream channelization, boat anchoring, oyster culture, and pesticide use (CMC 1998).

Large-scale losses of shoreline habitat arise not so much from site-specific alterations such as dock shading, dredging, etc., but mainly from large-scale changes in water quality (Mumford 1997). Changes in factors such as nutrients and eutrophication, sediments, and freshwater and toxicant inputs can alter the lower limit of vegetation or of the photic zone. Anthropogenic turbidity, pollution, and eutrophication all block light and can also contribute to decline of eelgrass beds (West 1997, Thom et al. 1998).

Methods are under development for rapid surveying of subtidal eelgrass coverage (Norris and Hutley 1998). These methods could be very useful for assessing the need for and success of eelgrass mitigation projects. King County Department of Natural Resources (KCDNR) is currently inventorying eelgrass using this method along the northern portion of King County, and WDNR is issuing an RFP to further refine this method and complete inventory in selected areas in 2000-1.

The introduced seagrass *Zostera japonica* has become widespread in the Northwest Straits area (West 1997). It is found higher in the intertidal zone than the native *Z. marina* but may still have effects on habitat quality.

<u>Emergent marshes</u>

Emergent marsh habitats (regularly flooded by tides and supporting rooted, non-woody vegetation) include salt marshes, salt meadows, and brackish water marshes. They are important feeding and nursery areas for juvenile and adult crab, shrimp, marine fish, juvenile salmon, shorebirds, waterfowl, and upland birds and mammals (NOAA in press B). Considerable area of this habitat type is present near river mouths in the Northwest Straits area, especially in the Skagit and Stillaguamish River estuaries. WDNR has inventoried these habitats in both their statewide ShoreZone and Whatcom, Island, and Skagit Counties vegetation mapping.

<u>Unvegetated habitats</u>

Shallow-water unvegetated habitats (for example, sand and mud flats) are considered among the most productive habitats in the Northwest Straits and are very important for baitfish spawning. However, these habitats are traditionally accorded low ecological value (Levings 1998). Their function has never been adequately assessed. WDNR has inventoried these habitats in both their statewide ShoreZone and Whatcom, Island and Skagit Counties vegetation mapping. Chinook salmon juveniles are known to use sand flats for rearing. It is likely that sand and mud flats are important building blocks for brackish marsh and other key habitats and their development should not be impaired.

Most species of flatfish and many other species of groundfish depend on deep and shallow water unvegetated habitats (Palsson pers. comm.). Metamorphosing flatfish have been shown to partition and depend upon the shallow water sand and mud flats (Thornburgh 1978) and English sole have been shown to partition unvegetated habitats between the sexes depending upon the grain size of the sand and mud.

STATUS OF RESOURCES

General nearshore habitats

In general, it is known that area-wide, soft-bottom habitats are in decline because of increasing human populations and alterations associated with shoreline development. According to a survey of scientists and managers, the greatest threats to the nearshore environment are shoreline armoring, residential development, large commercial or industrial development projects, water quality degradation, and overwater structures such as docks and piers (Broadhurst 1998). *Spartina* infestations also appear to be a growing problem.

Populations in San Juan and Jefferson counties are the fastest growing in the Northwest Straits, expected to increase at rates of 12.8 percent and 14.8 percent, respectively, from 1995 to 2000 (Battelle 1996, in NOAA in press A). By the year 2010, the human population in the combined Puget Sound and metropolitan Vancouver areas is predicted to increase by more than 60 percent from 1980 levels to top six million (BC/WA Marine Science Panel 1994).

In 1994, eight counties in and around the Northwest Straits granted 271 shoreline development permits (Battelle 1996). Shoreline development has been most intense in Whatcom, Snohomish and Skagit counties, and more moderate in San Juan, Island and Clallam counties. Shoreline development in the past two decades has been least intense in Jefferson County (Battelle 1996, in NOAA in press A).

WDFW (1996, in White 1997b) estimated that 30,000 acres of fish habitat are lost every year to other uses. For salmonids, habitat includes vast areas of upland rivers as well as open water and shoreline. These habitats are as vulnerable as shorelines. Beechie et al. (1994, in White 1997b) estimated that at least 24 to 34 percent of the coho rearing habitat in the Skagit River watershed (mostly riverside channels and sloughs) has been destroyed.

WDNR estimates that humans have altered one-third of Puget Sound's shoreline, approximately 800 miles (PSWQAT 1998). Twenty-five percent of the Sound's shoreline has been modified in the intertidal zone. The Northwest Straits area has the highest percentage of unmodified shoreline, nearly 80 percent. This percentage is highest in the San Juan Islands, where rocky substrate predominates.

According to recent surveys (Bailey et al. 1998), the San Juan Islands and Strait of Juan de Fuca have relatively low incidence of artificially modified shoreline (20.2 percent of shoreline length) compared to Puget Sound as a whole (33.2 percent). The Whidbey Basin had a higher-than-average incidence of modification, 32.4 percent of shoreline length. The percentage of modified shoreline in the Whidbey Basin, San Juans, and Strait of Juan de Fuca is reported to be within the confidence limits of previous measurements from the early 1990s (Bailey et al. 1998). However, bulkheading in San Juan County is described as increasing with the growing population (Richard Rutz, San Juan Co. Planning Dept. pers. comm. To C. Mills, UW).

Altering of lowland rivers, including diking, armoring and damming, has occurred extensively along all rivers of the Strait of Juan de Fuca, including the Clallam, Sekiu, Pysht, Elwha, and Dungeness Rivers. This alteration is thought to have resulted in extensive loss of estuarine habitat and function, including loss of estuarine wetland, eelgrass, and clam habitats (Shaffer 1999)

Bulkheading of the shoreline has taken place along the majority of the Strait of Juan de Fuca (Shaffer 1999). This bulkheading, associated with road-building (Highway 112), the old railroad bed, and urban growth in Port Angeles and Port Townsend, has gone largely undocumented.

Rocky-bottom habitats

According to recent surveys (Bailey et al. 1998), the San Juan Islands and Strait of Juan de Fuca in the Northwest Straits have a high frequency of bedrock (27.2 percent of shoreline length) and boulder (18.4 percent) habitats.

Kelp beds are common in shallow subtidal rocky areas of the Northwest Straits. They are especially abundant in the San Juan Islands, around Smith and Protection Islands, and in the outer Strait of Juan de Fuca (CMC 1998).

Kelp beds cover about 6,600 acres, or 12 percent, of shoreline of the Strait of Juan de Fuca (Thom and Hallum 1990, van Wagenen 1996, in PSWQAT 1998). WDNR is using aerial photography to map kelp beds. Dominated by bull kelp, this area includes 82 percent of the bull kelp and 73 percent of the giant kelp found in Washington west of Port Townsend. Despite interannual fluctuations, there was no significant change in total kelp coverage from 1991 to 1996.

The Strait of Juan de Fuca contains 50 percent of the combined kelp resources of the Strait and Puget Sound along only 300 km of the combined 1,500 km of shoreline (Shaffer 1998). Bull kelp dominates eastward of Freshwater Bay, while bull kelp and giant kelp are both common to the west. Differences in invertebrate communities depending on kelp composition are evident.

Nearshore vegetated habitats are dominant in the Strait of Juan de Fuca and are found along approximately 60 percent of the Strait shoreline (Shaffer 1999). In total, kelp beds of the Strait (found along at least 40 percent of the shore) make up 78 percent of the kelp resources found along coastal Washington. The kelp beds of the Strait of Juan de Fuca are therefore the majority of Washington’s coastal kelp resources.

The percentage of shoreline vegetated by kelp in the Whidbey Basin, San Juan Islands, and Strait of Juan de Fuca is within the confidence limits of previous measurements from the 1970s and earlier (Bailey et al. 1998). Based on these data, no trend in kelp abundance is visible. The area of kelp beds in the Northwest Straits and Puget Sound is estimated to have increased by more than 100 percent since European settlement (Levings and Thom 1994, in CMC 1998). Kelp coverage may have increased, perhaps because of increased shoreline armoring that has removed local sediment deposits, and because of increased nutrients in Puget Sound (Thom and Borde 1997). The presumed benefits of increased kelp habitat may be offset by loss of soft-bottom habitats.

Despite these possible gains, kelp beds are experiencing anthropogenic stressors, such as reduced water quality, that may affect their overall coverage in the future (West 1997). Invasion by *Sargassum muticum* and human harvest activities also may affect kelp abundance, at least in localized areas.

Soft-bottom habitats

Aquaculture operations have been examined as a potential source of habitat loss in Puget Sound (Simenstand and Fresh 1995, in West 1997). Habitat alterations include graveling and netting of beaches for hardshell clam culture, and spraying with pesticides and removal of natural vegetation such as eelgrass by oyster growers. Oyster culture also has displaced a number of nearshore invertebrate species.

Artificial reef construction seriously alters habitat and displaces organisms on a localized scale, but the current total area affected in Puget Sound is small (West 1997).

<u>Eelgrass beds</u>

Zostera marina eelgrass occupies at least 20 percent of Strait of Juan de Fuca shoreline (Shaffer 1999). The percentage of shoreline vegetated by eelgrass in the San Juan Islands and Strait of Juan de Fuca is within the confidence limits of previous measurements from the 1970s (Bailey et al. 1998). Based on data in those areas, no trend in eelgrass abundance is visible. Eelgrass abundance in the Whidbey Basin in the recent study is 40.5 percent of shoreline length, compared to 20.1 percent in the 1970s. This difference is statistically significant and suggests an increase in eelgrass coverage in the last two decades. Losses of eelgrass bed acreage are difficult to measure, but there is consensus that major losses or degradation have occurred in recent years (West 1997).

Throughout the area, private docks are proliferating, shading and killing eelgrass. Shoreline bulkheads to prevent erosion are on the increase, with the frequent result of altering the nearshore characteristics and causing the decline of eelgrass meadows (NOAA in press A).

Loss of critical eelgrass meadows has been locally severe, especially around industrialized areas such as Everett and Bellingham. Elsewhere, even in smaller embayments, cumulative loss of smaller meadows can add up. Marina expansion plans, such as in Port Townsend Bay, threaten to remove remaining critical eelgrass stands (NOAA in press A).

In some cases, eelgrass has been replaced by kelp, useful to some fish, but not the type of habitat upon which chum and chinook salmon depend (NOAA in press A).

Surveys have revealed large areas in Puget Sound where environmental conditions appear to be favorable for eelgrass. However eelgrass is absent or in very low abundance in these areas (Thom et al. 1998). Shading, propeller wash, and disturbance by foraging crabs have been documented to cause fragmentation of existing meadows. Fragmentation of eelgrass beds may have resulted in significant changes in habitat function (Ruckelshaus 1994, in West 1997).

Studies at ferry terminals, including at Port Townsend (Norris & Hutley 1998) and

Anacortes in the Northwest Straits, indicate that shading by *Ulva* blooms is likely responsible for some fragmentation of eelgrass beds (Thom et al. 1998). These blooms are attributed to local eutrophication resulting from nutrient runoff in small streams.

Seagrasses have been damaged in several bays. Effects of eutrophication on eelgrass stands south of Port Townsend are known (Thom and Borde 1997).

Macroalgae blooms are theorized to cause habitat shifts and decline in both eelgrass beds and recreational shellfish resources in Dungeness Bay (Shaffer 1999).

Introduced vegetation such as *Zostera japonica*, *Sargassum muticum*, and *Spartina* spp. are suspected of reducing area of native eelgrass. *Z. japonica* does not function as spawning habitat for Pacific herring, but is currently accepted as mitigation for loss of *Z. marina* in WDNR policy (West 1997).

<u>Emergent marshes</u>

The majority of Puget Sound salt marsh areas have been dramatically reduced as a result of human alteration of the shoreline and nearshore area (Bortleson et al. 1980, BC/WA Marine Science Panel 1994, in NOAA in press A)

The Northwest Straits have experienced heavy intertidal wetland loss since the settlement by Europeans. Overall, there has been a 43 percent loss of marshes within the major watersheds. In the Lummi, Samish, Snohomish and other watersheds, wetland losses have exceeded 75 percent (NOAA in press A). Loss estimates range from 73 percent in river delta wetlands (Bortleson et al 1980, in White 1997a) to 76 percent tidally influenced marshes and riparian habitat (Levings and Thom 1994, in CMC 1998). Sixty percent of this loss occurred in two Northwest Straits estuaries—the Skagit (25 percent loss, equaling 400 hectares) and Snohomish (74 percent loss, 2900 ha) (Hutchinson et al. 1989, in CMC 1998). The loss in the Skagit is considered an underestimate because most of the river-delta wetlands were already diked for conversion agricultural use before the first survey was conducted in 1890 (White 1997b).

Estimates of alterations in the area of other natural estuarine salt marsh habitats in the Northwest Straits range from a 20 percent gain (Stillaguamish delta) to a 98 percent loss (Samish delta) (NOAA in press B). White (1997a) gives some detail about the Lummi, Nooksack, and Snohomish river delta habitats. Because of their large areas and predominance of agricultural land use, the Skagit and Snohomish river deltas are considered to have the greatest potential for wetland restoration (White 1997b).

<u>Unvegetated habitat</u>

WDNR has inventoried these habitats in both their statewide ShoreZone and Whatcom, Island, and Skagit Counties vegetation mapping.

Nonindigenous species

Spartina infestations occur in the Northwest Straits at a few locations along the Strait of Juan de Fuca, and one location on San Juan Island, and in numerous areas along the shorelines of Skagit, Island, and Snohomish counties (PSWQAT 1998). The Washington Department of Agriculture (WDA) and volunteer organizations are monitoring and attempting to limit the spread of *Spartina* through removal and control programs.

Habitat Protection and Restoration

Restoration of most types of habitat has been attempted in the Puget Sound and Northwest Straits area, with some success (Thom and Borde 1997). Among the key findings:

- Eelgrass meadows are the most frequent target of restoration efforts, and in recent years the success rate of these efforts has improved, including one at a site at La Conner in the Northwest Straits study area. A former tidal wetland at Spencer Island in the Snohomish River estuary was restored with at least partial success by dike breaching.

- Small projects outside of the Straits area have demonstrated successful construction of cobble-gravel beaches and kelp beds.

- Experience so far indicates that habitat restoration projects can begin to show some desired ecological functions within two years, but that complete functioning may take many years to accomplish, perhaps as long as a century. Not all sites are amenable to restoration, and some guidelines have been developed for selecting good candidates for successful restoration.

- The costs of these projects, especially projects too large to depend on volunteer efforts, can be high. An important part of those costs is post-restoration monitoring, which fosters intelligent planning of projects, but monitoring is sometimes curtailed or eliminated as a cost-cutting measure.

Murray (1998) provided a comprehensive review of Marine Protected Areas in Puget Sound. He identified 102 areas of various sizes with various forms of management. (He does not separate those in the Northwest Straits area, but this could be done). Only 18 percent of these sites provide some protection from harvest for fish species, and only one (Edmonds Underwater Park) allows no take of any species.

DATA GAPS AND RESEARCH NEEDS

General nearshore habitats

There is a need for a large-scale consistent map and inventory of all these habitat types throughout Puget Sound—on a detailed basis (Palsson pers. comm.). NOAA has bottom-type information that has been collected over the years. The bathymetry data are slowly getting developed into a useable system (more detailed than PRISM needs) but another GIS layer could be developed with existing NOAA bottom type information (typically categorizes bottom type in mud, sand, pebbles, rocks, and boulders). WDFW has been surveying and mapping nearshore rocky reefs. This is a preliminary attempt at being able to inventory subtidal habitat. The next would be to employ undersea technology such as a high-tech side-scan profiler that will provide bathymetry, rugosity, and bottom type.

A centralized tracking system is needed for evaluating habitat changes on a Sound-wide basis (West 1997). This system should link upland and marine habitat management to account for the effects of upland activities on marine habitats.

The Puget Sound Ambient Monitoring Program (PSAMP) Nearshore Habitat Component should be expanded to include monitoring of turbidity and eutrophication and encroachment of exotic species as they effect intertidal and subtidal plant species (West 1997).

The degree to which aquaculture of Pacific oysters impacts endemic habitat in Puget Sound should be investigated (West 1997).

Applied research should address specific needs for better managing and protecting the habitats that support distressed species (West 1997).

Planning for the potential effects of global warming and sea-level rise on the Puget Sound ecosystem should begin (West 1997).

Despite the unique identity, critical species and habitat, and heavy use supported by the Strait of Juan de Fuca, little is known about its nearshore habitats (Shaffer 1999). Ecosystem links between upland and nearshore are extremely important, but largely unknown. There is a need to monitor restoration sites and to guage their success rate.

Rocky-bottom habitats

Several shallow marine banks lie between the San Juan Islands and Dungeness Spit/ Quimper Peninsula (NOAA in press A). These banks have not been studied in detail.

Three major questions persist regarding macroalgae: 1) the effects of harvest and anthropogenic environmental change on the long-term viability of seaweeds; 2) the habitat value and function of the seaweeds within the ecosystem; and 3) the trends in distribution and population abundance of these species (Mumford in West 1997).

A clearly documented and formalized seaweed policy with mitigation procedures should be established (West 1997).

Soft-bottom habitats

WDNR is inventorying nearshore habitats, especially intertidal and shallow subtidal eelgrass beds, using remote sensing and GIS to monitor habitats as indicators of success of water quality programs. Two major federal efforts (Coastwatch and EMAP) also are underway. The greatest need is for subtidal surveys (Mumford 1994). Very little is known about subtidal eelgrass beds, which are the majority of really productive habitats used by marine diving birds, species that have been declining for 20 years (Nysewander & Evenson 1998).

There are inadequate inventories of nearshore habitats and biological resources to enable managers to make informed decisions about protecting resources (Broadhurst 1998).

Shoreline (nearshore) is the least studied ecotone in the Puget Sound basin (PNCERS 1996, in Mumford 1997).

Existing nearshore mapping efforts need to be improved (Mumford 1997).

Information is especially lacking on the cumulative effect of many small impacts, or of habitat loss in remote but connected environments (such as watersheds and tidal deltas) on local shoreline and wetland systems (White 1997a).

Chemical degradation of nearshore habitats is poorly understood (Thom and Borde 1997).

Physical losses of kelp, eelgrass, and cobble shores are less understood and documented than tidal marsh wetland losses (Thom and Borde 1997).

White (1997a) specified several needs for studying habitat loss:

- Little is known about the extent and rate of increase in shoreline armoring and structures in the Northwest Straits area.

- The impacts of armoring and structures on the value and functioning of shoreline habitats have not been well studied.

- The physical processes affected by armoring are generally better studied and understood than the biological processes.

- Information is especially lacking on the functions and values of marine nearshore habitats for support of fish and wildlife and on effects of shoreline armoring on habitat.

- Information is especially lacking on the extent and health of marine shoreline and freshwater wetland habitats.

More information is needed on the impacts of aquaculture on nearshore habitat (West 1997).

There is no system to track cumulative, ecosystem-level effects of fragmented losses on shoreline habitat (West 1997).

Chronic Sea-Surface Pollution (CSSP) effects on communities associated with surface vegetation (e.g., intertidal eelgrass) and drift habitat should be investigated (West 1997). Baseline data are lacking on sea-surface pollution. Index or reference sites should be established to monitor CSSP and its effects on neuston and intertidal communities (West 1997).

Little is known about changes in water quality and its impact on nearshore resources, including ulvoid mats, essential fish habitat and shellfish resources.

Eelgrass Beds

Eelgrass data in the Puget Sound Environmental Atlas have not been updated. The highest needs are for subtidal inventories (Mumford 1994).

The WDNR survey program lacks the capability to distinguish *Z. marina* from *Z. japonica* and to survey below very shallow subtidal depths (Mumford in West 1997).

Early eelgrass survey data by Phillips have not been fully published. Unpublished records of seagrass occurrence in WDFW herring roe surveys have not been analyzed (Mumford 1994).

Integration of seagrass science and policy will require 1) assessing the significance of nursery residence in seagrass habitats for growth and survival of fishes and macroinvertebrates; 2) determining the relationship of seagrass habitat structure and function as fish and macroinvertebrate habitat; 3) tracing the contribution of seagrass-generated organic matter to food webs beyond the seagrass habitat, especially to deep subtidal habitats; 4) assessing the influence of seagrass patch structure; and 5) determining the rate of direct herbivory on seagrass from both macro- and microherbivores (Simenstad 1994).

A clearly documented and formalized seagrass policy with mitigation procedures should be established. The policy would need to distinguish between *Z. marina* and *Z. japonica* (West 1997).

Unvegetated habitat

WDNR has inventoried these habitats in both their statewide ShoreZone and Whatcom, Island and Skagit Counties vegetation mapping.

Non-indigenous species

No information on research needs was obtained.

Habitat Restoration

In 1997, the State and the Treaty Tribes adopted a joint Wild Salmonid Policy. The document lists a wide range of actions that are necessary to restore wild runs. Restoration of riparian habitat makes up the bulk of the document (NOAA in press A).

Information is especially lacking on the relative success of various approaches to habitat creation and restoration (White 1997a).

Research into the following topics would help us to implement restoration projects and improve their success rate: 1) minimum viable populations needed to initiate full restoration; 2) the size and distribution of habitat patches required to support desired functions; 3) physical, chemical, and hydrological requirements of plants potentially used in restoration efforts; and 4) propagation methods and nurseries for plants, such as eelgrass, in order to minimize the need to gather plants from natural stands (Thom and Borde 1997).

Habitat Protection

Habitat protection would be facilitated by a volunteer monitoring network with a central database and GIS accessible via Internet to utilize and augment existing agency databases (Thom and Borde 1997). A GIS and database for MPAs should be developed (Murray 1998). Research should be undertaken to identify additional MPA sites and integrating results with British Columbia. Additional site information should be gathered for existing MPAs.

The Snohomish, Stillaguamish, Skagit, Nooksack, and Elwha Rivers represent the best opportunities to restore estuarine wild chinook salmon habitat in Puget Sound (White et al. 1998). The first three have no dams in their lower reaches, have not been moved from their native channels, and are lightly impacted by industrial development.

III. INVERTEBRATES

CHARACTERIZATION OF THE RESOURCE

This report focuses on invertebrate resources identified as stressed or threatened. Invertebrates include several large and small taxonomic groups (Table 2). A complete list of invertebrates in the Northwest Straits is beyond the scope of this report. The organisms are distinguished into those that are "Classified" by the state for commercial and recreational harvest (more than 40 species) and those that are "Unclassified." The former group primarily includes species informally called "shellfish." The latter group, called "non-game" invertebrates (e.g., Kyte 1989) or "unclassified marine invertebrates" (UMI) (West 1997), are not formally monitored nor managed by WDFW or WDNR, but many of these species are harvested. WDFW collects UMI -Macro invertebrate information during trawl surveys in the Northwest Straits area (Palsson pers. comm.).

Table 2. Major types of commercial and recreational invertebrate resources in the Northwest Straits — Shellfish species classified by taxonomic group (NOAA in press B)

Phylum, Class	Major species
Mollusca, Gastropoda	snails, abalones
Mollusca, Bivalvia	oysters, clams, geoduck, mussels, scallops
Mollusca, Cephalopoda	squid, octopus
Arthropoda., Crustacea	crab, shrimp, barnacles
Echinodermata, Echinoidea	Sea urchins (roe)
Echinodermata, Holothuroidea	Sea cucumbers

Recreational & Commercial Shellfish

<u>Olympia oyster</u>

The Olympia oyster is native and was once harvested widely Sound-wide (West 1997). It is still raised commercially but is not as easy to grow as the introduced Pacific oyster (despite its popularity among consumers). It lives in the lower intertidal zone on firm substrate, since it is intolerant of siltation.

Discovery Bay was the first place that non-native people found and ate the now rare, historically important, Olympia oyster (Shaffer 1999).

<u>Other classified shellfish</u>

Oysters and clams are prevalent in the Strait of Juan de Fuca (Shaffer 1999). Numerous clams including the geoduck, (*Panope abrupta*), butter clam *(Saxidomous gigantea*), manila (Venerupis philippinarum) and native littleneck (*Prototheca staminea*) are found along beaches and flats of Dungeness, Discovery and Sequim Bays.

Spot shrimp (*Pandalus platyceros*), coon stripe shrimp (*P. danae*), and Dungeness crab (*Cancer magister*), are popular features of Port Angeles, Dungeness, Sequim, and Discovery Bays in the Strait of Juan de Fuca (among others in the Northwest Straits) (Shaffer 1999).

Juvenile spot shrimp depend on understory Laminarian beds in Canadian waters (Shaffer 1999). In Hood Canal, juvenile spot shrimp preferentially use shallow nearshore areas and river mouths in Hood Canal. Shrimp use of nearshore habitats, including understory kelp habitats and river mouths, is largely unknown in the Strait.

Pinto abalone occurs on shallow rocky substrate and feeds on seaweed (West 1997).

Unclassified Marine Invertebrates

Kyte (1989) identified 26 phyla and more than 2,900 species of Unclassified Marine Invertebrates (UMI) in Puget Sound. Some parts of the study area, such as the Strait of Juan de Fuca, have not been well surveyed, so it is likely that this number is low. UMI comprise 98 percent of all invertebrates in Washington (West 1997).

It is very difficult to generalize about these species, which vary widely in distribution, abundance, life cycles, and trophic interactions. The greatest need for protection of these species is in the intertidal zone because of shoreline harvesting by researchers, hobbyists, bait-fishers, and subsistence fishers.

The interest in protecting UMI arises not just from concern over individual species, but also from a desire to maintain biodiversity and natural structure and functioning of shoreline communities (West 1997).

Nonindigenous Species

Nonindigenous species (NIS) are invertibrates, algae, plants, and animals that are not native to the region and that have been introduced accidentally or intentionally into the region. There is no complete list of all nonindigenous species inhabiting the Northwest Straits waters (NOAA in press B). However, a group of experts surveyed the area in August 1998 (Cohen et al. 1998). Of 39 nonindigenous species found throughout Puget Sound, 20 species were found in the Northwest Straits, and 10 additional species are known to occur in the Straits. Of this total of 30 species, 3 are plants and 27 are invertebrates.

Prominent NIS include the Pacific oyster (*Crassostrea gigas*), manila clam, oyster drill (*Ceratostoma inornatum*), cordgrass (*Spartina* spp.), and Japanese eelgrass (*Zostera marina*). The former two arguably have had mainly beneficial effects (commercial and recreational harvest), while the latter three have had detrimental effects on native communities (as discussed in this document's *Habitat* section).

Contamination and Human Health

The National Oceanic and Atmospheric Administration (NOAA) monitors mussels (*Mytilus galloprovincialis*, *M. trossulus*, and *M. edulis*) in coastal waters as indicators of waterborne contaminants (PSWQAT 1998). The contaminants monitored include cadmium, copper, lead, mercury, nickel, zinc, and butyl tin, and the organic chemicals DDT, chlordane, PAHs, and PCBs. Since 1995, WDOE has monitored pesticides and PCBs in mussels at five sites in Puget Sound, including Padilla Bay in the Northwest Straits (PSWQAT 1998).

WDOH monitors shellfish for presence of fecal coliform bacteria, an indicator of the possible presence of pathogens originating from sewage contamination (PSWQAT 1998). It also monitors for another bacterial pathogen, *Vibrio parahaemolyticus*, and for biotoxins taken up from harmful algal blooms (HABs), both of which occur naturally in Puget Sound. WDOH classifies commercial shellfish growing areas as open, conditionally open (subject to closures at certain times), or closed based on contaminant levels. Not all areas are yet classified, but WDOH is working to expand the number of classified areas. Recreational shellfish beaches are opened or closed to harvest based on results of fecal coliform and/or PSP monitoring.

STATUS OF RESOURCE

General

Nearshore marine invertebrates, including stressed species such as the Olympia oyster and UMI are vulnerable to mortality resulting from oil spills (West 1997).

Studies have demonstrated sea-surface contaminant-related effects in oyster and clam larvae (West 1997).

Recreational & Commercial Shellfish

<u>Olympia oyster</u>

Samish Bay in the Northwest Straits once supported a large, naturally occurring Olympia oyster population, which was severely depleted in the 1800s by overharvesting (Cook et al. 1998). Olympia oyster populations in southern Puget Sound declined from the 1930s to the 1950s as a result of pulp mill pollution. Current populations are limited to Willapa Bay and reserves in southern Puget Sound. This species is not protected from harvest by WDFW because of the difficulty of distinguishing it from the Pacific oyster on oyster beds(West 1997). Olympia oysters are grown along with Pacific oysters in reserves, so separate harvest limits are not workable. Many of the largest commercial beds are on private tidelands and so beyond state regulation.

Accidental introduction of the Japanese oyster drill and flatworms has limited recovery of the Olympia oyster (West 1997). Existing stocks, including commercial stocks, are patchily distributed and are vulnerable to deteriorating water quality, increased shoreline siltation, competition with Pacific oysters, substrate undermining by burrowing shrimp, smothering by slipper shells, sea star predation, and overharvest (Cook et al. 1998).

Olympia oysters are susceptible to accumulation of toxic contaminants because they live in contact with the sediment (West 1997).

Other classified shellfish

Pinto (northern) abalone (*Haliotis kamtschatkana*) requires protection from overharvest (Bourne & Chew 1994). Pinto abalone populations are under stress because of overharvest, including poaching (West 1997).

Population of the species is not well known (West 1997). Commercial take of the species has never been legal in Washington, and recreational harvest was banned in 1994.

Purple (*Strongylocentrotus purpuratus*), red (*S. franciscanus)*, and green urchins *(S. droebachiensis*) have an abundant and patchy distribution in the Strait of Juan de Fuca (Shaffer 1999). Urchins are not thought to be the defining factor in kelp systems of the Strait of Juan de Fuca. Instead, physical features of the Strait are thought to limit kelp and rocky reef habitat distribution, which may in turn dictate urchin distribution and numbers (Carter 1999, Carter and VanBlaricom 1999, both in Shaffer 1999).

Unclassified Marine Invertebrates

Although UMI are not formally monitored, data indicate that unregulated harvest has increased recently. UMI are susceptible to accumulation of toxic contaminants because they live in contact with the sediment (West 1997). The most commonly harvested UMI in Puget Sound include marine snails, shore crabs crabs (*Hemigrapsus* spp.), polychaete worms, and moon snails (*Polinices lewisii*)(West 1997). Many of these species are thought to be sensitive to overharvest and other anthropogenic stressors and to be important components of intertidal and subtidal communities (West 1997).

Deep-water benthic communities studied by Llanso (1998) showed impoverished fauna at the heads of sheltered embayments far from sources of ocean water, including Holmes Harbor, Sequim Bay, and the Strait of Georgia. The latter two sites are heavily affected by feshwater runoff. Low dissolved oxygen concentrations were suggested as a cause for the impoverished fauna, which were also observed in some south Puget Sound inlets. Commercial trawling likely impacts UMIs as well (Palsson pers. comm.).

Contamination and Human Health

Results of NOAA's Mussel Watch Program show that mussels at three sites in the Northwest Straits have relatively high concentrations of multiple contaminants: PAHs, zinc, nickel, and copper in Bellingham Bay; PAHs and PCBs at Port Townsend; and zinc and nickel at Point Roberts (PSWQAT 1998). Mussels at Possession Point were high on one contaminant — nickel.

Mussel Watch results also indicate that concentrations of at least one toxic chemical decreased at six of seven stations on Puget Sound sampled routinely between 1986 and 1993 (PSWQAT 1998). There was no evidence of increasing contamination at any site. In the Northwest Straits, Point Roberts showed a 96 percent decrease in PCBs, Possession Point showed a 51 percent decrease in mercury and a 20 percent decrease in zinc, and Bellingham Bay showed no decrease in any contaminants.

Pesticide and PCB concentrations in mussels at five sites monitored by WDOE were lowest at Padilla Bay in the Northwest Straits (PSWQAT 1998). Concentrations at all sites were below U.S. Environmental Protection Agency guidelines.

WDOH downgraded the shellfish-gathering classification status in the areas of Samish Bay in 1994 and Drayton Harbor in 1995 based on the presence of fecal coliform contamination (PSWQAT 1998). Conditions since then in Samish Bay have been mixed, but efforts are bringing some control of the contamination sources (i.e., failing septic systems and raw sewage discharge) (Determan 1998a). The role of fecal contamination from agricultural runoff in this watershed appears to be minimal.

Penn Cove and Sequim Bay in the Northwest Straits are classified as "conditionally approved," and most of East Sound is classified "approved" (Determan 1998a). As of 1996, 47 percent of shellfish harvesting beaches classified by WDOH throughout Puget Sound were closed or conditionally open (PSWQAT 1998).

The Strait of Juan de Fuca is routinely closed to shellfish harvesting from April through October each year because of the potential presence of paralytic shellfish poisoning (PSP) (Determan 1998b). There is no apparent relationship between human activities and incidence of PSP.

Two sites in the Northwest Straits — Sequim and Discovery Bays — are rated as highly impacted by PSP, based on the duration of algal blooms in the years 1991to 1997 (PSWQAT 1998, Determan 1998b). Kilisut Harbor (near Port Townsend) showed a moderate impact. Drayton Harbor and Birch Bay in the Strait of Georgia and Port Ludlow at the mouth of Hood Canal showed low impact. Penn Cove and Holmes Harbor showed no impact; however, Penn Cove suffered severe impacts in the late 1970s. Strong PSP blooms have also been observed in the Strait of Juan de Fuca and the San Juan Islands, which were not part of the PSAMP PSP monitoring program.

Blooms of *Pseudo-nitzschia* spp., which are associated with Amnesic Shellfish Poisoning (ASP) from domoic acid and which cause regular closures of outer coast shellfishing, were detected in Port Angeles in 1992 and in Penn Cove in 1997 (Horner 1998, Trainer et al. 1998). This condition is monitored by WDOH, and to date these blooms have not caused problems for shellfish harvesting in Puget Sound.

DATA GAPS AND RESEARCH NEEDS

General

There is a need to establish a standard, fishery-independent, annual survey of marine invertebrates to identify temporal and spatial trends in abundance, distribution, and population- and community-level parameters (West 1997). These surveys should be coordinated with the above for other species such as marine birds and mammals.

There is a need to conduct research on the trophic and competitive interactions among stressed resources and other ecosystem components (West 1997). These studies should be coordinated with environmental monitoring efforts.

Recreational & Commercial shellfish

There is a need to expand the Habitat Component of the Puget Sound Ambient Monitoring Program to include monitoring the spatial coverage and functioning of subtidal habitats, and coordinate with WDFW's Shellfish Program to map and monitor Olympia oyster habitat (West 1997).

There is a need to support applied research addressing specific needs for better management and protection of the habitats that support Olympia oyster, and population parameters of Olympia oysters needed to evaluate allowable harvest (West 1997).

There is a need to continue monitoring effects of the Japanese oyster drill on Olympia oyster (West 1997).

Five recommendations have been issued to avoid ESA listing of Olympia oysters (West 1997): 1) map current distribution, abundance, and habitat; 2) prohibit harvest until population parameters have been obtained and estimates of allowable harvest made; 3) control habitat loss and degradation, especially water quality degradation associated with pollution, eutrophication, and erosional siltation; 4) develop a database to help efforts in habitat restoration and restocking; and 5) continue controls on Japanese oyster drill and research competition with Pacific oyster.

Populations of Olympia oyster currently are unmonitored (Cook et al. 1998, West 1997).

Populations of Pinto abalone currently are unmonitored (West 1997).

Unclassified Marine Invertebrates

In many cases, little is known about the abundance, distribution, life history, or ecology of UMI (West 1997). They receive little or no monitoring.

The cumulative effects of harvesting on UMI are unknown (West 1997). Sufficient funding must be supplied to adequately inventory the resource and monitor its health (West 1997). Education of the harvesting community, local stewards (cities, counties, private beach owners), and tribes is essential to protecting the resource.

IV. FISHES

CHARACTERIZATION OF THE RESOURCE

The Northwest Straits and Puget Sound are inhabited by more than 220 species of fish (NOAA in press B). WDFW actively assesses and manages three baitfish species and 20 groundfish species or species groups (Palsson et al. 1998). These groups encompass approximately 80 groundfish species and now include all other marine fishes categorized as unclassified marine fishes (UMFs). WDFW is in the process of adopting rules to better manage UMFs.

Populations of most fish species that are harvested commercially or recreationally in Puget Sound and the Northwest Straits study area have declined significantly during the 1980s and 90s (WDFW 1996, Palsson et al. 1997). Many causes for these declines have been cited, including overharvesting, habitat alteration, increased predation, and climate change. Much less is known about noncommercial species that may be important components of the food web.

Major categories of commercially and recreationally harvested fishes and representative species in each category in the Northwest Straits area are presented in Table 3.1. Baitfish are small forage species that are important prey for larger fish, including groundfish and salmonids, as well as for birds and mammals. “Groundfish” encompasses all species that inhabit the bottom or mid-water that may be taken in trawls and constitutes the majority of finfish species in Puget Sound. Baitfish and groundfish are referred to collectively as “marine fish” and are managed separately from salmonids. General spatial occurrences of these categories of finfishes are mapped in CMC (1998). More specific data are found in Solomon and Mills (1983) and Puget Sound Environmental Atlas (Evans-Hamilton, 1987-1992).

Table 3.1. Major fishery resources in the Northwest Straits Area (NOAA in press B)

Category	*Major species*
Baitfish	Pacific herring, Pacific sandlance, surf smelt, northern anchovy
Anadromous baitfish	longfin smelt, eulachon
Groundfish	
Gadids	Pacific cod, walleye pollock, Pacific whiting (hake)
Flatfishes	English sole, Pacific halibut, starry flounder, sand sole, rock sole, Dover sole
Rockfishes	eight major species
Greenlings & Sculpins	ling cod, greenlings, cabezon
Other	spiny dogfish, surfperches, skates
Salmonids	Chinook, coho, chum, pink, sockeye salmon; sea-run trout (steelhead, cutthroat, Dolly Varden)

Restoration of most types of fishery habitat has been attempted in the Puget Sound and Northwest Straits area, with some success (Thom and Borde 1997). Palsson and Pacunski (1995) and Palsson (1998) show that rockfish do benefit from marine protected areas in Puget Sound. Rockfish and lingcod (*Ophiodon elongatus*) surveyed in harvest refugia were larger, more abundant, and had a greater reproductive potential than those from nearby fished areas.

Studies have shown that in Edmonds Underwater Park (a no-take recreational protected area) rockfish are abundant and found in sizes which are rarely seen anywhere else in the inland waters (Palsson and Pacunski 1995, Palsson 1998). This has led to an effort by the State to develop a policy on establishing marine protected areas. Recently, as a response to depletion of rockfish resources, the citizens of San Juan County established a network of eight small voluntary no-take preserves in the waters surrounding the islands. (NOAA in press A).

Baitfish

Baitfish are found near the surface in the water column of both open-water and nearshore habitats. They mainly feed on zooplankton.

Pacific herring (*Clupea harengus pallasi*) is the most important species; its large populations make it a primary prey for higher animals, and both the fish and the roe are harvested by humans (CMC 1998). Eelgrass and seaweeds are critical spawning habitats for herring (West 1997).

Surf smelt (*Hypomesus pretiosus*) and sand lance (*Ammodytes hexapterus*) spawn in the high intertidal zone on protected gravel beaches, most of which are located in central and southern Puget Sound, but several of which have been identified in the Northwest Straits (WDFW Forage Fish Unit 1997). Surf smelt spawn year-round and sand lance spawn during winter. Little is known of the remainder of the life cycles of these species.

Northern anchovy (*Engraulis mordax*) is less abundant but is known to be resident, because eggs are observed in the plankton off Whatcom County during spring and young-of-the-year are observed in the San Juan Islands during summer (NOAA in press B).

There is a substantial commercial take of smelt and eulachon (*Thaleichthys pacificus*) though the contribution in terms of overall commercial landings in the state is minimal (NOAA in press A). Pacific herring in the Northwest Straits also support a spawn-on-kelp fishery, in which the adults are released alive (West 1997). Except for herring, little is known about the life histories of these fish (NOAA in press A).

One factor in the herring's decline is adult mortality, which possibly may be related to the unusually warm water conditions that have been recorded in recent years (NOAA in press A). Although adverse to herring reproduction, these high temperatures are believed to favor predators such as pinnipeds, spiny dogfish, and salmon. Loss of vegetated nearshore habitat or pollution of that habitat may also be depressing spawning success.

The health of these stocks is critical for the continued abundance of the predator fish, birds, and mammals. The populations of forage fish are subject to large fluctuations year to year (NOAA in press A). Pacific herring are considered susceptible to accumulation of toxic contaminants because of their high body fat content (West 1997).

Herring and sandlance eggs, larvae, and juveniles find nursery habitat in the neuston, where these species may be vulnerable to toxic contaminants (West 1997). Studies have demonstrated sea-surface contaminant-related effects in herring larvae. Herring eggs attached to eelgrass and kelp may be exposed to CSSP, and water quality in spawning and nursery habitats has been suggested as an important factor in herring survival (West 1997).

Longfin smelt (*Spirinchus thaleichthys*) return to the Nooksack River during winter, and this stock may be an important component of the fish community of Bellingham Bay during winter (NOAA in press B).

Eulachon has a spring spawning run to the Fraser River (NOAA in press B).

Groundfishes

General

Juvenile rockfish, lingcod, walleye pollock (*Theragra chalcogramma*), and hake (*Merluccius productus*) aggregate in surface waters where they may be exposed to contaminated water or prey (West 1997).

Gadids

Cod, hake, and pollock inhabit midwater in sheltered bays such as Port Townsend Bay (cod) and Saratoga Passage (hake). Hake and pollock school in midwater and consume mainly zooplankton and small baitfish (West 1997). Pollock juveniles inhabit inshore, shallow habitats during their first year.

Hake in Puget Sound are at the northern end of their commercial range (Palsson, pers. comm.). There is another population in the BC Strait of Georgia and the coastal population migrates into central BC coastal waters on a regular basis. Only part of the population is resident in the Northwest Straits. There appear to be resident spawning aggregations in Port Susan and Saratoga Passage, in Dabob Bay (Hood Canal), and in the Strait of Georgia. Because of a preference for cooler temperatures, cod and pollock are considered to be at the southern limit of their commercial range.

Larval and juvenile cod closely associated with the bottom, and ~~to~~ settle in shallow demersal habitats such as sand-eelgrass beds in late summer. Adult cod are more demersal than the other species, preying on baitfishes, flatfishes, rockfishes, and crustaceans (Palsson 1990). Stocks in the Northwest Straits reside in the southern Strait of Georgia and in the eastern Strait of Juan de Fuca.

Pacific tomcod (*Microgadus proximus*) populations are not commercially or recreationally important, but are monitored during occasional trawl surveys (Palsson et al. 1997).

Flatfishes

Flatfishes generally are found in soft-bottom habitats. English sole (*Parophrys vetulus*), Rock sole, Dover sole, and starry flounder populations are monitored regularly, and other flatfish species are assessed during occasional trawl surveys (Palsson et al. 1997).

English sole have been used by WDFW and National Marine Fisheries Service for research on effects of toxic chemicals on fish (West 1997) because of their high degree of contact with the sediments, especially in the vicinity of contaminated urban bays (PSWQAT 1998).

Many flatfish eggs, larvae, and juveniles find nursery habitat in the neuston, where they may be vulnerable to toxic contaminants (West 1997). Eggs of sand sole (*Psettichthys melanostictus*) incubated at the surface in urban areas showed poorer survival than in rural controls. However, life stages of these organisms are more common in the subsurface pelagic zone or, as they age, in benthic habitats (Palsson pers. comm.).

Rockfishes

At least 26 species of rockfish (*Sebastes* spp.) inhabit the Northwest Straits area (NOAA in press B). Researchers know little about the reproductive strategies of many of the rockfish species. For some species it appears that the young are reared and recruited to the same area where they were spawned. Others seem to disperse over a wider area. In some cases, currents may play a role in dispersing juvenile rockfish to other habitats (NOAA in press A).

Rockfishes use several different habitats throughout their life cycles. Larval and early juvenile rockfishes are found in the near-surface pelagic zone (West 1997). Later, juveniles settle to take up a demersal existence, during their first year of which they are common in nearshore vegetated habitats such as eelgrass and kelp beds.

Adult rockfishes prefer high-relief hard-bottom environments such as rocky reefs and kelp beds (West 1997, Pacunski and Palsson 1998). The majority of rocky bottom areas in Puget Sound are located in the Northwest Straits area (NOAA in press B). These species are long-lived, reproduce slowly, and have small home ranges — all traits that make these species vulnerable to overfishing and slow to recover from population decline (West 1997).

Rockfishes are considered susceptible to accumulation of toxic contaminants because they are long-lived, highly carnivorous, non-migratory, and live in direct contact with sediments (West 1997).

Their long life span and carnivorous trophic status makes copper (*S. caurinus*) and quillback (*Sebastes maliger*) rockfishes more susceptible to accumulation of contaminants. PCB and mercury concentrations in quillback rockfish were studied by WDFW from 1989–1996 at 11 locations in Puget Sound, including the San Juan Islands (PSWQAT 1998, West and O'Neill 1998).

Copper rockfish are observed relatively frequently on artificial reef substrates (Pacunski and Palsson 1998).

Greenlings and Sculpins

Lingcod require several different habitats to complete their life cycles. Adults are associated with rocky reefs habitats, and are highly territorial, with nest-guarding behavior (Pacunski and Palsson 1998). Eggs hatch in early spring, and larvae and juveniles remain pelagic during that time. They initially feed on zooplankton, and, at later stages, on juvenile herring. In late spring, juveniles settle to nearshore vegetated habitats such as kelp and eelgrass beds, then in fall to deeper, flat, featureless bottoms for one to two years before finding territory in reefs.

Lingcod are considered susceptible to accumulation of toxic contaminants because they are moderately long-lived, highly piscivorous, non-migratory, and live in direct contact with sediments (West 1997).

Other

Sturgeon (*Acipenser* spp.) are observed in the Fraser and Nooksack Rivers, where existing populations may be in need of protection (NOAA in press B).

Salmonids

Salmonids are by far the most economically valuable and culturally important fish species in the Northwest Straits, and form an important component of the natural food chain. They undergo a complex anadromous life cycle, with most species migrating into the open Pacific as well as spawning in rivers (NOAA in press B). The population in the Puget Sound area is composed of 209 individual stocks originating in and returning to particular spawning grounds. Thus, the Northwest Straits area is a major migratory corridor for these species, and conditions in a wide variety of habitats and several management jurisdictions (including Canada) influence their abundance.

Salmonids are thought to be particularly sensitive to alterations in the freshwater spawning habitat and the nearshore saltwater habitat. Upland alterations are beyond the scope of this report. However, hardening of shoreline substrate and destruction of eelgrass beds and tidal marshes, all important nursery habitats, are believed to be significant causes of declining salmonid populations (CMC 1998).

Salmon

All anadromous salmonids are vulnerable due to destruction of river and nearshore habitat. Most individuals in salmon populations migrate to the open Pacific to feed as adults, so they are not as vulnerable to changes in food supplies and predator populations of inland waters. However, they are affected by climate conditions, food supplies and predator populations in the open Pacific.

Recent evidence (for example, Francis and Hare 1994) indicates that West Coast salmon populations decline during the positive phase of the Pacific Decadal Oscillation (PDO), when conditions are generally warmer and drier than average. These conditions were experienced from about the late 1970s until the mid-1990s. Conditions in the late 1990s are not yet well analyzed. The mechanism by which salmon populations are affected by the PDO—in particular, whether spawning, rearing, or adult feeding conditions are most important—is not well understood.

Surveys of four locations in Puget Sound, including Admiralty Inlet and Possession Sound in the Northwest Straits, during 1997 showed that adult coho (*Oncorhynchus kisutch*) disappear from the Sound by September (Beamish et al. 1998). Most of these coho are believed to move seaward into the Strait of Juan de Fuca. At the same time, catches of juvenile chum (*O. keta*) increase markedly. Because both species show no evidence of food scarcity, these migrations are believed to be behavioral. The common hypothesis that year-class survival in these species is determined shortly after entering the ocean is not consistent with these observations.

Salmon research and management are complicated by the extensive production of hatchery fish, which accounts for Puget Sound's most numerous fish stocks (NOAA in press B). The heavy catch rate on hatchery fish in the past is believed to have produced unsustainable losses of wild fish, and competition between hatchery and wild fish for spawning grounds and prey may also have contributed to the decline of wild stocks (CMC 1998). In addition, predation rates on salmon-prey such as herring, sardine larvae, and juvenile cod and rockfish may have been increased with the production of hatchery-reared "resistant" salmon.

Some arguments have been raised that net-pen aquaculture of nonindigenous Atlantic salmon (located at eight sites in the Northwest Straits) also poses risks to wild salmon populations through potential introduction of disease and non-indigenous species (NOAA in press B). Net-pen reared Atlantic salmon (*Salmo salar*) have been showing up in fishermen's net from time to time. Prior to 1998, fisheries biologists held the view that Atlantic salmon could not reproduce on the West Coast. Now this conventional wisdom has been turned on its head with the discovery of Atlantic salmon fry in at least one stream in British Columbia. Atlantic salmon have already been classified as a pollutant in the Northwest (NOAA in press A).

<u>Sea-Run Trout</u>

Dolly Varden (*Salvelinus malma*) and cutthroat trout (*Salmo clarki clarki*) are generally found in shallow water in the marine environment, and do not migrate to the Pacific. Thus, they are more vulnerable than other salmonids to alteration of nearshore habitat, changes in food supplies and predator populations in inland waters. Although they are of recreational importance, these species are not fished commercially.

STATUS OF RESOURCE

Baitfishes

Port Susan and Cherry Point herring stocks in the Northwest Straits are listed as critical or depressed because of declining spawning biomass (WDFW Forage Fish Unit 1997). Predation is considered a major cause, and habitat loss, climate change, and contamination are considered as secondary causes (West 1997). Habitat mitigation and restoration measures have not been demonstrated to replace the values of lost habitat.

The Discovery Bay herring stock in the Northwest Straits is listed as critical, and has likely suffered permanent damage (PSWQAT 1998). The status of seven other Puget Sound stocks is unknown.

Many herring stocks are classified as either depressed or critical, experiencing long-term declines in spawning biomass (NOAA in press A). Herring catches are at low levels and some herring stocks are not rebuilding despite closure of the fishery (NOAA in press A). San Juan, early run at Cherry Point, and Fidalgo Bay are still considered to be in good condition (Palsson pers. comm.).

Pacific herring is identified as having suffered significant anthropogenic stress and being in need of special consideration for protection (West 1997). Besides declining spawning biomass, these populations show increased natural mortality, decreased number of age classes, and increased sightings of harbor seal predation.

Declining abundance of Pacific herring is observed off western Vancouver Island under warm conditions, due to direct temperature effects and increased predation by hake and mackerel (West 1997). These factors (especially predation) are thought to have contributed to recent increases in mortality of herring in Puget Sound. Herring eggs have been shown to be vulnerable to increases in UV radiation (West 1997).

There is considerable evidence that predation by salmon, dogfish, mackerel, and harbor seals is a major factor in recent herring population declines (West 1997). The evidence is indirect, based on increases in predator populations, and the relative impact of each of these predators is unknown. Relatively high levels of PCBs have been observed recently in Pacific herring (West 1997).

Groundfishes

Palsson et al. (1997) documented the substantial decline of five groundfish species: Pacific cod, Pacific hake, walleye pollock, demersal rockfish, and lingcod. Restrictions on bottom trawling and the disappearance of commercially exploitable quantities of groundfish species have limited these fisheries in the Northwest Straits (NOAA in press A). However, more groundfish stocks are in good condition in the Straits than in other parts of Puget Sound (Palsson pers. comm.).

The majority of stocks in North Puget Sound were found to be in good condition. Despite efforts to manage commercial and recreational fisheries, certain marine fish populations in Puget Sound have not recovered, and harvests are at their lowest levels in 55 years (Palsson et al. 1997). The cause for the decline in each of the species vary. A Warm oceanographic climate is implicated in declines of cod and pollock (Palsson et al. 1997). Fishing mortality is a major factor shaping rockfish and lingcod (Palsson et al. 1997).

The status of major and minor groundfish species in the North Sound (roughly corresponding to the Northwest Straits study area) has been reviewed recently by Palsson et al. (1997) and is summarized in Table 3.2.

Table 3.2 Status of Groundfish Populations in North Puget Sound (Palsson et al. 1997)

Species group	Population status	Population trend	Fishery utilization
Spiny dogfish	Above average	None	Fully
Skates	Above average	Increasing	Under
Spotted ratfish	Unknown	Unknown	Unknown
Pacific cod	Depressed	None	Over
Walleye pollock	Critical	Declining	Under
Pacific whiting	Above average	Increasing	Under
Rockfish	Average	None	Fully
Sablefish	Above average	Increasing	Unknown
Greenlings	Above average	Increasing	Under
Lingcod	Depressed	Declining	Fully
Sculpins	Average	Increasing	Under
Pile Perch	Critical	Declining	Unknown
Pacific halibut	Below average	Declining	Fully
Rock sole	Depressed	Declining	Under
Dover sole	Depressed	Declining	Under
English sole	Above average	Increasing	Over
Starry flounder	Above average	None	Over
Sand sole	Above average	Increasing	Over

The causes of abundance changes in marine fish populations are poorly understood (Palsson et al. 1997). Climatic cycles are shown to have an effect; for example, warming may inhibit Pacific cod. Increases in harbor seal and California sea lion populations are also believed to have an effect. Habitat loss, fishing, and pollution all are suspected as well.

There is considerable circumstantive evidence that predation by California sea lions and harbor seals is a major factor in preventing the recovery of hake and lingcod populations (West 1997). The evidence is indirect, based on increases in predator populations, and the relative impact of each of these predators is unknown.

<u>Gadids</u>

Hake supported a significant commercial fishery in Saratoga Passage during the 1980s, but biomass assessments have dropped from 15,000 tons in 1983 approximately 500 tons of adults in 1995 (Palsson et al. 1997). The fishery has been closed since 1987. Recovery of the population may be limited by predator populations. Pacific cod are cited as having a “depressed” status in the Northern Sound and pollock are considered to have a “critical status” rating (Palsson et al. 1997). Climate is a potentially complicating factor, especially in the case of cod, which are at the southern end of their geographic range (Palsson 1990).

Pacific hake populations in Puget Sound are believed to be low due to pinniped predation and overfishing in the early 1980s. Other species of concern include rockfish, pollock, Pacific cod, and some flatfish (BC/WA Marine Science Panel 1994, in NOAA in press A).

Three species of gadids—Pacific cod (*Gadus macrocephalus*), Pacific hake, and walleye pollock—are identified as having suffered significant anthropogenic stress and are in need of special consideration for protection (West 1997).

Pacific cod is known to be sensitive to increased temperatures at the southern end of its range in the Northwest Straits area. It seems likely that warmer temperatures in recent years (in addition to harvest) contributed to the decline of this species (West 1997). Palsson (unpub.) implicated warmer climatic regimes with poor pollock recruitment.

Additional factors possibly contributing to the decline in cod include predation by California sea lions, harbor seals, and dogfish; reductions in herring and pollock prey; loss of nearshore nursery habitat; predation on juveniles and competition for prey by delayed-release hatchery-reared Pacific salmon (West 1997).

Flatfishes

Liver lesions in English sole were studied from 1989–1996 as an indicator of contaminant-related health effects on bottomfish (PSWQAT 1998). These lesions were observed in fish throughout Puget Sound, including fish from non-urban areas (the Strait of Georgia, Saratoga Passage, Possession Point, and Discovery Bay) and near-urban areas (Port Townsend, Bellingham Bay, Port Gardner) in the Northwest Straits. No lesions were observed in the Strait of Juan de Fuca or Orcas Island in this study. Much higher frequency of lesions was observed in urban areas outside the Northwest Straits.

The incidence of lesions in English sole correlated primarily with sediment PAH concentrations and secondarily with PCB in fish muscle tissue, which in turn correlated with sediment PCB concentrations (PSWQAT 1998). Lesion frequency also increases with fish age.

Studies from 1991–1996 could not discern temporal trends in PCB concentrations in English sole muscle tissue nor in the frequency of liver lesions at most locations (PSWQAT 1998). However, an increasing trend in liver lesions that could not be explained by changes in fish age was observed at a station in the Strait of Georgia. Lesions at this location were still less frequent than those in highly contaminated urban areas.

Negative effects on reproduction resulting from chemical contamination have been observed in English sole from contaminated sites in Puget Sound, but not from the Northwest Straits to date (West 1997). Port Susan has been used as an uncontaminated reference area for contamination studies.

Rockfishes

WDFW trawl surveys indicate that rockfish inhabit all depths in Puget Sound (to 180 m). Because little recreational fishing effort occurs below depths of 60 m, these deep-water stocks may be larger than those in shallow water, and might serve as a broodstock for the Sound (Pacunski and Palsson 1995).

Other factors possibly contributing to the decline in rockfish are loss of nearshore nursery habitat, increased predation by California sea lions and harbor seals, increased predation on larvae and juveniles by delayed-release hatchery Pacific salmon, and disease related to contaminants (West 1997).

Three species of rockfishes—quillback (*Sebastes maliger*), copper (*S. caurinus*), and brown (*S. auriculatus*)—are identified as having suffered significant anthropogenic stress and being in need of special consideration for protection (West 1997).

Some of the highest levels of contaminants (such as mercury and PCB) found in Puget Sound fishes have been found in quillback rockfish. The effects of these contaminants are unknown, however they are presumed to cause reproductive impairment based on the effects on English sole (West 1997).

Concentrations of PCBs and mercury in quillback and brown rockfish were relatively low at sampling sites in the San Juan Islands compared to those at urban areas outside the Northwest Straits (PSWQAT 1998). PCBs were detected rarely in San Juan Island rockfish, however, mercury accumulated in rockfish at all sites (West and O'Neill 1998).

<u>Greenlings and Sculpins</u>

Lingcod stocks are very low, most likely because of overfishing (CMC 1998). Lingcod was identified as having suffered significant anthropogenic stress and being in need of special consideration for protection (Palsson et al. 1997). However, recent WDFW harvest restrictions appear to be encouraging the repopulation of central Puget Sound.

Other factors possibly contributing to the decline in lingcod are loss of nearshore nursery habitat, increased predation by California sea lions and harbor seals, increased predation on larvae and juveniles by delayed-release hatchery Pacific salmon, and disease related to contaminants (West 1997).

WDFW trawl surveys indicate that lingcod inhabit all depths in Puget Sound (to 180 m). Because little recreational fishing effort occurs below depths of 60 m, these deep-water stocks may be larger than those in shallow water, and might serve as a broodstock for the Sound (Pacunski and Palsson 1998).

<u>Other</u>

Spiny dogfish (*Squalus acanthias*) populations have decreased substantially in recent years (Palsson pers. comm.). This increase may be related to the discontinuation of commercial fishing on this species and to the dogfish moving into the ecological niche of depleted stocks of other groundfishes (West 1997, CMC 1998).

Salmonids

In 1992, the State of Washington and the Treaty Tribes undertook a joint assessment of the status of wild salmon and steelhead stocks. Of the 208 stocks identified and examined, only 93 were given "healthy" status, while 55 were classified depressed or critical, 60 additional stocks had insufficient data to make a determination, and one stock was extinct (NOAA in press A). Data for the Northwest Straits area are shown in Table 3.3.

Table 3.3 Status of salmon stocks in Northwest Straits area in 1992 (PSWQAT 1998).

	Percentage of stocks			
Area	Healthy	Depressed	Critical	Unknown
North Puget Sound	38	17	6	39
Strait of Juan de Fuca	23	34	13	34

In March 1999, the federal government listed two species of wild salmon, Puget Sound chinook and Hood Canal summer-run chum, as threatened under the Endangered Species Act. This listing requires that a restoration plan be drawn up by the state and regional governments and approved by the National Marine Fisheries Service. Scientists have identified Evolutionarily Significant Units (ESUs) for each of these species and both ESUs extend into the Northwest Straits, as far west as the Elwha River and as far north as the Canadian border (NOAA in press A).

Chemical contaminants have been detected in Pacific salmon tissues (West 1997). Higher PCB levels are observed in chinook salmon than in coho, and higher in offshore mixed stocks than in fish returning to rivers to spawn (PSWQAT 1998). These differences are attributed mostly to such factors as age, diet, and lipid content of the fish.

Coho salmon originating from the Nooksack and Skagit Rivers had lower levels of PCBS in muscle tissue than coho originating from rivers in the central and southern Sound (PSWQAT 1998), even after lipid content was accounted for. This difference was not observed in chinook salmon.

Salmon appear to accumulate only negligible amounts of PCBs during early residency in rivers and estuaries (O'Neill et al. 1998). Salmon are believed to accumulate most tissue PCBs after entering salt water, so the regional differences among coho may be related to migration patterns, diet, hatchery versus wild origin, or duration of residence in Puget Sound.

The effects of PCB accumulation on the health of chinook and coho salmon from Puget Sound are unknown (O'Neill et al. 1998). Some studies indicate suppression of immune function in juvenile chinook from exposure to chlorinated hydrocarbons and PAHs in the laboratory and in adult chinook from exposure to contaminated natural waters.

Delaying the release of hatchery-reared Pacific salmon to increase the number of resident salmon in Puget Sound may exceed the carrying capacity of the system, and may be a contributing factor in the decline of some marine species (West 1997). The effects of the recent order-of-magnitude increase in production of delayed-release salmon on resident prey (such as larval and juvenile fishes) and competitors (such as hake and pollock) are unknown.

Local watershed management plans have been created for all priority watersheds draining into Puget Sound and the Northwest Straits. Many of these include plans for improving salmonid habitat. In 1997, the State and the Treaty Tribes adopted a joint Wild Salmonid Policy. The document lists a wide range of actions that are necessary to restore wild salmon runs. Restoration of riparian habitat makes up the bulk of the document (NOAA in press A).

DATA GAPS AND RESEARCH NEEDS

General

Effects of contaminants on reproductive success in marine organisms from Puget Sound should be evaluated, and present PSAMP monitoring work with English sole continued as indicator of fish health (West 1997).

The need exists for coordinating annual gadid and herring surveys with existing PSAMP water-column monitoring to search for correlations and predictive relationships between temperature and fish abundance (West 1997).

A standard, fishery-independent, annual survey of marine fishes should be established to identify temporal and spatial trends in abundance, distribution, and population- and community-level parameters (West 1997). Coordinate these surveys with those for other species such as marine birds and mammals.

There is a need to conduct research on the trophic and competitive interactions among stressed resources and other ecosystem components (West 1997). These studies should be coordinated with environmental monitoring efforts.

Abundance surveys and environmental studies should be coordinated with those conducted by British Columbian researchers (West 1997).

Baitfishes

There is a need to continue monitoring abundance and mortality of Pacific herring (West 1997).

There is a need to coordinate with PSAMP to correlate climatic and environmental variables with Pacific herring abundance (West 1997).

There is a need to continue and expand research on accumulation, effects, and sources of contamination in Pacific herring (West 1997).

There is a need to investigate relative contribution of predators (especially those whose abundance has changed substantially in recent years) to natural mortality of Pacific herring (West 1997).

There is a need to investigate the effects of temperature on the abundance of transient predators on herring such as mackerel (West 1997).

The potential effects of anthropogenic increases in UV radiation on Pacific herring eggs should be studied to see whether this is a source of stress (West 1997).

Sandlance are probably of equal importance to herring in the food web, but very little is known about the status of stocks, distribution, or life cycle of this species (Nysewander pers. comm.)

Groundfishes

General

The data used for assessing status and trends of stocks were only of fair quality at best (Palsson et al. 1997). Only one of 36 assessments was rated as having good quality data, and a number were rated as poor, mainly because they were based on catch data alone rather than an independent survey. Data quality by species is summarized in Table 3.4.

Table 3.4. Data Quality of Groundfish Population Assessments in North Puget Sound (Palsson et al. 1997)

Species group	**Data Quality**
Spiny dogfish	Fair
Skates	Fair
Spotted ratfish	Poor
Pacific cod	Fair
Walleye pollock	Fair
Pacific whiting	Poor
Rockfish	Fair
Sablefish	Poor
Greenlings	Poor
Lingcod	Fair
Sculpins	Poor
Pile Perch	Poor
Pacific halibut	Fair
Rock sole	Fair
Dover sole	Fair
English sole	Fair
Starry flounder	Fair
Sand sole	Fair

Gadids

Research is needed to estimate the magnitude of bycatch mortality for gadids.

There is a need to investigate natural (predation) mortality of Pacific cod, as well as its trophic interactions with other species such as delayed-release hatchery Pacific salmon (West 1997).

There is a need to continue hydroacoustic monitoring of hake, increasing frequency to three times yearly (West 1997).

Pollock stocks should be monitored, using fishery census studies and fishery-independent surveys (West 1997).

Flatfishes

No research needs were identified for flatfishes.

Rockfishes

There is a need to continue evaluating the video-acoustic technique for estimating demersal rockfish and lingcod abundance (West 1997).

There is a need to expand the Recreational Fisheries Information Network program and implement collection of biological data for parameterization of stock-assessment models (West 1997). Increase spatial and temporal coverage of recreational surveys.

Bycatch-mortality effects on stressed species are unknown. However, bycatch contributes a substantial amount to overall mortality in rockfishes (West 1997). Research is needed to estimate bycatch mortality.

The effects of contaminants in rockfish are unknown. However, given the observed reproductive impairment in English sole, such impairment is likely in rockfish as well (West 1997).

There is a need to continue assessing accumulation, source, and effects of contaminants in rockfish (West 1997).

Effects of marine mammal predation and trophic interactions with other species should be identified (West 1997).

Efforts to develop fishery-independent monitoring of rockfish using video-acoustic techniques should be furthered(West 1997). The depth range of the current technique should be extended and the technique modified for estimating fish size underwater.

Greenlings and Sculpins

Bycatch-mortality effects on stressed species are unknown. However, bycatch contributes a substantial amount to overall mortality in lingcod (West 1997). Research is needed to estimate bycatch mortality.

There is a need to continue assessing accumulation, source, and effects of contaminants in lingcod (West 1997).

There is a need to investigate the effects on lingcod of marine mammal predation and trophic interactions with other species (West 1997).

There is a need to continue the development of fishery-independent monitoring of lingcod. Video-acoustic techniques should be used to extend the depth range of the technique, and adapt it to estimate fish size underwater (West 1997).

Salmonids

Further research needs to be done to determine when and where Atlantic salmon net-pen escapees are spawning (NOAA in press A).

There is a need to evaluate the effects of Pacific salmon extended-rearing practices on resident marine organisms, and investigate ways to better tailor timing, location, and size of releases to the carrying capacity of the system (West 1997).

The use of nearshore habitats in the Straits by salmonids needs further study.

V. BIRDS

CHARACTERIZATION OF THE RESOURCE

Marine birds use the rocky coastline and rocks and islands of the Northwest Straits as breeding and nesting habitat, feeding areas, and as rest stops and shelters along migration routes. The continental shelf and estuaries provide rich food resources (RMRP 1993).

The Northwest Straits is a critical habitat for marine birds. As many as 116 species of marine birds have been identified, including year-round populations of waterfowl, seabirds, shorebirds and raptors (CMC). The area serves as a critical link along the Pacific flyway, the route taken by migrating Pacific coast birds. Several million shorebirds and other water birds stop in Puget Sound during migration (NOAA in press B). In general, the winter populations of marine birds are the largest and most diverse, while summer populations tend to be smaller. Many species of marine birds currently thriving in the Northwest Straits have almost ceased to breed in the main basin of Puget Sound. (Species list in NOAA in press B).

Marine birds are highly mobile and do not recognize political boundaries separating the U.S. and Canada. Information on the status and distribution of marine birds in Canada is contained in Campbell (1976), and Manuwal and Campbell (1979), Vermeer et al. (1983), Vermeer and Butler (1989), and Mahaffy et al. (1994).

STATUS OF RESOURCE

The study area is a dynamic system in which seasonal changes in species composition and abundance interact with the physical and biotic characteristics of the marine environment (Wahl et al. 1981). Rich foraging habitats of protected bays, areas of convergence, kelp beds, and the ephemeral herring spawn all contribute to the large number of marine birds.

Areas of the Northwest Straits serve as critical habitat for breeding seabird colonies. Eighty-one percent of the seabirds in the U.S. part of the Northwest Straits are concentrated at various important breeding sites: Tatoosh Island, Protection Island, Smith and Minor Islands, and Colville Island had (Wahl et al. 1981). The highest species diversity is found during the fall migration period, but the species composition changes seasonally, and reflects migration periods and breeding season activities.

Areas of significant shorebird concentrations have been identified through recent surveys by Cascadia Research Collective, part of the Pacific Flyway Project (The Project has been undertaking surveys to determine suitable locations for appropriate long-term shorebird monitoring sites). Surveys were carried out in 1990 - 1991, 1992 - 1993, 1993- 1994 (Evenson and Buchanan 1995).

Other recent bird surveys have been conducted by WDFW in accordance with the

Puget Sound Ambient Monitoring Program. Marine shorelines and open waters of Puget Sound were surveyed in 1992 - 1993, and again in1993 - 1994 (Nysewander 1995).

Bird surveys have been performed in July and December–February each year 1992–1999 throughout greater Puget Sound in both nearshore and offshore waters (Nysewander and Evenson 2000). The data from these surveys could be used to improve descriptions of spatial concentrations of bird populations. These data are available through GIS mapping products of the WDFW Wildlife Resource Data Systems in Olympia.

In spring, two events are of particular importance: 1) the spawning of Pacific herring, primarily at Discovery Bay, Cherry Point, and eastern Georgia Strait, which attracts large numbers of birds, especially surf scoters; and 2) the spring migration of black brant, which can bring 50,000 birds to the eelgrass beds of Padilla Bay (Wahl et al. 1981).

Excluding cobble shorelines where spawning herring attract the largest concentrations of birds, the highest consistent seasonal densities of birds have been observed in shallow bays. Densities in those bays may be 10 times larger than in open water areas.

Studies have shown variations in use of differing marine habitats in the Puget Sound/Northwest Straits area (CMC 1998). Of 18 species of marine birds breeding within marine shoreline habitat of Washingon in 1989, 22 percent breed in inner waters, with 16 percent found at Protection Island alone. Shorebirds occur in large concentrations in the low-lying sheltered shorelines of the area. More than 5,000 shorebirds have been counted at Drayton Harbor and Lummi Bay in winter months. Ten thousand shorebirds have been counted at Samish Bay, Padilla Bay, and Skagit Bay and 20,000 counted at Port Susan in winter months.

In winter, waterfowl usage of shorelines and river deltas increases. Grebes and loons migrate to deeper protected waters, including regions of the Northwest Straits such as Whidbey/Camano Island area, Bellingham and Padilla/Samish Bay areas, portions of the San Juan Islands, and portions of the Point Roberts/Boundary Bay area (NOAA in press B).

Common murre (*Uria aalge*), rhinoceros auklet (*Cerorhinca monocerata*), ancient murrelet (*Synthliboramphus antiquus*), Brandt's cormorant (*Phalacrocorax penicillatus*), and occasionally, Pacific loon (*Gavia immer*) flocks are among the seabirds that use exposed offshore waters of the Northwest Straits. Seabirds foraging in offshore waters often concentrate feeding efforts along tidal fronts and the associated schools of prey, such as euphausids and herring (NOAA in press B).

Protected and semi-protected deeper waters are used by resting flocks of western grebe, most of the loon species, and other marine birds. Nearshore habitats are used by pigeon guillemot, double-crested cormorant, black oystercatcher (at rocky intertidal shores), marbled murrelet, harlequin duck, red-necked and horned grebe, and many of the diving sea and bay ducks. In bays and the leeward side of islands, large flocks of marine birds often come to rest, wait out storms, mate, and breed (Angell and Balcomb 1982).

Increasing human populations have had a number of negative effects on marine birds, including the disruption of food resources, disruption of colony sites, reduction in available habitat, and increased mortality.

Nest disturbance is a major concern, including disturbance due to low flying aircraft. Currently, primary nesting sites on Protection Island and Smith Island have minimum altitude advisories of 2,000 feet in order to minimize disturbance from aircraft. Boaters and beach walkers also disturb nesting areas. Dungeness Spit, a foraging habitat for certain marine bird species, is also subject to minimum altitude advisories (Nysewander Pers. comm.).

Food resources have been affected by industrial thermal and chemical discharges, by human garbage and sewage disposal, and by direct competition for prey species such as herring.

Habitat loss is also of critical concern. Colony sites have been used for lighthouses and bombing targets, by recreationalists, and disturbed by vessel traffic. Habitat has been reduced by dredge-and-fill and diking operations and by shoreline development.

Diving birds (murres, auklets, murrelets) are particularly prone to entanglement and drowning in fishing nets. WDFW estimates that 3,569 seabirds (primarily murres and rhinoceros auklets) were caught in commercial fishing nets in 1994, with 90 percent taken around San Juan Island.

Diving marine birds and ducks are extremely vulnerable to oil spills. Three oil spills in the past 15 years have affected populations. Because adult marine birds are at the apex of the marine food web, they are particularly vulnerable to bioaccumulation of organic compounds such as PCBs and DDT. Dabbling ducks are less susceptible to oil spills because they utilize freshwater and inland habitats as well as marine waters (Nysewander pers. comm).

Marbled murrelet (*Brachyramphus marmoratus*)

- Numbers are greatly reduced; listed federally as threatened species in Washington, Oregon, and California.

- Primarily suffering loss of nesting habitat. Nest high in old growth forest, and destruction of this habitat on Olympic Peninsula has decreased number of nesting sites.

- Experiencing very low recruitment rates. Predation on remaining sites may play a role in recruitment of younger birds.

- Occasionally caught in gillnets when diving.

- Half of the 5,000 counted are found in inner waters; population numbers based on estimates prior to 1989 and need updating.

- Use nearshore habitats.

Harlequin duck (*Histrionicus histrionicus*)

- Numbers are low but stable or slightly increasing. Species is vulnerable because their preferred habitat) is exposed, restricted, and highly vulnerable to oil spills. Areas of concentration include kelp beds in Strait of Juan de Fuca and points and headlands near Cherry Point, Point Roberts, Smith Island, west shore of Whidbey Island, and Oak Harbor area (Nysewander pers. comm.).

- Utilize shallow water, nearshore zone where mollusks and crustaceans are in abundance.

- Breed in swift running rivers and streams which empty into Northwest Straits.

- Very vulnerable to oil spills because they remain close to shore.

- Concentrate near Marrowstone and Protection Islands.

Common murre (*Uria aalge*)

- Depressed populations

- Coastal breeders; utilize inner marine waters for significant portion of year; use exposed offshore waters of Northwest Straits for foraging

- Areas of concentration in eastern Strait of Juan de Fuca (WDFW GIS data, PSAMP report—Nysewander).

- Decreased population from 30,000 in 1979/80 to 565 in 1993 along WA coasts

- Failed to reproduce in 1993, possibly in 1992.

- Oregon's population has remained stable.

- No definite cause for decline identified.

- Significant numbers drown in gillnets each year.

- Experimentation with different kinds of nets has been undertaken by the University of Washington, U.S. Fish and Wildlife Service (USFWS), and WDFW.

- Predation by raptors has had significant impact on nesting population on Tatoosh Island.

- Highly vulnerable to oil pollution.

Great blue heron (*Ardea herodias*)

- Utilize nearshore habitats.

- Resident and non-migratory, therefore suitable for use to monitor accumulations of biotoxins.

- Blue heron colonies have been changing during the 1990s. It is unknown whether they are decreasing or just moving and breaking into smaller colonies due to increased eagle harassment and associated reproductive losses (Nysewander pers. comm.).

- 36,804 birds in 1989

- Two of three main colonies occur at Protection and Smith Islands, which contain 60 percent of the state's breeding population.

- Appear to have stable breeding population, but only three surveys conducted since 1976.

- Make daily movements from breeding sites to foraging sites, primarily at dusk and dawn.

- Will use the exposed offshore waters for foraging.

- Data are available from WDFW GIS specifying foraging areas in Admiralty Inlet, eastern Strait of Juan de Fuca, and passes in San Juan Islands (Nysewander pers. comm.).

Glaucous-winged gull (*Larus glaucescens*)

- 19,200 birds in 1989.

- Greater than half of the state's breeding population are in greater Puget Sound; 30% at Protection Island alone.

- Breeding population increased by approximately four percent annually in the early 1980s, then remained stable.

- Make daily movements from breeding sites to foraging sites, primarily at dusk and dawn.

Pigeon guillemot (*Cepphus columba*)

- At least 8,691 guillemots in Northwest Straits area (Nysewander pers. comm.). Survey numbers are higher in recent years because of better methodology. Protection Island is breeding site for 19.6 percent of guillemots in all inland marine waters of Washington or 23.9 percent of Northwest Straits population.

- Appear to have a stable population.

- Use nearshore habitats.

Pelagic cormorant (*Phalacrocorax pelagicus*)

- 2,238 birds in 1989.

- Eighteen percent breed at Protection Island and 28 percent breed elsewhere in the Northwest Straits, primarily in the San Juan Islands.

- Population levels appear steady.

- Colonies move between the San Juan Islands and Protection and Smith Islands as part of a normal behavioral pattern (Nysewander pers. comm.). Harassment by eagles and to some extent humans may have contributed to these relocations.

Double-crested cormorant (*Phalacrocorax auritus*)

- 1,100 birds in 1989.

- One-third of the state's population in inner marine waters, primarily at southern end of Rosario Strait.

- Populations appear to have increased slightly

- Make daily movements from breeding to foraging sites, primarily at dusk and dawn.

- Use nearshore habitat.

Black oystercatcher (*Haematopus bachmani*)

- 120 birds in 1989 — significant portion of its North American population.

- Relatively stable breeding population.

- Oystercatchers have not been surveyed in a consistent complete manner since Nysewander's 1977 dissertation (Nysewander pers. comm.). They are vulnerable to reproductive failure if disturbed at critical times in the breeding cycle, and their populations may not be stable.

- Use nearshore habitats at rocky intertidal shores.

Caspian tern (*Sterna caspia*)

- Found mostly in outer coast estuaries, but in 1992 a colony of 600 nesting birds established at Everett.

- Non-breeding population also present in Northwest Straits study area.

Ring-billed gull (*Larus delawarensis*)

- Non-breeding but common in Puget Sound in summer.

- Other gulls also use the Northwest Straits during summer: Heerman's (from Baja California), Bonaparte (from Canada and Alaska), and California (from inland U.S. breeding grounds). Winter use by mew gulls, Thayer's gull, and others (Nysewander pers. comm.).

Canada goose (*Branta canadensis*)

- Uncommon 30 years ago; however from 1988 to 1993 numbers have doubled in Bellingham to over 1,000.

- With increasing populations, numerous smaller islands and rocks in the San Juans and nearbby areas are used for nesting (Nysewander pers. comm.).

Tufted puffin (*Lunda cirrhata*)

- Have declined from 1,066 historically to 74 in 1989. Numbers have been consistently low for last 20 years at most sites in eastern Strait of Juan de Fuca and the San Juan Islands.

- Declining population on Protection Island; in 1993, only 13 nesting pairs.

- Currently, on Protection and Smith Islands there are 13 to 15 nesting pairs, down from 30 pair in the mid-1970s.

Western grebe (*Aechmophorus occidentalis*)

- 60,00 or more overwinter in Northwest Straits study area.

- Use protected and semi-protected deeper waters.

- Overwintering numbers have greatly decreased in the last 20 years, similar to all diving ducks. Bellingham Bay stocks dropped to 4,000–9,000 from 40,000 birds in 1979–1988. Cause may be declining baitfish stocks (Nysewander pers. comm.).

Surf scoter (*Melanitta perspicillata*)

- Large concentrations are attracted to spawning herring in the spring.

- Scoters (dominated by surf scoters in Northwest Straits) have declined 40–50 percent in last 20 years (Nysewander & Evenson 1998, PS Research Conference). Fore example, Cherry Point stock dropped to 6,000–7,000 in 1999 from up to 60,000 in 1979-80. The leading theory is that this decline resulted from the simultaneous collapse of herring spawning numbers at Cherry Point during the same time period (Nysewander pers. comm.).

Black brant (*Branta bernicla*)

- 50,000 spend several weeks at eelgrass beds and may be limited by the extent of eelgrass beds. (Wilson and Atkinson 1995).
- Spring and fall migrant, winter resident.
- Padilla, Fidalgo, and Samish Bays heavily utilized.
- Potentially threatened by oiling, due to nearness of wintering areas to shipping activity and oil refineries.

Bald eagle (*Haliaeetus leucocephalus*)

- Federally listed as a Threatened Species.
- San Juan Islands support one of the largest breeding populations of bald eagles in the U.S.
- Populations have increased dramatically, from 114 nesting territories within the Northwest Straits study area in 1975 to 459 in 1992.

Peregrine falcon (*Falco peregrinus*)

- Federally listed as an Endangered Species.
- Increased statewide, with the San Juan Island population growing from one territory in 1980 to nine in 1992.

Osprey (*Pandion haliaetus*)

- Statewide, territories have increased 220 percent; much of increase has taken place in greater Puget Sound area.

DATA GAPS AND RESEARCH NEEDS

Monitoring

Except for unpublished waterfowl surveys by the Washington Department of Game and USFWS, no intensive studies on distribution and abundance of marine birds in the Strait of Juan de Fuca/northern Puget Sound were conducted prior to 1978. The first year of a two-year distributional study as part of the EPA MESA study (Wahl et al. 1981) was first reported in Manuwal et al. (1979). Additional studies include one by Speich and Wahl (1989) and surveys of the San Juan Islands and Protection and Smith Islands conducted by USFWS biologists at the Nisqually National Wildlife Refuge.

Programs to monitor marine bird populations year-round should be initiated. Those programs that address species that have not been included in current monitoring efforts should be expanded.

Existing PSAMP bird surveys conducted 1992–1999 have had limited species, habitat, and seasonal coverage (Nysewander pers. comm.). Budget cuts will soon eliminate summer surveys except for pigeon guilllemot colony censuses, with only winter monitoring of diving ducks continuing.

Current efforts need to be continued and/or increased to address data gaps and improve the analysis of status and trend information. Collection of year-round data is crucial.

The monitoring of marine bird populations should be continued or expanded during all seasons. Special surveys for species of concern (such as marbled murrelet and harlequin duck) should be mounted.

Drastic decreases in certain species (e.g., seas ducks, western grebes) need further attention with regard to food chain, habitat alteration, etc. (Nysewander pers. comm.).

Inland marine areas that are highly utilized by summer populations of subadults/nonbreeders should be identified. These may be critical areas for the long-term well-being of certain species, as inland waters often harbor large numbers of nonbreeders and should be considered for habitat preservation and/or management activities.

Studies are needed to identify specific seasonal prey items taken by marine bird species. Knowledge of seasonal prey availability and food chain dynamics must be better understood.

Where unknown, diets of marine birds should be identified to support prey-base recommendations by fisheries managers. The adequacy of the prey base for marine birds and the role of fisheries management in addressing the sufficiency of that prey base should be examined.

The interaction of hydrographic features on the distribution of wintering concentrations of both marine birds and their forage fish or prey items should be studied, and existing baseline data on distribution, timing, and movements of non-commercial forage fish in marine waters should be expanded.

Environmental contaminants

A long-term program to monitor contaminant levels in fish-eating birds as ecosystem indicators should be developed and implemented.

Research is needed to identify and determine the sources of contaminants that are bioconcentrated in bird species.

A program to determine the impact of sublethal levels of contaminants and other health stressors on bird species at the top of the marine foodchain is also needed, as is a program to measure contaminant levels in game species to establish the potential impact on human health.

Human/bird interactions

Loss of essential habitats due to human development and other activities should be evaluated. Estuarine habitats in particular are among the most threatened by human development and contamination. Habitats of immediate concern should be identified and recommendations developed to reduce habitat loss rate and/or protect important habitats

Efforts should be taken to identify and protect nesting colonies where human disturbance is a problem

Existing monitoring of impacts to seabirds by net fisheries should be continued and recommendations developed to reduce bird mortalities from such activities.

Direct and indirect impacts of mariculture on marine birds should be evaluated and management practices and/or recommendations developed to reduce impacts.

The impacts of glaucous-winged gulls on the following should be studied: colonial nesting seabirds, as nuisance factors on roofs of buildings and at landfills; safety risks at airports; and as vectors in the dispersal of organisms harmful to human health.

The use of habitat and population restoration techniques for the recovery of declining species or populations should be evaluated.

Impacts of vessel and aircraft on marine bird behavior should be evaluated.

Oil spill risk factors should be assessed and differences in risk from trans-shipment versus pipline modes of transportation evaluated.

VI. MARINE MAMMALS

CHARACTERIZATION OF THE RESOURCE

The Northwest Straits are inhabited by 29 species of marine mammals. Nine of these are considered common, including four species of pinnipeds and five species of cetaceans. These species are considered in greater detail below. An additional 19 are occasional, rare, or accidental.

These marine mammals occupy and cross the transboundary waters of British Columbia and Washington. However management of marine mammals has primarily been conducted independently by each country, due to legal and logistical constraints (Calambokidis and Baird 1994).

As top-level predators, marine mammals are especially vulnerable to the effects of contaminants. High levels of contaminants, particularly chlorinated hydrocarbons and some metals have been identified in these animals. In addition, marine mammals are occasionally killed incidental to commercial fishing operations.

Some species of marine mammals are also highly sensitive to human activity, such as boating, which has increased greatly in the Northwest Straits area over the past decade. Currently, there is not adequate information to assess the effects of these human impacts on the marine mammal populations inhabiting the Northwest Straits (Calambokidis and Baird 1994).

Segments of the commercial fishing community are concerned about the impact marine mammals may have on vulnerable fishery resources, particularly salmon runs.

STATUS OF RESOURCE

Pinnipeds

Four species of pinnipeds are commonly found in the Northwest Straits study area. Common threats to pinnipeds include: oil spills and other catastrophic events that can threaten haul-out areas; disturbances by boats, aircraft, and beachwalkers; and entanglement in fishing gear, especially salmon gillnets. In addition, some threats are posed to seals and sea lions by the battle over salmon resources. Overall, it is estimated that harbor seals take from 3 percent 4 percent, sea lions take about 10 percent of the annual commercial take of salmon. Overall, pinnipeds account for about 10 percent of this catch (CMC 1998).

Northern Harbor Seal (*Phoca vitulina*)

- Year-round residents, northern harbor seals are the largest population of marine mammals in the Northwest Straits.

- 17,000 were killed by bounty hunters from 1947 to 1960.

- Population has since rebounded to approximately 12,000 in 1992, increasing at annual rate of 12 percent in British Columbia and 5 to 15 percent in Washington.

- Distinct sub-population of harbor seals occupying northern Puget Sound and Strait of Juan de Fuca region.

- Considered non-migratory, but may move extensively.

- Opportunistic feeders, widely on hake and herring, also eelpouts, sculpin, cod, mollusks.

- Primary prey of transient killer whales.

- Extremely sensitive to disturbance at haul out sites from vessels engaged in wildlife viewing.

- Continued monitoring of numbers and aspects of their biology and human impacts in the Northwest Straits is underway.

- Conflicts exist with commercial fishers, due to predation on commercially valuable fish and damage to gear and gillnets. In rare circumstances can affect salmon runs.

- Implicated in closure of some shellfish beds near haulout areas, due to high concentrations of fecal coliform bacteria.

Elephant Seal (*Mirounga angustirostris*)

- Hunted to near extinction in 1800s, now approximately 30,000 animals in the northern Pacific Ocean.

- Common migratory visitor from California and Mexico; most common in spring.

- Breeding range is currently being extended toward the north. Pupping has occurred on Protection and Smith Islands in 1998–1999, and both males and females have been hauling out at these locations in summer (Evenson, WDFW in prep.).

- Most animals forage in the open ocean, but some individuals enter the Northwest Straits area, beginning in spring. In the Northwest Straits, most often occupy deep, open channels, resting at the water's surface.

- From May through August, molting seals are found on some Puget Sound sandy beaches. Not usually found in southern Puget Sound or north of the San Juan and Gulf islands.

- Haulout areas are less predictably located than with other species. Only one area —

Race Rocks, near Victoria — is identified as regular haulout area. Individuals are often observed there with harbor seals and sea lions.

- No population estimates are available, but numbers appear to be increasing.
- Narrow, genetically confined population is more susceptible to disease outbreaks.
- Data on diet are limited to anecdotal information. Prey include spiny dogfish and ratfish. Also known to feed elsewhere on a variety of species, including shrimp, crab, squid, octopus, tunicates, skates, rays, lamprey and bony fish such hake and rockfish.
- Regional mortality is attributed to predation by orcas, entanglement in gillnets, complications with molts.
- In the Northwest Straits, research has been limited to inspecting hauled-out animals for tags and molting status, and examining some strandings.

California Sea Lion (*Zalophus californianus*)

- More abundant of the Northwest's two sea lion species.
- Common migratory visitor, present late August to June, with peak numbers in December (after breeding season).
- Range is expanding northward into inner marine waters of Washington (Nysewander pers. comm.).
- Populations composed primarily of migratory males, come to feed. Effects on groundfish and salmon stocks are uncertain (Nysewander pers. comm.).
- Monthly counts of as many as 74 at sites such as Sucia Island and Whale Rocks in the San Juan Island region, and Race Rocks and Sombrio Point in British Columbia.
- Total populations on West Coast are thought to exceed 161,000. Populations increased sharply through late 1970s to early 1980s after passage of the federal Marine Mammal Protection Act. Population may currently be as many as 3,000 in boundary waters.
- Opportunistic feeder on hake, walleye pollock, herring, spiny dogfish, and cephalopods.
- Sometimes regarded as nuisance or threat to fisheries resources.
- Not known to breed in the Northwest Straits; however one birth was witnessed during the winter of 1998 - 99 on a sand spit at Protection Island.
- Monitoring of the population throughout its range is important to assessing the long-term viability of this recovered species.

Northern (Steller's) Sea Lion (*Eumatopias jubatus*)

- Year-round resident in British Columbia; common migratory visitor, generally from September through May, with peak numbers from August to March. In winter, numbers can range from several hundred to more than 1,000.
- Majority occupy haulout sites in the Strait of Juan de Fuca early in the season.
- Predictably found at approximately 10 haulout areas within the Northwest Straits.
- Majority are males; females remain closer to breeding colonies.
- Population has recently dropped dramatically (up to 50 percent, especially in Alaskan waters). Listed as threatened in U.S. British Columbia population appears stable.
- Opportunistic feeders, preying locally upon: octopus, squid, lamprey, skate, spiny dogfish, ratfish, herring , eulachon, hake, rockfish, halibut, lingcod, and salmon. Salmon account for less than four percent of the diet. In Alaska, these animals also prey upon young harbor and fur seals.
- Washington and British Columbia populations are in all likelihood mixed.

Cetaceans/Odontocetes

Harbor Porpoise (*Phocoena phocoena*)

- Historically abundant. Common, occuring year-round and breeding in the Northwest Straits.
- Overall abundance is unknown.
- Historically taken by indigenous fishers.
- Very shy, hence difficult to study and vulnerable to human activity.
- Aerial surveys and boat counts suggest approximately 100 individuals in the San Juan Islands. Sightings are common in Rosario Strait and Boundary Pass.
- 1991 abundance estimates for the Strait of Juan de Fuca and San Juan Island area were about 3,300 animals.
- Prey on small fish, including smelt, herring, gadoids, plus squid and other invertebrates.
- Once common in Puget Sound south of Admiralty Inlet, but now virtually absent from this region, possibly because of increased vessel traffic and loss/disturbance of

nearshore habitat. There is anecdotal evidence that populations in southern British Columbia have decreased.

- Small number are known to be captured by gillnets in the Northwest Straits region.

- No evidence of migration in Northwest Straits populations.

Dall's Porpoise (*Phocoenoides dalli*)

- Occur year-round; generally seen late spring to fall.

- Limited information on abundance in the Northwest Straits.

- Widely distributed throughout the northern Pacific Ocean, with estimates of 3,015 for the Strait of Juan de Fuca and 133 for the San Juan Islands.

- Gregarious, enjoy bow waves, rapid swimmers (30 knots).

- Prey on squid and small schooling fish.

- Seen primarily in large and open straits and sounds, less often in protected areas.

- Common in Strait of Juan de Fuca, frequently seen between Port Angeles and Victoria British Columbia, Admiralty Inlet, southern Whidbey Island, and main channels of the San Juan Islands. Rarely found south of Seattle or east of Whidbey Island.

- Incidental captures by fishers in the Northwest Straits, no data on population trends or impact this is having on population.

- Degree of movements within the Northwest Straits is not known.

- Year-round presence could suggest resident animals, or could be differing groups moving through area.

Orca *(Orcinus orca)*

- Two populations of orcas — Resident and Transient — exist in the Northwest Straits. They exhibit differences in external morphology and mitochondrial DNA, imply that the populations may be reproductively isolated.

- Both are year-round residents; both have forms of long-ranging movement.

- Northwest Straits has the only resident population of orcas in continental U.S., one of the most extensively studied populations of cetaceans in the world.

- Resident orcas appear subdivided into two distinct populations, with southern residents occupying the Northwest Straits. Numbers have increased 1.3 to 2.0 percent per year since 1977. Core of range lies within waters of Haro Strait, southern Strait of Georgia, and eastern Juan de Fuca Strait. Three extended family groups, or pods (J, K, and L), have been identified.

- Between 1967 and 1973, 58 individuals were taken or killed by collectors for marine parks. Since 1970s, numbers are up 41 percent (96 or 98 members). Six calves have been born since 1994.
- Majority of prey for resident population is salmon, although it is thought that bottomfish are also regularly taken.
- Residents concentrate along the west side and southern end of San Juan Island.
- Since 1996, the resident pods have lost nearly 10 percent of their members. No known reason for decline. May be normal population fluctuation, but a number of the missing animals were young and/or in good health when last observed.
- Ongoing research on residents includes year-round monitoring of movements, photo-id, and behavioral studies.
- Population size for transient whales is unknown. 85 individuals in approximately 50 pods have been sporadically sighted.
- No information is available on transient population trends.
- Transient orcas feed almost exclusively on marine mammals; 96 percent of these are harbor seals.

Cetaceans/Balaenoptera

<u>Minke (*Balaenopter acutorostrata*)</u>

- Worldwide, one of most abundant species of baleen whales.
- Aerobatic, high speed swimmers.
- Seasonally common in the eastern Strait of Juan de Fuca and around the San Juan Islands from March through November. Some are year-round residents. Most are adults and subadults.
- Regularly sighted near marine banks and upwelling area, especially at Partridge, Hein, and Middle banks.
- Population fluctuates seasonally, but some 20 individuals may be residents.

- Reports on occurrence of Minke are stable over last two decades.
- Population size and trends in eastern North Pacific are unknown.
- Northwest Straits serves primarily as a feeding area.
- Employ various feeding techniques, including lunge feeding. Form feeding associations with birds. Feeding concentrated in depths of 20m to 100m.
- Juvenile herring and juvenile sandlance identified as prey species.
- Current research in the Northwest Straits is limited to collation of sighting records by Marine Mammal Research Group in British Columbia and the Whale Museum in Friday Harbor.

Gray whale (*Eschrichtius robustus*)

- Seasonally common during migration of 20,000 whales from Baja California to Vancouver Island and Chuckchi Sea.
- Between 1854 and 1864, 8,000 gray whales were killed by whalers, reducing numbers to about 2,000 animals. Population has since rebounded to pre-hunting levels.
- Records of gray whales east of Cape Flattery exist for every month of the year.
- Recent studies indicate repeated sightings of individuals for extended periods during spring and summer months. A summer resident population may exist.
- Gray whales feed all summer in the western Strait of Juan de Fuca near Neah Bay.
- Prey includes invertebratess such as mysids, fish larvae and shrimp, and especially ghost shrimp primarily captured in shallow areas close to shore.
- Individuals wash up dead each year, primarily in spring and summer months. Controversy exists over the role of pollutants in these deaths. Many carcasses revealed poor nutritional condition. Scientists have no definitive answer for the cause of this starvation. A number of theories have been advanced—lack of food due to changing oceanic conditions, natural die-off from exceeding the carrying capacity of the oceanic ecosystem, or a disease reducing the whales' appetite.
- In 1999, an unusually large number of gray whale carcasses washed onto the shores of the Northwest Straits and Puget Sound.

Otters *(mustelidae)*

River Otter (*Lutra canadensis*)

- Terrestrial mammals that live near and forage in shallow fresh water and salt water.
- Little is known about river otter abundance and distribution. Information based on trapping records and field observations suggests these animals are distributed throughout the San Juan Islands, Skagit River system, Dungeness area, Port Angeles, and Cape Flattery.
- Prey include crayfish, sculpins, flounders, and spawning salmon.
- Predators include domestic dogs, killer whales, and humans.
- Unlike other marine mammals, sea otters are not protected from hunting.

Sea Otter (*Enydra lutris*)

- Eliminated from Washington by overharvesting during the 19th century .
- Transplantation efforts were begun in 1969 and 1970 with introduction of about 59 individuals from the Aleutian Islands. Now thriving, with coastal population of about 500, primarily along the Pacific Ocean coast. Individuals have been sighted in western Strait of Juan de Fuca, where they appear to be recolonizing the shore.
- During winter months, rafts of males are found in the Northwest Straits as far east as Clallam Bay.
- Sea otters favor rocky substrates with kelp forests, where a variety of prey (especially urchins, abalone, and crab) can be found.
- It is possible that over time, sea otters may establish themselves in the Strait of Juan de Fuca.

DATA GAPS AND RESEARCH NEEDS

Scientists and managers need better information on the effects of changing environmental conditions and human impacts and the relationship to population fluctuations of marine mammals (Calambokidis and Baird, 1994).

Of particular concern is the gray whale population, due to the large number of emaciated whales showing up in state waters. Because of their interaction with salmon and other commercial fish, the northern harbor seal and the California sea lion require greater research. Human interventions to manage predator populations often have unintended cascading effects throughout the ecosystem. A better approach would be to develop strategies, which work simultaneously to rebuild the stocks of all the prey organisms. This would allow these animals to return to previous feeding behaviors and reduce their impact on depleted species.

There are virtually no research studies to date with estimates of population size (especially harbor porpoise, Dall's porpoise, Minke) within Canadian waters.

Information is needed on population trends, especially Harbor porpoise, Dall's porpoise, which are occasionally killed in fisheries. Investigate circumstantial evidence of decline in harbor porpoise.

Greater understanding is needed of the range, stock structure, and movements of marine mammals in the Northwest Straits study area.

Levels of incidental mortality need to be researched, especially in Harbor porpoise and Dall's porpoise, in various commercial, native and research fisheries.

Investigation of natural mortality levels and effects of viral and bacterial outbreaks biotoxins, on populations are needed.

Research on pollutant levels and potential impacts on marine mammals needs to be conducted. Research to date indicates high concentrations of some contaminants in some marine mammal species in the Northwest Straits. Relatively few samples, obtained from the occasional strandings, have been analyzed. Additional data from biopsies of live animals would 1) allow better evaluation of contaminant concentrations and relationship to reproductive success and other parameters; and 2) Would provide a good method for examining overall trends of contaminants in a broad sector of the marine environment.

Causes of high levels of contaminants in harbor seals should be explored through food habit and food chain research especially focused on fishes (Nysewander pers. comm.). Seal studies now concentrated in southern Puget Sound should be expanded to northern waters and coordinated with Canadian research. Orca and harbor porpoise should be included in these studies.

Information is needed on the community ecology of marine mammals, including competition between marine mammals and commercial fisheries. No research has been conducted on the impacts on marine mammals of declines in some of their primary prey.

Studies on impacts of disturbance from human activity are needed. Some studies have been done on killer whales and harbor seals. The results of these studies indicate that there is no immediate changes in behavior of Orcas despite dramatic increase in number of boats approaching whales. The reaction by harbor seals to disturbance is generally to re-enter water. Potential impacts include separation of mothers and pups, interruption of nursing, and abandonment of haulout areas.

[1] Treating these habitats separately overlooks the reality of important linkages between habitats. There is general awareness of these linkages, but there has been minimal research focused on them. For example, plankton—nominally “open water” organisms—are essential food for many species in both the rocky and soft-bottom habitats, although their role in the food budget has not been well quantified. Likewise, a significant fraction (considered to be approximately half) of benthic species have open water planktonic egg, larval, and juvenile stages. In addition, numerous important open water recreational and commercial species—notably salmon, herring, and Dungeness crab—use nearshore soft-bottom habitats for spawning and/or juvenile nursery refuge areas.