APPENDIX
DATA GAPS AND KEY FINDINGS

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Nutrient Dynamics and Other Water Properties

Data Gaps

Water property data, including nutrient data, are lacking in the study area. No long-term data of offshore or nearshore water properties exist; therefore, changing conditions and human impacts cannot be evaluated. However, an encouraging first step is the WDOE Marine Water Monitoring program that was initiated in 1992. The program has two approaches: long-term monitoring and focused monitoring. Long-term monitoring consists of visiting numerous selected stations once per month with the goal of establishing and maintaining consistent baseline environmental data. Focused monitoring entails sampling individual locations for a short period of time with increased spatial and temporal resolution relative to long-term monitoring (Newton et al. 1998). This program, however, is focused in offshore waters of Puget Sound. Collection of nearshore data is seriously lacking as well. Most data collected to date have been part of a specific research agenda and in highly localized geographic regions. The recently implemented King County MOSS water quality sampling is collecting valuable data in WRIAs 8 and 9 that will begin to fill a gap in the nearshore data.

Key Findings

Based on limited data, it appears that nurient dynamics and other water properties may be modified by anthropogenic influences, particularly during seasonal periods with higher runoff. However, seasonal, interannual, geographic and spatial data are lacking to draw definitive conclusions.

Primary Productivity Dynamics and Rates

Data Gaps

Primary productivity estimates available for benthic and water column components are lacking in any great detail with the exception of early studies done in the Duwamish River and estuary (Table 4). Production estimates are a critical component in understanding the links between phytoplankton, zooplankton, and higher trophic levels in the food chain. In addition, no systematic, standardized sampling has been conducted over the years to allow a comprehensive examination of long-term changes in productivity. Most research to date has been conducted with agency-specific goals in mind. While the collected data are very useful within a specific context, they do not address the larger questions of spatial and temporal variation or long-term distributional change.

Table 4: Data gaps for primary productivity

Gaps	WRIA 8	WRIA 9
Primary productivity estimates for both benthic and water column components	All reaches	All reaches
Time-series data to allow assessment in changes over time, including spatial, temporal, and long-term distributional changes	All reaches	All reaches

Key Findings

- The nearshore zone in Puget Sound represents an area of relatively strong benthic-water column coupling, and nutrient limitation may occur under conditions of limited vertical mixing during the spring and summer.
- Preliminary data indicates primary productivity is limited by light in winter and nutrients in summer at some areas.
- Puget Sound is a relatively productive temperate estuary.

Food Web

Phytoplankton

Data Gaps

Long-term data on phytoplankton species abundance in Puget Sound, including harmful and toxic species, are unavailable (Table 5). This data gap precludes an understanding of interannual variations in community structure, and the possible long-term effects of changes in natural and anthropogenic sources of nutrients. Although studies in the Central Basin are beginning to indicate smaller scale temporal and spatial relationships among nutrients, chlorophyll, and production, additional studies are needed to fully understand phytoplankton production. Concurrent monitoring of nutrients, insolation, salinity, water temperature, and dominant zooplankton throughout the water column is needed to clarify nutrient-phytoplankton-zooplankton relationships. All of these factors have been shown to be important in determining species composition and distribution (Takahashi and Parson 1973; Parametrix, Inc. 1984).

Despite continuous closures to recreational harvesting in WRIAs 8 and 9, there has been no direct causal link established between nutrient enrichment, eutrophication, and PSP in Puget Sound (Rensel 1993).

Table 5: Data gaps for phytoplankton

Gaps	WRIA 9	WRIA 8
Long-term abundance data	All reaches	All reaches
Interannual changes in community structure	All reaches	All reaches
Long-term effects of changes in natural and anthropogenic sources of nutrients	All reaches	All reaches
Relationships among nutrients, phytoplankton, and zooplankton	All reaches	All reaches

Zooplankton and Other Heterotrophs

Data Gaps

The need for analysis of archived samples described above as well as routine sample collection of present assemblages is essential for understanding the relationship of zooplankton abundance and distribution, human activity, natural cycles, and fish populations in Puget Sound (Table 6). Specifically, useful information would include species composition at varying depths and locations around Puget Sound; seasonal distribution and relationship to human activities; links among salmon, forage fish, and zooplankton; a comparison of fish and zooplankton diets between the late 1970s and early 2000s; and baseline zooplankton data for Puget Sound so that future comparisons can be made (Frost, pers. comm.).

Table 6: Data gaps for zooplankton

	WRIA 8	WRIA 9
Distribution and abundance time-series data	All reaches	All reaches
Species composition at varying depths and locations	All reaches	All reaches
Seasonal distribution and relationship to human activities	All reaches	All reaches
Links among salmon, forage fish, and zooplankton	All reaches	All reaches
Comparison of fish and zooplankton diets in the 1970s versus the early 2000s to assess potential changes	All reaches	All reaches
Baseline zooplankton data	All reaches	All reaches

Benthic Infauna and Epifauna

Key Findings

- Planktonic, as well as benthic algal and eelgrass-dominated habitats, are highly susceptible to anthropogenic nutrient increases.
- Harmful algal blooms can be intense and result in toxic shellfish as well as other health problems affecting humans and aquatic animals. Harmful algal blooms and elevated fecal

coliform levels have closed virtually all WRIA 8 and 9 nearshore habitats to recreational shellfish harvesting.

- El Niño and other anomalous climatic events affect the dynamics of planktonic and benthic habitats.
- There are a large number of introduced benthic and planktonic species that may affect the food web and functions of benthic and planktonic habitats.
- No comprehensive study has addressed food web interactions in WRIA 8 and 9 nearshore marine habitats. However, similar studies in northern Puget Sound and the Strait of Juan de Fuca offer a number of insights into Central Puget Sound processes.
- The food web of shallow nearshore habitats of the region is based upon detritus produced by marine algae, estuarine and saltmarsh vascular plants, and especially eelgrass.
- Gammarid amphipods and calanoid copepods are important primary consumers that convert organic matter to upper trophic levels. Important secondary consumers include herring, sand lance, surf smelt, and juvenile salmon.

Selected Nearshore Habitat Types

Eelgrass Meadows

<u>Data Gaps</u>

Gaps in our knowledge of eelgrass within WRIAs 8 and 9 include the effects of shoreline armoring and bivalve harvest (Table 10) on eelgrass meadows. We also do not know enough about the historical distribution and abundance of eelgrass to draw any meaningful conclusions. Monitoring of eelgrass beds eventually would show trends in density and abundance, and perhaps allow scientists to distinguish natural variability from adverse effects of human activities. Better data on fish use of eelgrass, and the effects of urban runoff on eelgrass, would contribute to improved management efforts.

Table 10: Data gaps for eelgrass

Gaps	WRIA 8	WRIA 9
Complete maps, including measurements of area	Northern portion of reach 1 and southern portion of reach 3	All reaches
Monitoring of eelgrass beds	All reaches	All reaches
Incidence, causes, and effects of ulvoid blooms	All reaches	All reaches except 7
Effects of nutrient loading and urban runoff on eelgrass	All reaches	All reaches
Anoxic sediment impacts	All reaches	All reaches
Clam harvesting impacts and recovery rates	All reaches	All reaches
Effects of shoreline hardening	All reaches	All reaches
Interannual variability and natural vs. human-influenced controls of variability	All reaches	All reaches
Fish (especially juvenile salmon) and invertebrate use	All reaches	All reaches

Kelp Forests

Data Gaps

The general lack of historical and recent studies of kelp in Puget Sound results in numerous gaps in our knowledge. Mapping distribution and monitoring over time, studies of kelp forest ecosystems and species interactions, and the impacts of development and changes in water chemistry would prove invaluable for enhancing our understanding and improvement of our management of kelp and kelp dependent species. The most critical data gaps in our knowledge of kelp are provided in Table 11.

Table 11: Data gaps for kelp

Gaps	WRIA 8	WRIA 9
Complete maps of kelp forest area	Reach 3	All reaches
Monitoring of kelp forests	All reaches	All reaches
Interannual variability and natural vs. human-influenced controls of variability	All reaches	All reaches
Role of kelp in the food web	All reaches	All reaches
Harvest impacts	All reaches	All reaches
Effects of shoreline hardening	All reaches	All reaches
Ecological tradeoffs of kelp forest expansion due to shoreline armoring	All reaches	All reaches
Fish (especially juvenile salmon) and invertebrate use	All reaches	All reaches
Role of nutrients, temperature, and chemical contaminants on kelp growth and health	All reaches	All reaches
Effects of anthropogenic discharges on kelp	All reaches	All reaches
Effects of *Sargassum muticum* competition in disturbed kelp forests	All reaches	All reaches

Flats

Data Gaps

Although massive filling and development of the Duwamish Estuary and Elliott Bay has occurred over the past 125 years, eliminating 97 percent of mudflat and sandflat habitats, the total impact on juvenile salmonids and other estuarine resident species is not well understood (Table 12). The following data gaps have been identified:

Table 12: Data gaps for flats

Gaps	WRIA 8	WRIA 9
Complete maps of flat area	All reaches	All reaches
Interannual variability and natural vs. human-influenced controls of variability	All reaches	All reaches
Role of flat production in the food web	All reaches	All reaches
Bivalve harvest impacts	All reaches	All reaches
Effects of shoreline hardening	All reaches	All reaches
Fish (especially juvenile salmon) and invertebrate use	All reaches	All reaches
Comparison of fish use of disturbed and undisturbed flats	All reaches	All reaches
Role of nutrients, temperature and chemical contaminants on benthic plant and animal growth and health	All reaches	All reaches

Tidal Marshes

Data Gaps

Although massive filling and development of the Duwamish Estuary and Elliott Bay have occurred over the past 125 years, the total impact on juvenile anadromous salmonids and other estuarine resident species is not well understood. Significant data gaps in marsh ecology, such as the extent of interannual variability, role of upland buffers in marsh migration, and interactions between marshes and riparian zones, also exist. The significance of marshes in groundwater recharge, the role of periodic disturbance in marsh ecology, and the importance of large woody debris as habitat structure in marshes also are not well studied. Table 13 lists the identified data gaps.

Table 13: Data gaps for tidal marshes

Gaps	WRIA 8	WRIA 9
Complete maps of marsh area	All reaches	All reaches
Interannual variability and natural vs. human-influenced controls of variability	All reaches	All reaches
Role of reduced or altered upland buffers in allowing marshes to migrate inland with sea level rise	All reaches	All reaches
Role of marsh production in the food web	All reaches	All reaches
Fish (especially juvenile salmon) and invertebrate use	All reaches	All reaches
Interactions between marshes and riparian zones	All reaches	All reaches
Role of marshes in groundwater recharge	All reaches	All reaches
Role of periodic disturbance in marsh ecology	All reaches	All reaches
Role of large woody debris as habitat in marshes	All reaches	All reaches
Carrying capacity of disturbed and undisturbed marshes	All reaches	All reaches
Role of nutrients, temperature, and chemical contaminants on benthic plant and animal growth and health	All reaches	All reaches

Subestuaries (River Mouths and Deltas)

Data Gaps

More information regarding salmon use of small streams could be gathered. As of 1990, when the last sensitive areas map was constructed, there were several small streams that had not been classified because salmonid use had not been determined. However, city of Seattle streams have recently been assessed for stream type, habitat, fish type and salmon barriers and spawning (report in preparation, Gail Arnold, SPU, pers. comm.). Data gaps for subestuaries are listed in Table 14.

Table 14: Data gaps for subestuaries

Gaps	WRIA 8	WRIA 9
Information on juvenile salmonid use of small streams	All reaches	All reaches
Extent of impervious surface development in small stream watersheds	All reaches	All reaches
Relationship between impervious surface and subestuary degradation	All reaches	All reaches
Importance of subestuaries to migrating salmonids and other fish and wildlife	All reaches	All reaches
Effects of degraded water quality and habitat loss on subestuarine carrying capacity	All reaches	All reaches

Sand Spits

Data Gaps

Little current and historical information on sand spits is available for WRIAs 8 and 9, and we do not know conclusively how natural and human-influenced forces affect them. Table 15 shows gaps in our knowledge of sand spits, including their role in the food web and as habitat for fish and invertebrates.

Table 15: Data gaps for sand spits

Gaps	WRIA 8	WRIA 9
Natural interannual variability vs. human-influenced controls of variability	All reaches	All reaches
Role of sand spit production in the food web	All reaches	All reaches
Fish ,invertebrate, and wildlife use of existing spits	All reaches	All reaches
Cumulative and site-specific effects of shoreline armoring and other development practices on spits	All reaches	All reaches
Carrying capacity of disturbed and undisturbed spits	All reaches	All reaches

Beaches and Backshore

Data Gaps

Although massive urbanization has taken place in Elliott Bay and the Duwamish Estuary, and lower levels of development have occurred on the rest of the WRIA 8 and 9 shorelines, the cumulative effects of development on beaches and backshore are not well understood. Table 17 lists some of the gaps in our knowledge of beaches and backshore.

Table 17: Data gaps for beaches and backshore

Gaps	WRIA 8	WRIA 9
Role of production in the food web	All reaches	All reaches
Bivalve harvest impacts	All reaches	All reaches
Effects of shoreline hardening and other development practices	All reaches	All reaches
Fish (especially juvenile salmon and forage fish) and invertebrate use	All reaches	All reaches
Role of woody debris in nearshore ecosystem	All reaches	All reaches
Carrying capacity of degraded and undisturbed beaches and backshore areas	All reaches	All reaches

Banks and Bluffs

Data Gaps

Within WRIAs 8 and 9, massive shoreline development and armoring activities have taken place over the last 125 years. However, the total impact this urbanization has on banks and bluffs is not well understood. Table 19 lists some of the gaps in our knowledge of bluff and bank habitats.

Table 19: Data gaps for banks and bluffs

Gaps	WRIA 8	WRIA 9
Incidence of drainage/stability problems on bluffs	All reaches	All reaches
Effects of shoreline armoring and other development on banks and bluffs	All reaches	All reaches
Portion of beach sediment budget contributed by bluffs	All reaches	All reaches
Groundwater input from bluffs and banks	All reaches	All reaches

Marine Riparian Zones

Data Gaps

Relatively little research has been conducted on marine riparian areas compared to freshwater systems. Some research has occurred in other parts of the country on the effects of marine riparian vegetation on pollution abatement, soil stability, wildlife habitat, and fish habitat. However, little research has focused on Pacific Northwest systems. Additionally, regulations regarding functional buffer widths and riparian protection are not in place compared to freshwater systems. The functions and values of marine riparian vegetation need to be better documented in the scientific literature in order to provide a better understanding of riparian functions in marine ecosystems and to create adequate policies for protection and restoration.

Table 20: Data Gaps for Marine Riparian Zones

Gaps	WRIA 8	WRIA 9
Complete maps of marine riparian vegetation, including extent (width, continuity), type, density, composition	All reaches	All reaches
Percent impervious area and type of cover (i.e., concrete, asphalt, structures)	All reaches	All reaches
Role of MRV in food web (contribution of organic carbon, insects, etc.)	All reaches	All reaches
Role of MRV in providing water quality functions, especially non-point source pollution	All reaches	All reaches
Importance of MRV in providing shade to fish & wildlife	All reaches	All reaches
Role of MRV in providing microclimates	All reaches	All reaches
Role of MRV in providing wildlife habitat	All reaches	All reaches
Role of MRV in providing fish habitat	All reaches	All reaches
Role of MRV in increasing slope stability	All reaches	All reaches
Cumulative impacts of shoreline armoring and other shoreline development and land use practices on MRV and MRV functions	All reaches	All reaches

- Key Findings
- Distribution of Habitat Types
- Nearshore marine habitats in WRIA 8 and 9 are diverse and include marine riparian vegetation, banks and bluffs, beach and backshore, tidal marshes, tidal flats, eelgrass meadows, kelp forests, and water column habitats.

- These habitats act together to create the productive Puget Sound ecosystem by providing the physical, chemical and biological processes that form habitats and drive critical functions.
- Historical maps of nearshore marine and estuarine habitats are lacking in WRIAs 8 and 9; only recently have comprehensive mapping efforts (WDNR Washington State ShoreZone Inventory) been undertaken that adequately assess the region's nearshore marine resources.
- Eelgrass productivity exceeds that of most other aquatic plants. Organic carbon produced by eelgrass is especially important in driving the nearshore marine food web of Puget Sound.
- Overwater structures, shoreline armoring, fecal contamination, climate change, dredging, filling, resource exploitation, contamination, ship wakes and propellers have all contributed to major losses of habitat area and their functions in the region
- Monitoring programs have not adequately addressed long-term changes in habitat distribution.

There is no comprehensive understanding of the effects of multiple stressors on the viability of nearshore marine habitats in the region

Selected Fishes

Salmonids

Table 23: Data gaps for salmonids

Gaps	WRIA 8	WRIA 9
Standardized habitat assessment methodologies	All reaches	All reaches
Historic data for nearshore seasonal distribution and abundance	All reaches	All reaches
Residence times and rate of migration through the nearshore	All reaches	All reaches
Annual stock assessment data for forage fish species	All reaches	All reaches
Cutthroat trout use of nearshore habitats	All reaches	All reaches
Native char (bull trout) use of nearshore habitats	All reaches	All reaches
Carrying capacity of disturbed and undisturbed nearshore habitats for salmonids	All reaches	All reaches
Relationship of prey utilization to population dynamics		
Effects of pollutants on rapidly growing juveniles	All reaches	All reaches
Magnitude and sources of natural mortality vs. mortality under stressed conditions	All reaches	All reaches
Effects of over-water structures on predation rates, migration, and habitat	All reaches	All reaches
Effects of shoreline armoring and other modifications on salmonids	All reaches	All reaches
Assessment of cumulative effects	All reaches	All reaches
Effects of loss of connectivity between nearshore habitats	All reaches	All reaches

Key Findings

There are several key findings to note from this investigation.

- Salmonids use the nearshore for key elements of their survival, including: physiological transition, migration, nursery areas, juvenile food production and feeding, adult food production, and residence and refuge.
- Some stocks of young salmon enter and pass through nearshore habitats between early March and late June, but there is substantial variability depending on the species, location, and inter-annual differences. Several stocks migrate earlier (i.e., summer chum) and many other migrate through the summer and into the fall (i.e., various chinook stocks).
- Juvenile salmonids are present in many different nearshore habitat types with a very diverse range of biological and physical conditions, indicating juvenile salmonids are adaptable to a wide range of habitats, both constructed and natural.
- Depending on species and size, many salmonids are consistent in their diet composition when in estuarine/nearshore environments, most notably chum fry but also chinook. Conversely, in some estuarine environments, such as oligohaline marshes, they appear to be relatively non-selective, especially in some developed estuaries (i.e., Duwamish and Snohomish estuaries). When salmonids convert to pelagic foraging, their diets may become more diverse, but some species (i.e., chum, coho) still show specific diet affinities for certain taxa.
- Nearshore habitats have added importance because they are spawning sites for forage fish species, and salmonids feed on all life history stages of these species.
- Chinook salmon and cutthroat trout appear to be most dependent on the nearshore environment for all stages of their marine existence. Chum and pink salmon are also highly dependent during their fry and juvenile stages. Sockeye and coho salmon appear to be less dependent than other salmonids on estuaries and the nearshore, but do utilize the nearshore environment during their outmigration.
- In addition to natural stressors, human activities such as filling estuarine wetlands and intertidal areas, armoring shorelines, fishing, and polluting nearshore waters are also significant stressors of salmonid resources in WRIAs 8 and 9.
- A number of gaps in existing data need to be filled to attain a better understanding of ecosystem change across a multitude of spatial and temporal scales.

Forage Fish

Data Gaps

Reasons for increased natural mortality in herring are unclear, especially in light of the relatively low recent abundance levels of most Puget Sound herring predators.

Smelt migrations and movements of surf smelt are unstudied, and it is unclear if adults return to natal spawning beaches or exhibit fidelity to specific spawning beaches. In fact, little basic biological information exists for all forage fish in Puget Sound. Stock assessments, dietary studies, additional spawning surveys, and information about other life history requirements are needed for all forage fish (Table 25) (Bargmann 1998).

Table 25: Data gaps for forage fish

Gaps	WRIA 8	WRIA 9
Reasons for increased mortality of Pacific herring	All reaches	All reaches
Water quality effects on nursery grounds and young-of-year	All reaches	All reaches
Complete life history requirements of forage fish species	All reaches	All reaches
Information on forage fish stocks and biomass	All reaches	All reaches
Complete spawning ground surveys	All reaches	All reaches
Quantitative data on the effects of shoreline armoring and other shoreline development on spawning grounds	All reaches	All reaches
Complete spawning ground surveys	All reaches	All reaches

Key Findings

- Forage fish found within nearshore marine habitats of WRIAs 8 and 9 include herring, surf smelt, Pacific sand lance, eulachon, and longfin smelt. Forage fish use these habitats for feeding, migration, spawning, and rearing.
- Forage fish represent a significant component of the Puget Sound food web.
- Herring natural mortality in Puget Sound has increased in recent years; Puget Sound herring stocks are a candidate species under the ESA.
- Herring return to natal spawning grounds; egg attachment sites include firm substrates such as eelgrass and macroalgae. Sand lance and surf smelt spawn on upper intertidal beach habitats with sand/gravel sediments. All of these habitats are especially vulnerable to shoreline development.
- Within WRIA 8, there are no known herring spawning areas and only a limited number of documented surf smelt and sand lance spawning beaches. Within WRIA 9, one herring stock spawns in Quartermaster Harbor (Vashon Island). Surf smelt and sand lance spawning beaches are widespread on WRIA 9 shorelines, although spawning habitat inventories are incomplete. Regular spawning surveys and stock assessment are needed throughout the study area.

Groundfish

Data Gaps

Stressors, critical life history stages, habitat requirements, and reasons for poor year-class recruitment are generally unknown for all groundfish species listed above. Current distribution and habitat use data are lacking for nearshore habitats (Table 27).

The early life history of juvenile rock sole is poorly documented, and time-series of abundance data for English sole are generally not available for unfished areas to assess the effects of chemical contaminants or habitat alteration.

Table 27: Data gaps for groundfish

Gaps	WRIA 8	WRIA 9
Stressors to all species	All reaches	All reaches
Life history information for pollock and rock sole	All reaches	All reaches
Use of nearshore habitats for pollock, hake, lingcod, and rock sole	All reaches	All reaches
Factors influencing year-class recruitment of pollock and lingcod	All reaches	All reaches
Reasons for hake population decline	All reaches	All reaches
Time-series abundance data to assess the effects of chemical contamination and habitat alterations on English sole in unfished areas	All reaches	All reaches

<u>Key Findings</u>

- Important groundfish (defined as foodfish that reside near or on bottom) species in WRIAs 8 and 9 include the cods (Pacific cod, walleye pollock, Pacific hake), lingcod, English sole, and rock sole. Juvenile stages of all these species rely upon shallow vegetated nearshore marine habitats for rearing.
- Puget Sound stocks of Pacific cod, walleye pollock, Pacific hake are listed as candidate species under the ESA and as critical species by WDFW. Cods once supported large commercial fisheries, which have since collapsed. Cods are short-lived with highly variable interannual recruitment success and high susceptibility to demographic overfishing.
- Lingcod are listed as candidate species under ESA, although populations are considered stable by WDFW within south Puget Sound. Large lingcod individuals are the most susceptible to overharvest. Targeting large, highly fecund individuals reduces important brood stock for future generations.
- English sole and rock sole are widespread and abundant within Puget Sound; adults use nearshore areas for feeding, refuge, and spawning. These species are susceptible to the effects of sediment contamination, fishery overharvest, and habitat loss.

Rockfish

<u>Data Gaps</u>

Lack of reliable abundance estimates and general life history information for many species has hampered management and conservation efforts (Buckley 1997; West 1997; Musick et al. 2000). The importance of landscape position and the availability of habitat links in siting harvest refugia need to be further clarified. Impacts of habitat fragmentation are unknown. Table 30 lists these and other data gaps for rockfish.

Table 30: Data gaps for rockfish

Gaps	WRIA 8	WRIA 9
Life history information	All reaches	All reaches
Distribution and abundance	All reaches	All reaches
Importance of landscape position and habitat connectivity in siting harvest refugia	All reaches	All reaches
Effects of habitat alteration and fragmentation	All reaches	All reaches
Effects of contaminants	All reaches	All reaches
Species specific catch information	All reaches	All reaches
Stock assessments	All reaches	All reaches

Key Findings

- Over 20 species of rockfish inhabit Puget Sound, but only 3 (copper, quillback, and brown rockfish) are commonly caught by recreational or commercial fisheries in nearshore marine habitats.
- All rockfish stocks in Puget Sound for which there are adequate data are considered vulnerable or below average by WDFW; four species copper, quillback, brown, and boccaccio rockfish were candidate species under the ESA.
- Recreational and commercial catch records show long-term declines in rockfish populations. Rockfish are susceptible to overfishing, primarily because they are long-lived and fishing selects for the largest, most fecund, individuals. Marine protected areas may be an option for protecting their home range, but recruitment is poorly understood.
- Rockfish, particularly adults, require specific habitats.
- Much recent knowledge of rockfish distribution and abundance in WRIA 8 and 9 is derived from WDFW dive, video, acoustic, and trawl surveys. Studies of artificial reefs and marine refuges in WRIA 8 and 9 (Edmonds Underwater Park, Boeing Creek) have improved understanding of rockfish population dynamics in the region.
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Selected Invertebrates

Data Gaps

Along the mainland, there are no recent quantitative studies of invertebrates from WRIAs 8 and 9. Along the coast of Vashon Island, studies for native littlenecks have concentrated on and near Maury Island. The west coast of Vashon Island (reach 12) and much of the northeast coast (reach 9) remains unstudied. There are no data available to accurately assess population trends. Table 32 lists the abundance of three species of hardshell clams at selected King County beaches.

No data are available to accurately assess population trends of Manila clams. It is not known whether Manila clams are invasive or simply filling a previously vacant ecological niche in Puget Sound.

Except for a limited area around Edmonds, there are no recent population data for geoduck beds in WRIAs 8 and 9. There are no data for population trends that is not confounded by harvesting.

Data are lacking on the effects of stressors on geoduck populations (Table 31). Although they do not occur in the study area, assessments of Olympia Oyster and abalone population structure and trends are lacking

The abundance of Dungeness crab in central Puget Sound is unknown. This is because King County is at the southern range of abundance and fishing effort is not concentrated or consistent. A mark/recapture study is planned for the winter of 2000-2001 (J. Odell, WDFW, pers. comm.). Additional information would be valuable regarding lethal and sublethal effects of organic and inorganic pollution, and impacts of shoreline alterations on various life history stages of Dungeness crab (Table 31).

Table 31: Data gaps for invertebrates

Gaps	WRIA 8	WRIA 9
Recent quantitative abundance studies for all species	Reach 3	Reaches 4 and 12, and much of reaches 7-9
Effects of changes in habitat structure due to shoreline armoring, dredging, filling, and other development practices on recruitment and survival	All reaches	All reaches
Effects of exposure to lethal and sublethal contaminants on invertebrate populations and community structure	All reaches	All reaches
Effects of changes in detrital organic matter due to loss of marine and riparian vegetation on food supply	All reaches	All reaches

Key Findings

- Shellfish populations occurring within WRIAs 8 and 9 include native littleneck clams, butter clams, Manila clams, geoduck and other clams, and Dungeness crab. All of these species are commercially and/or recreationally harvested.
- Current information on hardshell clam distribution and abundance in WRIAs 8 and 9 is derived from the King County Beach Assessment Program. Some discrepancies and inconsistencies in sampling methods and locations exist to complicate analysis of hardshell clam abundance trends.
- Lincoln Park is one of the only beach habitats that has been quantitatively sampled repeatedly between the early 1970s and late 1990s.
- Shoreline siltation, loss of habitat, and water pollution affect hardshell clam populations.
- Except for a limited area around Edmonds, the most recent geoduck surveys from the mainland sections of nearshore marine habitats of WRIA 8 and 9 were collected in the 1970s; more recent surveys were conducted (1990s) from around Vashon and Maury Islands.

Shoreline Conditions

Shoreline Armoring

Data Gaps

Although there is qualitative evidence for many of the effects of shoreline armoring on the nearshore ecosystem, there is little quantitative data linking shoreline armoring to physical and biological changes. Ecological changes within drift cells should be quantified, as well as the cumulative effects of these changes on WRIAs 8 and 9. Table 33 lists some specific data gaps that need to be filled to better understand the effects of shoreline armoring.

Table 33: Shoreline Armoring Data Gaps

Gaps	WRIA 8	WRIA 9
Quantified relationships between shoreline armoring and changes in sediment budgets	All reaches	All reaches
Quantified relationships between shoreline armoring and changes in substrate	All reaches	All reaches
Quantified relationships between shoreline armoring and loss of shallow-water habitat	All reaches	All reaches
Quantified information on cumulative effects of shoreline armoring on intertidal and subtidal benthic communities	All reaches	All reaches
Quantitative studies of the effects of shoreline armoring on juvenile salmonid feeding opportunities	All reaches	All reaches
Quantitative studies of the effects of shoreline steepening on vulnerability of juvenile salmonids to predation	All reaches	All reaches
Carrying capacity of armored versus undisturbed shorelines	All reaches	All reaches
Effective and ecologically sound alternatives to conventional shoreline armoring	All reaches	All reaches

Overwater Structures

Data Gaps

There is limited information on the distribution and abundance of overwater structures in Puget Sound. Additional information on the effects of overwater structures on plant and animal communities is needed. Table 34 lists specific data gaps for overwater structures.

Table 34: Overwater Structures Data Gaps

Gaps	WRIA 8	WRIA 9
Cumulative and site-specific effects of overwater structures on nearshore processes and biological communities	All reaches	All reaches
Effective alternatives to and mitigation measures for docks and piers	All reaches	All reaches
Assessments of risk to juvenile salmonids posed by delays in migration caused by disorientation, lack of schooling in refugia, and changes of migratory route to avoid overwater structures.	All reaches	All reaches
Quantified relationships between overwater structures and predation rates on juvenile salmonids	All reaches	All reaches

Dredging

<u>Data Gaps</u>

While the effects of dredging on nearshore habitats and species are known in a general sense, little quantitative data links dredging to changes in habitats and species. Data gaps are summarized in Table 35.

Table 35: Data gaps for dredging

Gaps	WRIA 8	WRIA 9
Quantitative information on the effects of dredging on benthic habitat and communities.	All reaches	All reaches
Quantitative information on the potential to entrain salmonids including bull trout		Reach 4
Quantitative information on the effects of dredging on other nearshore species.	All reaches	All reaches

Filling

<u>Data Gaps</u>

There are very few studies of the changes in physical and biological environments that may have occurred as a result of historical fill activities. In addition, few studies have quantified the potential beneficial effects of beach nourishment and restoration projects. Data gaps are summarized in Table 36.

Table 36: Data gaps for filling

Gaps	WRIA 8	WRIA 9
Monitoring of beach nourishment sites to determine the effects of nourishment on sediment budgets and biota	All reaches	All reaches
Assessment of beach nourishment as an option for restoring beach habitat and protecting upland property	All reaches	All reaches
Quantitative estimates of the amount of nearshore habitat filled for shoreline armoring and other development purposes	All reaches	All reaches, except Elliott Bay & Duwamish Estuary
Cumulative effects of loss of nearshore habitats to filling on biota, especially juvenile salmonids	All reaches	All reaches

Sewage Discharges

<u>Data Gaps</u>

Few studies have identified and documented in a comprehensive manner the effects of discharges on the nearshore environment. Not only are studies of the effects of discharges on these ecosystems lacking, there is also a lack of basic baseline data for these habitats in general. Without this baseline information it is difficult to identify and separate impacts caused by human activity from the natural variation inherent in the nearshore. An effort should be made to identify and categorize the baseline condition of these habitats. Site-specific studies then should be conducted to examine the condition of the habitats adjacent to different types of discharges to determine if cause and effect relationships can be drawn. Data gaps are summarized in Table 37.

Table 37: Data gaps for sewage discharges

Gaps	WRIA 8	WRIA 9
Effects of sewage discharges on the nearshore ecosystem	All reaches	All reaches
Baseline data for habitats surrounding CSOs	All reaches	All reaches

Sediment Contamination

Data Gaps

There is a lack of basic knowledge on community-level effects from the mixtures of chemicals found in the environment (Table 39). Much is known about the effects of specific chemicals on individual species from toxicity testing, however the complex mixtures found in sediment habitats make it difficult to separate the effects of one chemical from another. This is an emerging science and rudimentary tests are available; however, their cost make them prohibitive for use in monitoring studies.

Table 39: Data gaps for sediment contamination

Gaps	WRIA 8	WRIA 9
Community-level effects of mixtures of chemicals	All reaches	All reaches
Sublethal effects of single contaminants and mixtures of contaminants	All reaches	All reaches
Relationships between sublethal effects and survival of organisms, particularly salmonids	All reaches	All reaches
Characterization of sediment contamination in the subsurface	All reaches	All reaches

Non-Point Pollution

Data Gaps

The primary data gaps of non-point pollution effects on the nearshore environment are related to the location, timing, identification, and quantification of contaminants (Table 40). More investigation is needed to identify how organisms respond to contaminants. In situ monitoring using mussels and the eggs or larvae of herring and sea urchins can be used to gain insight into the sub-lethal impacts of various pollutants. Investigations related to the synergistic effects of combinations of various levels of contaminants would also be helpful in prioritizing mitigation measures and regulation enforcement.

Table 40: Data gaps for non-point pollution

Gaps	WRIA 8	WRIA 9
Location, timing, identification, and quantification of contaminants	All reaches	All reaches
Sublethal effects of single contaminants and mixtures of contaminants	All reaches	All reaches

Non-Native Species

Data Gaps

The Puget Sound Expedition was conducted over only a brief period, and much of its work is provisional. Additional taxonomic work and review is needed. There is a need to do more sampling in low salinity areas and to expand research into the waters of British Columbia. Additional information is needed on smaller organisms, such as amphipods. Relationships of these organisms to the native food chain and microhabitats need further understanding. Much work needs to be done to understand the nature of these invasions and potential solutions to impacts. See Table 43 for a list of data gaps.

Table 43: Data gaps for non-native species

Gaps	WRIA 8	WRIA 9
Repeat sampling in all seasons	All reaches	All reaches
Additional taxonomic work and review of Puget Sound Expedition samples	All reaches	All reaches
Abundance, diversity, and effects of non-native species in low salinity areas	All reaches	All reaches
Abundance, diversity, and effects of smaller non-native species, such as amphipods	All reaches	All reaches
Distribution and abundance of non-native species in the study area	All reaches	All reaches
Effects of already established non-native species	All reaches	All reaches
Effective control measures	All reaches	All reaches

Key Findings

Shoreline Armoring

- Within WRIAs 8 and 9, between 75% and 87% of the shoreline has been armored or otherwise modified from historic conditions.
- Armoring modifies shoreline processes, affecting habitat structure and biological community composition.
- Shoreline armoring activities likely represent one of the most dramatic sources of nearshore marine habitat modification in Puget Sound.
- The linkages between shoreline armoring and biological impacts have not been adequately quantified to determine the types and levels of impact to nearshore biota.

Elliott Bay and The Duwamish River Estuary

Shoreline Conditions

Data Gaps

Despite the level of shoreline armoring in the Duwamish Estuary, Elliott Bay, and other urban embayments adjacent to anadromous streams, the effects of armoring on nearshore ecosystems have not been studied extensively. Table 46 shows the identified data gaps.

Table 46: Data gaps for shoreline armoring

Data Gaps – Shoreline Armoring
▪ There have been no definitive studies investigating the effects of armoring on juvenile salmon feeding opportunities. A few studies have investigated changes in the epibenthic community on armored habitats vs. natural habitats. Armored habitats have been found to provide suitable habitat for some forms of epibenthos that are known prey of juvenile salmonids; however, the ecological significance of different epibenthic communities to salmonids has not been studied. ▪ There have been no quantitative studies investigating the effects of shoreline armoring and associated shoreline steepening on the vulnerability of juvenile salmonids to predation. Existing data are qualitative, observational, or anecdotal (Heiser and Finn Jr. 1970; Pentec 1991). ▪ Long-term multi-estuary studies investigating residence time, survival, and growth in disturbed and undisturbed estuaries are needed to determine how highly modified environments affect salmonid populations.

Overwater Structures

Data Gaps

Studies conducted directly in Elliott Bay as well as other areas repeatedly verify that changes in the underwater light environment affect salmonid behavior and physiology. Table 47 shows the identified data gaps.

Table 47: Data gaps for overwater structures

Data Gaps – Overwater Structures
▪ Quantitative data are needed to determine the effects of overwater structures on migrating salmonids.
▪ Quantitative data are needed to determine the effects of overwater structures on predator-prey interactions, shifts in species composition, and physical dynamics of nearshore habitat.
▪ Quantitative and experimental data are needed to assess the risk to juvenile salmonids posed by:
▪ Delays in migration caused by disorientation
▪ Loss of schooling in refugia because fish schools disperse under low light conditions
▪ Changes of migratory route into deeper waters without refugia to avoid the light change
▪ Increases in losses to predators attracted to overwater structures.

Dredging

Data Gaps

Records of ACOE dredging in the Duwamish begin in 1928. No records of earlier dredging activities in the Duwamish were found.

Little is known about the cumulative effects of dredging on the nearshore ecosystem. Additional studies are needed to determine the short-term and long-term impacts to multiple species and ecosystem functions at dredging and disposal sites.

Filling

Data Gaps

The extensive filling of the Lower Duwamish River and Elliott Bay has undoubtedly had a dramatic impact on ecosystem processes, structure, and functions. Yet, there have been few studies that have attempted to quantify lost functions and the resultant impacts on aquatic resources.

Sewage Discharges

Data Gaps

Although numerous sediment and water quality investigations have been conducted in the Duwamish Estuary, some data gaps remain. Table 48 shows the identified data gaps.

Table 48: Data gaps for sewage discharges

Data Gaps – Sewage Discharges
▪ There is a lack of water and sediment monitoring data for nearshore habitats—most studies are conducted in deeper water, farther offshore. ▪ The CSO Water Quality Assessment conducted by Parametrix and King County DNR uses a water quality assessment model that could be further refined and validated by implementing a sampling program to verify the model's prediction of sediment transport and chemical concentrations. ▪ Additional studies are needed to determine the contaminant levels and impacts of acute stormwater discharges in the Duwamish and other industrialized drainages

Sediment Contamination

Data Gaps

Numerous sediment investigations have been conducted in the Duwamish Estuary and Elliott Bay; the areal distribution of surficial sediment contamination in the nearshore study area is relatively well known. Table 49 shows several data gaps that have been identified.

Table 49: Data gaps for sediment contamination

Data Gaps – Sediment Contamination
▪ Sediment contamination farther out into Elliott Bay is not as well characterized as in the nearshore. Although juvenile salmonids are less likely to contact these deeper sediments, studies have shown physiological impacts to flatfish associated with highly contaminated areas. ▪ The rate and role of natural attenuation is not well understood in the estuary and bay. Given recent reductions in contaminant inputs, it is not clear whether, or to what degree, natural burial and attenuation is reducing contaminant concentrations over time. ▪ Sediment contamination in the subsurface is not as well characterized as in surface sediments. Understanding the degree of subsurface contamination and the potential for it to become biologically unavailable is important when evaluating dredging and natural attenuation remedial options. ▪ The relationship between observed sublethal biological effects and the survival of fish, such as juvenile salmon and demersal resident marine fish, is largely unknown. Biochemical effects and physiological effects have been associated with contaminated areas, but whether this reduces growth or survival or affects behavior is not clear. As evidence, despite the documented levels of contamination along the Duwamish Estuary, hatchery chinook salmon released to the Green River by the Washington Department of Fish and Wildlife (WDFW) have a high fry-to-adult survival rate compared to other hatchery stocks released to cleaner areas of Puget Sound.

Key Findings

<u>Shoreline Armoring</u>

- Nearly 100 percent of the shoreline of the Duwamish Estuary is modified by riprap, steep mud banks, levees, or bulkheads.
- Seawalls with riprap toes, in conjunction with overwater structures, are present along much of the Elliott Bay waterfront. Seawalls are also present along about half of the sandy beach habitats along Alki Beach.
- The most substantial unarmored area in the study area is about 3,870 linear ft situated along Magnolia Bluff adjacent to Discovery Park.
- Very few studies have evaluated the effects of armoring on fish and other aquatic resources in the study area.

Elliott Bay

<u>Data Gaps</u>

Although several studies have examined the effects of changes in sediment dynamics on Elliott Bay and the Duwamish, numerous data gaps remain. Table 50 lists these data gaps.

Table 50: Data gaps for sediment dynamics

Data Gaps – Sediment Dynamics
▪ A comparison of the volume of silt, clays, and sands that currently are transported through the Howard Hansen Dam to sediment loading of these materials prior to the dam's inception would be useful. ▪ More definitive studies that address sediment transport from Elliott Bay to the Turning Basin in the Duwamish River are needed. ▪ Studies that address the impact of dredging activities on sediment transport from Elliott Bay to the Duwamish River are lacking. ▪ Calculation of sediment budget to determine if Duwamish River estuary habitats are stable or threatened by the loss of sediment supply.

Key Findings

<u>Duwamish River</u>

Dramatic alterations to flooding, stream flow, channel form, and sediment supply have significantly altered the sediment dynamics of the Duwamish River in ways that will continue to have long-term effects on its evolution. Large floods were primarily responsible for transporting and depositing large woody debris and sediments that regularly changed the configurations of the main active channel, side channels, and sloughs as well as providing abundant habitat for a variety of fish and wildlife. Today, the largest floods are a fraction of historical volumes and are allowed to occur only during the wettest time of the year (December through February). In conclusion:

- The sum total of these activities have resulted in a highly controlled river that has effectively eliminated the Duwamish River's ability to form and maintain channel complexity, such as lateral migration of the main channel, side channel and slough formation, and delta formation.
- Howard Hansen Dam has undoubtedly affected flooding in the Duwamish River, however its impact to sediment loading (silts, clays, sands) is largely unknown.
- There remains a question of how much contaminant transport occurs in the Duwamish River resulting from the tidal pumping of sediments landward. The assumption presented by ACOE (1997 p.36) implicates dredging practices for allowing the tide to migrate farther upstream than it had prior to channelization and dredging. This assumption may have some validity considering the potential combined effects of deepening the channel, reducing the watershed area by 70 percent, and reducing the freshwater discharge by 70 percent (ACOE 1997). Reducing the mean annual flow may have compromised the stream's ability to resist upstream migration of the high tides for greater time periods. Dredging the channel lowers the elevation of the channel bottom, which also makes it more accessible to a wider range of tides.
- The materials that compose the streambed may contain a greater concentration of sediments from Elliott Bay over a larger stretch of the Duwamish River if: (1) GeoSea Consulting's (1994) assertion is correct in that tidal activity dominates sediment deposition in the Duwamish Waterway; and (2) tidal activity is occurring farther upstream than it had previously.
- More conclusive studies are required in order to show: (1) if sediment transport occurs from Elliott Bay to the Duwamish River; (2) if and to what extent dredging operations increase sediment transport from Elliott Bay to the Duwamish River; and (3) the spatial distribution of marine sediment deposition and riverine deposition.

<u>Elliott Bay</u>

- Two drift cells are present along the shore of Elliott Bay—one cell along the shore of Magnolia Bluff and another segment of a drift cell between Alki Point and Duwamish Head.
- Net shore drift along the southwest shore of Magnolia Bluff is dominated by westerly drift converging with shore drift from the northwest side of the bluff, forming a cuspate spit at West Point. The origin of the southwest Magnolia drift cell is immediately west of the Elliott Bay Marina.
- Net shore drift between Alki Point and Duwamish Head is also dominated by a westerly drift that begins well south of Elliott Bay near Burien. Sediments reaching the south shore of Alki Point are transported west and north around the point.
- Most of the Elliott Bay waterfront between Pier 91 and Duwamish Head has no appreciable net shore drift because of shoreline development. Water depth and the obstruction of piers precludes any significant longshore transport. At present, the only source of sediment for shore drift is erosion of undefended fill material.

Salmonid Distribution and Use

Data Gaps

Numerous studies have been conducted on salmonid use in the Duwamish Estuary, Elliott Bay, and other areas of Puget Sound. Much is understood regarding the general migratory behavior, timing, distribution, and feeding habits of juvenile salmonids, but key questions remain, particularly with regard to restoration issues and optimal habitats and the quantitative effects of degraded habitats. The following data gaps are summarized in Table 54:

Table 54 Data gaps for salmonids

▪ **Data Gaps – Salmonids**
▪ Most estuarine and nearshore habitat studies have been conducted in developed areas; relatively little information has been collected in less- or non-degraded habitats. The responses of juvenile salmonids in developed areas may not be representative of natural estuaries. There is a need to study and document juvenile salmonid behavior in undisturbed areas to establish a baseline. ▪ There is a lack of quantitative sampling data for juvenile salmonids' use of nearshore and open beach habitats around Elliott Bay. ▪ Juvenile salmonids grow rapidly, but there are no data on possible food limitations in the Duwamish Estuary and Elliott Bay, nor comparison data from undisturbed estuaries and bays (i.e., on the growth potential of these fish in the absence of the high degree of habitat disturbance evident in the area). ▪ More data are needed regarding predation on juvenile salmonids in the estuary and the effects of highly modified habitats on survival. The interactions between overwater structures and shoreline hardening and salmonid predation rates are not known. Habitat modifications that increase predation, or which offer a greater degree of protection and refuge, have not been well studied. A better understanding of physical separation that may or may not exist between juvenile salmonids and their predators is needed. ▪ The role of shoreline armoring and other upland development practices, such as modifying riparian zones, on juvenile salmonids is poorly understood. ▪ Additional information is needed on the presence and habitat utilization of native char. ▪ There is also a need for the long-term collection of quantitative data on residence time and condition indices, and the same from relatively undisturbed estuaries. These data, collected annually, would provide the necessary baselines to better evaluate future development projects for their impacts on juvenile salmon habitats, and would guide the selection and construction of restoration sites in the estuary. ▪ The long-term effects of bioaccumulation and toxicological pathways through the food chain have not been assessed. ▪ Estuarine carrying capacity for the Duwamish and Elliott Bay need to be addressed. There is a lack of quantified information on habitat carrying capacity for juvenile salmonids.

Key Findings

- Eight species of anadromous salmonids use the Duwamish Estuary, Green River, and Elliott Bay. Chinook and coho salmon and steelhead are common, while pink and sockeye salmon, sea-run cutthroat trout, and bull trout are much less common.. Small runs of chum salmon also occur, with larger runs in recent years.
- Juvenile chinook and chum salmon are highly dependent on estuarine habitats, as evidenced by studies of residence time, diets, and behavior. During their downstream migration, these species enter the estuary during the late winter/early spring and most individuals appear to spend 1 to 2 weeks in the estuary before entering Elliott Bay. They are, however, likely to be present in the estuary during at least eight months of the year. Less is known about residence times in the bay, but most have left the bay by the end of summer. The other salmonids are less abundant and do not appear as estuarine dependent as chinook or chum salmon.
- All of the juvenile salmonids in the estuary have been found to feed on gammarid amphipods, dipteran insects, and harpacticoid copepods.
- Adult chinook and coho salmon runs in the Green River appear stable, with larger runs over the past 15 years compared to earlier years. Chum salmon runs have historically been small in the Green River, but over the past 3 years larger runs exceeding 10,000 fish have been observed. In contrast, winter steelhead runs have shown a steady decline over the past 30 years. Appreciable pink and sockeye salmon runs do not occur in the Green River.
- Sea-run cutthroat trout are present in the Green River, but little is known about the species.
- Bull trout have been reported in the river, but are not believed to spawn in the basin.
- Historically, it is believed that spring and fall chinook, coho, sockeye, pink, and chum salmon; winter run steelhead, sea-run cutthroat, Dolly Varden char, and bull trout used the basin.
- Changes in species composition and abundance can be linked to the development of the estuary. The substantial elimination of sockeye and spring chinook salmon runs are likely linked to the diversion of the Black and White Rivers early in the century. The substantial elimination of pink salmon may be due to diversions or channel armoring in the lower river.
- There is a general lack of sufficient ecological data to quantify the role of estuaries in the development and survival of juvenile salmonids. Many distributional studies have been conducted, but the links between habitat use, growth and survival, and armoring, industrial development, and other alterations to habitat and ecosystem processes and functions are limited in terms of ecosystem modeling and scientific monitoring.

Other Fin-Fish Distribution and Use

Data Gaps

Although the Duwamish Estuary and Elliott Bay have been fairly well studied, the focus has been on salmonid use as juveniles, and adult salmonid stock assessment. Gear types most effective at sampling non-salmonids (i.e., bottom and mid-water trawls, purse seines) have not been used in recent studies. Several data gaps regarding other fin fish species are apparent and identified in Table 57:

Table 57: Data gaps for other fin-fish species

Data Gaps – Other Fin-fish Species
▪ Stock assessments of demersal fish species are needed. Very little is known regarding the populations and movements of demersal species, particularly those candidates for ESA listing. Interactions of fish populations with oceanographic conditions, such as long-term temperature regimes and interactions with predators, are not clear. ▪ Existing data sets for demersal fish species have been collected by WDFW and the University of Washington, but have not been fully analyzed or published. The Muckleshoot Indian Tribe has not analyzed extensive beach seining data from 1995. ▪ Stock assessment of important forage fishes such as surf smelt and sand lance are lacking. Beach spawning habitats in the study area are not fully known and it is unclear whether discrete spawning populations exist or use specific beach habitats. ▪ An assessment of toxicological pathways through the food chain is needed.

<u>Key Findings</u>

- Non-anadromous fish species documented within the Duwamish Estuary are dominated by estuarine and marine species, with only a few freshwater species. Thirty-three species were observed in a recent survey dominated by shiner perch, staghorn sculpin, starry flounder, sand lance, and prickleback.
- In contrast, the fish assemblage in Elliott Bay is much larger; fish surveys have documented about 80 species. Dominant species include English and rock sole, Pacific tomcod, shiner and striped seaperch, tubesnout, and ratfish.
- The highest abundance and species richness occurs during the summer and fall with the lowest during the late winter and early spring.
- Studies have found striking increases in abundance and species richness in fish assemblages associated with eelgrass compared to sand substrates.

Shellfish Distribution

<u>Data Gaps</u>

Shellfish populations in Elliott Bay are presently not harvested because of high fecal coliform counts and industrial effluent inputs. However, the ability of shellfish to improve water quality by removing pollutants from the water column is unknown. The effects of this bioaccumulation on shellfish and other species are also unknown.

<u>Key Findings</u>

Limited data suggests that over 400 acres of suitable geoduck habitat may exist in Elliott Bay, which could support over 700,000 clams.