8. SELECTED FISHES

8. SELECTED FISHES

In this section we summarize existing information on selected nearshore fish species, including distribution, habitat utilization and stressors, within WRIAs 8 and 9 nearshore boundaries. We focus on WDFW species of concern, which have been subdivided into salmonids, forage fish, groundfish, and rockfish (Table 21).

In WRIAs 8 and 9, most fish populations are at all-time lows (Palsson et al. 1996). Some are listed for protection under the Endangered Species Act or are candidates for protection. This decline can be attributed to changes in environmental conditions caused by known stressors to fish. These stressors include overfishing, shoreline development, loss of estuarine habitat, alteration of freshwater flows, blockages to migration corridors, changes in temperature, industrial pollution, and decreased prey availability..

Numerous data gaps exist in our understanding of nearshore fishes, making it difficult to thoroughly assess them. Information about the historical distribution/abundance is lacking, and the cumulative effects of stressors are unknown. Details about how nearshore fish use their prey, how long they stay in the nearshore, and what their migration and movements might be are also unknown.

Table 21: Common and Scientific Names of WDFW Priority Fish Species

Common Name	Scientific Name
Salmonids	
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Sockeye salmon	*Oncorhynchus nerka*
Pink salmon	*Oncorhynchus gorbuscha*
Cutthroat trout	*Oncorhynchus clarki*
Steelhead	*Oncorhynchus mykiss*
Bull trout	*Salvelinus confluentus*
Forage fish	
Pacific Herring	*Clupea harengus pallasi*
Surf Smelt	*Hypomesus pretiosus*
Eulachon	*Thaleichthys pacificus*
Longfin smelt	*Spirinchus thaleichthys*
Pacific Sand Lance	*Ammodytes hexapterus*
Groundfish	
Pacific Cod	*Gadus macrocephalus*
Walleye Pollock	*Theragra chalcogramma*

Common Name	Scientific Name
Pacific Hake	*Merluccius productus*
Lingcod	*Ophiodon elongatus*
English Sole	*Pleuronectes vetulus*
Rock Sole	*Lepidopsetta bilineata*
Rockfish	
Black Rockfish	*Sebastes melanops*
Blue Rockfish	*Sebastes mystinus*
Bocaccio Rockfish	*Sebastes paucispinus*
Brown Rockfish	*Sebastes auriculatus*
Canary Rockfish	*Sebastes pinniger*
China Rockfish	*Sebastes nebulosus*
Copper Rockfish	*Sebastes caurinus*
Greenstriped Rockfish	*Sebastes elongates*
Quillback Rockfish	*Sebastes maliger*
Redstripe Rockfish	*Sebastes proriger*
Tiger Rockfish	*Sebastes nigrocinctus*
Widow Rockfish	*Sebastes entomelus*
Yelloweye Rockfish	*Sebastes ruberrimus*
Yellowtail Rockfish	*Sebastes flavidus*

Adapted from: http://www.wa.gov/wdfw/hab/phsvert.htm#fish (May 1, 2001)

SALMONIDS

The importance of estuarine and nearshore marine habitats for salmon and trout cannot be overemphasized. Salmonids (family Salmonidae) are an ecologically, economically, and culturally prominent group of fishes in the Pacific Northwest. They are the focus of many regional research, management, and conservation efforts. Salmonids use the nearshore for physiological transition (adaptation from freshwater to saltwater), for migration, as nursery areas, for juvenile and adult food production and feeding, and as residence and refuge. Use by salmonids and duration in the nearshore varies greatly by species

Eight species of native salmonids use the nearshore environments of WRIAs 8 and 9, including chinook, chum, coho, sockeye, and pink salmon, and cutthroat, steelhead, and bull trout. All species have anadromous forms, with most species undertaking extensive ocean migrations before returning to spawn in their natal stream. The different species of Pacific salmon have diverse life-history types, taking advantage of the environmental variability of the landscapes and seascapes they occupy over time. The variable life-history characteristics are assumed to be the result of evolution across large oceanic and coastal geographic regions for perhaps several million years. As a result, salmonids have evolved complex life-history patterns that sustain viable populations over a broad spectrum of ecosystem change at varying temporal and spatial scales (Wissmar and Simenstad 1998).

From a fishery management perspective, salmon species can be grouped into stocks, defined as a group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. A population of fish may include a single stock or a mixture of stocks. Under the Endangered Species Act (ESA), stocks of salmonids may be grouped as Distinct Population Segments (DPSs), as is the case for bull trout under jurisdiction of the United States Fish and Wildlife Service (USFWS). Stocks may also belong to Evolutionarily Significant Units (ESUs), as is the case for the five species of Pacific salmon under the jurisdiction of the National Marine Fisheries Service (NMFS). An ESU is a population (or group of populations) that is reproductively isolated from other population units, or represents an important component in the evolutionary legacy of the species. Many salmonid stocks are in serious decline. Chinook salmon (within the Puget Sound ESU), summer-run chum salmon (within the Hood Canal), and bull trout (within the Coastal-Puget Sound DPS) have been listed as threatened under the ESA. Coho salmon (within the Puget Sound/Strait of Georgia ESU) is a candidate species for listing.

Contributing to many of the declines in salmonid populations are urbanization and anthropogenic activities in nearshore marine and estuarine habitats. More than 70 percent of Puget Sound's coastal wetlands/estuaries have been lost to urbanization, port development, industrial use, dredging and filling, and agricultural development (PSWQAT 1999). In addition, the degradation or loss of shallow vegetated habitats may have altered migration corridors for all species.

Salmonid Use of the Nearshore Environment

The saltwater habitats used by anadromous salmonids in WRIAs 8 and 9 provide a critical component of their life histories (Simenstad 1983; Simenstad et al. 1991; Thom 1987). All anadromous salmonids use nearshore and estuarine habitats during adult spawning migrations and for juvenile migration and rearing to some extent (Figure 18), but chinook, chum, pink, and cutthroat use these habitats more than others do. In fact, ocean-type chinook originating in WRIAs 8 and 9 are the most estuarine-dependent salmonid in the scope of this report, with chum as second.

A substantial number of young salmon enter and pass through estuaries and the nearshore environment between early March and late June. These dates vary substantially depending on the species, location, and inter-annual differences. For example, recent beach seining studies found juvenile salmonids in the WRIA 8 and 9 nearshore through August (King County unpublished data). Depending on the species and life stage (fry or smolt), there is also wide variability in the duration of occurrence in the nearshore (Weitkamp 2000). Fry and juvenile salmonids enter estuaries primarily at night (MacDonald 1960; Davis 1981).

Estuaries provide a wide variety of habitat characteristics. Juvenile salmonids are present in many different estuaries with a diverse range of biological and physical conditions. This is an indication that juvenile salmonids are adaptable to a wide range of habitats. It is important to distinguish, however, where salmonids <u>occur</u> in nearshore environments versus those habitat features upon which they are dependent upon it for a fundamental function/period of their life history. Juvenile salmonids use both constructed and natural habitats that appear to be meeting their needs. The extent to which constructed habitat characteristics can be modified and critical natural habitat can be preserved to better meet salmonid needs remains difficult to determine. An excellent literature review of the roles that a variety of estuarine habitats provide for many species of juvenile salmon is summarized in Weitkamp (2000).

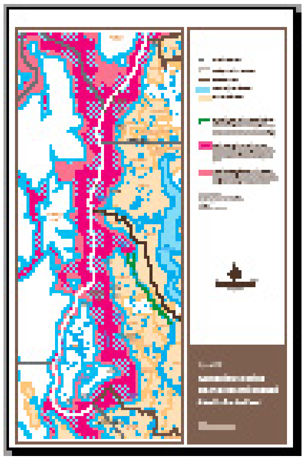
Some juvenile salmonids are widely distributed in nearshore waters while others are strongly shoreline oriented. Different species may behave similarly in many situations. Many investigations show two or more species together in the same habitat. Each species, however, exhibits tendencies that separate it from others to some degree. Smaller fish tend to use shallower water than larger fish (MacDonald et al. 1986). Chinook, chum, and pink salmon are found within 2 to 3 meters of the water's surface (MacDonald et al. 1987), and can be either along shallow shorelines or over deeper water along the face of piers or naturally steep shorelines (Kask and Parker 1972). Migratory behavior is very size-structured and most juvenile salmon <55-65 mm FL preferentially select shallow water unless they have no option, such as when confronted with a pier apron or docks. Larger fish are much less confined to shallow water. An excellent review of this is found in Simenstad, et al.(1999).

Young salmon tend to resist large changes in light intensity during migration. Changes to ambient underwater light environments pose a risk of altering fish migration behavior and increasing mortality risks (Nightingale and Simenstad). Studies in the Puget Sound region have suggested that shade-induced light changes could result in the following behavioral changes: (1) migration delays due to disorientation; (2) loss of schooling in refugia due to fish school dispersal under light-limited conditions; and (3) increased size-selective predation risk due to changes in migratory routes to deeper waters to avoid light changes (Nightingale and Simenstad 2001).

While in the nearshore, salmonids, as a group, prey on an array of benthic, epibenthic, and pelagic organisms. The prey species vary depending on the estuarine or nearshore habitat type and the size and species of the fish. Irrespective of the variation in quantity, quality, and timing of organic matter contributing to the food web, evidence indicates that individual stocks and life history stages of juvenile salmonids focus their foraging on certain types, species and life history stages of prey taxa. There is evidence that the densities of certain prey taxa play an important role in determining residence time and growth of salmonid stocks (Wissmar and Simenstad 1998, and Simenstad et al. 1982).

Returning adult salmon and some resident stocks (cutthroat and bull trout) use nearshore habitats as foraging areas where they feed on baitfish (forage fish) such as Pacific herring (*Clupea harengus pallasi*), surf smelt (*Hypomesus pretiosus*), and sand lance (*Ammodytes hexapterus*) (Penttila 1995; Brodeur 1990; Fresh et al. 1981). Adult salmon may delay their entry into freshwater or into terminal spawning areas at the end of the marine phase of their life cycle, milling within estuary and nearshore habitats for up to 21 days (Johnson et al. 1997).

Figure 18 Salmonid Use of the Nearshore Environment



Click here to view figure

A number of references provide extensive descriptions of salmon life history and ecology (National Research Council 1996; Pearce et al. 1982; Emmett et al. 1991), which we do not attempt to summarize here.

Current Distribution and Use in WRIAs 8 and 9

Table 22 summarizes juvenile and adult nearshore distribution and use within WRIAs 8 and 9 for each species.

Table 22: Salmonids: Summary of nearshore and estuarine habitat use

Species	Scientific	Nearshore Use			Freshwater Use			
	Name	Juvenile Rearing and Migration	Adult Migration	Adult Residence	WRIA 8 Spawn	WRIA 8 Stray	WRIA 9 Spawn	WRIA 9 Stray
Chinook	*Oncorhynchus tshawytscha*	●	●	❍	●	⊕	●	⊕
Chum	*Oncorhynchus keta*	●	●	❍	❍	❍	●	⊕
Coho	*Oncorhynchus kisutch*	⊕	●	❍	●	⊕	●	⊕
Sockeye	*Oncorhynchus nerka*	⊕	●	❍	●	⊕	❍	❍
Pink	*Oncorhynchus gorbuscha*	●	●	❍	❍	❍	⊕	⊕
Cutthroat	*Oncorhynchus clarki*	●	●	●	●	❍	●	❍
Steelhead	*Oncorhynchus mykiss*	⊕	●	❍	●	❍	●	❍
Bull Trout	*Salvelinus confluentus*	⊕	●	⊕	●	❍	●	❍

Notes: Filled circles represent extensive use of estuarine and/or marine nearshore habitat. Open circles indicate little use or use not known in these areas. Cross-filled circles represent some use.

Chinook Salmon (Oncorhynchus tshawytscha)

Chinook salmon are found in most of the rivers in the Puget Sound region. WDFW et al. (1992) recognizes 27 distinct stocks of chinook salmon: 8 spring-run, 4 summer-run, and 15 summer/fall-run stocks. Most regional adult chinook salmon return to these rivers to spawn in the fall (summer/fall-run fish) and will be found in most nearshore marine waters and estuaries of WRIA 8 and 9 at this time. Recent mean spawning escapement estimates correspond to a run entering Puget Sound of approximately 160,000 fish (Myers et al. 1998).

Juveniles

Juvenile chinook have several life-history patterns for emigration from river to ocean. Wissmar and Simenstad (1998) cite at least 36 distinct life history pathways. Ocean-type juveniles migrate seaward either soon after yolk resorption (30-45 mm), as fry 60-150 days after hatching, or as fingerlings in the late summer or fall of their first year. Stream-type chinook salmon migrate during their second or, more rarely, third spring (Myers et al. 1998). Of the two, ocean-type chinook salmon predominate in coastal regions, including Puget Sound, and use estuaries and coastal areas more extensively for juvenile rearing (Levy and Northcote 1982; Pearce et al. 1982). Juveniles may reside up to 189 days in estuarine habitats (Wallace and Collins 1997; Levy and Northcote 1982). There are no published data on residence times in nearshore areas. Juveniles migrate along the shorelines of estuaries and the nearshore zone, where they are known to feed and rear. Preliminary results from 1999 sampling on the seaward side of the Lake Washington Ship Canal indicate that juvenile chinook salmon fry were the most abundant salmon species present from June through August (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resource Division 2000). Recent data indicate that juvenile chinook are in the nearshore from late January/early February through September, and it is possible that they may be found in the nearshore year-round. Collections with beach seines suggest that juvenile chinook are oriented to shallow water habitats located close to shore, and are most abundant in intertidal flats and shallow subtidal channels near estuarine and tidal marshes and eelgrass meadows. As opportunistic feeders, chinook juveniles prey on a diverse array of benthic, epibenthic, and pelagic organisms associated with these highly productive, detritus-rich habitats (Fresh et al. 1981). Important prey include harpacticoid copepods, gammarid amphipods, aquatic insect larvae and adults, *Daphnia*, *Neomysis* (Simenstad and Cordell 2000), and terrestrial insects (Fresh et al. 1981; Cordell et al. 1999a,b). Brackish water areas in estuaries also are important for moderating physiological stress during parr-smolt transition (Myers et al. 1998).

Adults

All chinook in the Puget Sound region exhibit an ocean-type lifestyle and tend to have coastal-oriented ocean migration patterns. In addition to ocean migrating populations, Puget Sound has resident populations of chinook salmon, referred to as “blackmouth” salmon. Puget Sound chinook are almost entirely piscivorous, with Pacific herring making up a major portion (60 percent biomass) of the diet, and gadids (codfishes), Pacific sand lance, anchovies, and shiner perch comprising the remainder (Fresh et al. 1981).

Historical Distribution and Use

Overall, the abundance of chinook salmon in the Puget Sound ESU has declined substantially, and both long- and short-term abundance trends are predominantly downward (Myers et al. 1998). The peak recorded harvest in Puget Sound occurred in 1908 and corresponded to a run-size of approximately 690,000 chinook salmon (Myers et al. 1998).

WRIA 8 – A compilation of distribution data for Puget Sound fishes through 1973 documented shapshots of observations of chinook salmon within most nearshore areas of WRIA 8 (Miller and Borton 1980). Many of these records were clustered around Edwards Point and Point Wells (reach 2) and in Shilshole Bay (reach 3) at the mouth of the ship canal into Lake

Washington. Within these snapshot observations, chinook salmon (presumably juveniles) were considered rare to common (23 fish total) in monthly beach seine collections made off West Point in 1975 (Miller et al. 1976). (Note: Caution should be used in considering qualitative language, such as abundant or rare, discussed in these studies because these terms may misrepresent species distribution and abundance if sampling methodology was not designed to sample for certain species in a variety of habitats during appropriate times.)

WRIA 9 – A compilation of distribution data for Puget Sound fishes through 1973 documented shapshots of observations of chinook salmon within most nearshore areas of WRIA 9 (Miller and Borton 1980). Most of these records were clustered in Elliott Bay (reach 4) and along the entire western shoreline of Vashon Island (reach 12). Chinook salmon (presumably juveniles) were considered rare in monthly beach seine collections made off Alki Point (reach 4; 15 fish total) and Three Tree Point (reach 8; 13 fish total) in 1975 (Miller et al. 1976).

Chum Salmon (Oncorhynchus keta)

Chum salmon stocks in the Puget Sound region are characterized by much diversity in life history. WDFW et al. (1992) recognizes 38 distinct stocks of chum salmon in the Puget Sound region, 23 of which were considered to have increasing escapement trends (Johnson and Summers 1999). The recent average chum salmon harvest from Puget Sound (1988-1992) was 1.185 million fish, suggesting a total abundance of about 1.5 million adult chum salmon. Increasing harvest, coupled with generally increasing trends in spawning escapement, provides evidence that chum salmon are abundant and have been increasing in abundance in recent years within this ESU (Johnson et al. 1997). However, chum salmon in the Hood Canal ESU are listed as threatened under ESA.

Juveniles

Chum salmon fry migrate seaward almost immediately after hatching, and enter the estuary at a relatively small size (30-55 mm). The migration period in Washington estuaries is between January and July, with a peak from March to May. Juvenile chum salmon depend on estuarine and nearshore habitats for rearing, and usually have longer residence times (from days to three months) in estuaries than other anadromous salmonids besides chinook (Pearce et al. 1982; Johnson et al. 1997). Estuarine survival may largely depend on timing of entry into saltwater because of the strong seasonality of epibenthic prey and plankton in estuaries (Johnson et al. 1997). Food web linkages at this stage have been presumed to be detritus based, but may also include some epibenthic primary production organisms (i.e., diatoms) (Sibert 1979). Small (50-60 mm) chum salmon juveniles feed primarily on epibenthic harpacticoid copepods, gammarid amphipods, and aquatic insect larvae such as chironomids, whereas larger juveniles (>50-60 mm FL) in neritic habitats feed on drift insects and on such plankton as calanoid copepods, larvaceans, and hyperiid amphipods (Fresh et al. 1981; Simenstad et al. 1982; Simenstad and Cordell 2000). During this time, chum salmon tend to remain in shallow estuarine channels or other productive areas near estuarine and tidal marshes, eelgrass meadows, and over tideflats (Sibert et al. 1977). Estuarine growth is rapid (3.5-10 percent/day) and greatly influences the survival and migration timing of juvenile chum salmon (Sibert et al. 1977). In late spring to early summer, chum salmon juveniles move offshore as they reach a size that allows them to feed on the larger neritic plankton, and this movement normally occurs as inshore prey resources decline (Simenstad et al. 1982).

For juvenile chum salmon, the period of peak abundance in WRIAs 8 and 9 nearshore and estuarine habitats is generally between March and April; many of these fish are likely from stocks in southern Puget Sound.

Adults

Most chum salmon in Washington are classified as fall-run fish, generally returning to their natal streams from October to November, where they spawn in the lowermost reaches of rivers and streams. They will be found in nearshore marine waters and estuaries of WRIAs 8 and 9 at this time. Adult chum salmon may delay their entry into freshwater or into terminal spawning areas at the end of the marine phase of their lifecycle, milling within estuary and nearshore habitats for up to 21 days. Some chum stocks do not appear to migrate and may remain in Puget Sound (Johnson et al. 1997).

Historical Distribution and Use

WRIA 8 – A compilation of distribution data for Puget Sound fishes through 1973 documented shapshots of observations of chum salmon within several nearshore areas of WRIA 8 (Miller and Borton 1980). Many of these sightings were clustered just north of Edwards Point (reach 1), near Meadow Point, off Golden Gardens beach (reach 2), and in Shilshole Bay at the mouth of the ship canal into Lake Washington (reach 3). Juvenile chum salmon were rare to common (91 fish total) in monthly beach seine collections made off West Point in 1975 (Miller et al. 1976).

WRIA 9 – A compilation of distribution data for Puget Sound fishes through 1973 documented shapshots of observations of chum salmon within most nearshore areas of WRIA 9 (Miller and Borton 1980). Most of these records were clustered around West Point and in Elliott Bay at the mouth of the Duwamish River (reach 4), along the northeastern shore of Vashon Island (reach 9), and along the entire Colvos Passage (reach 12). Juvenile chum salmon occurred frequently in spring and summer beach seines made near Seahurst Bay (reach 7; 0.5 to 4 fish/haul), Saltwater State Park (reach 8, 1 to 2.5 fish/haul), Point Vashon (0.5 to 8 fish/haul), and north of Point Robinson (1.5 to 12.5 fish/haul) on eastern Vashon Island (reach 9) (Donnelly et al. 1984). Chum salmon (presumably juveniles) were rare in monthly beach seine collections made off Alki Point (reach 4, 41 fish total) and Three Tree Point (reach 8; 35 fish total) in 1975 (Miller et al. 1976). For additional information on historic Elliott Bay chum salmon distribution and use, see Section 11.

Coho Salmon (Oncorhynchus kisutch)

While some assessments have shown that current Puget Sound coho populations are near historical levels, none of the stocks classified as healthy is strictly of native origin. The coho Puget Sound/Strait of Georgia ESU is currently a candidate species for listing under the ESA (Weitkamp et al. 1995). In the Cedar-Sammamish River watershed (WRIA 8) annual run sizes of coho salmon have declined annually by 2.74 percent from 1965-1993 (Weitkamp et al. 1995). A mixed stock of hatchery wild fish from the Lake Washington and Sammamish River tributaries is considered depressed due to a short-term, severe decline in escapement. However, the coho run in the Sammamish system was strong enough to allow a sport fishery in 2000.

The Cedar River stock, which has wild production supplemented with some hatchery releases, is considered healthy (WDFW 1992). In the Green/Duwamish watershed (WRIA 9), WDFW et al. (1992) reported two stocks: one in the Green River/Soos Creek drainage and one in Newaukum Creek. The Green River/Soos Creek stock is considered healthy with mixed hatchery and wild production. The Newaukum Creek stock is considered depressed due to a short-term, severe decline in escapement.

Juveniles

Puget Sound coho salmon fry generally spend 18 months rearing in freshwater before migrating through the estuaries and into marine waters. It is assumed that they migrate through the estuary and nearshore zone rather rapidly. Smolt outmigration timing exhibits considerable interannual variation and can vary by several weeks to a month (Weitkamp et al. 1995). Coho smolts are much larger than chinook and chum juveniles in nearshore areas and it is thought they prefer deep, marine-influenced habitats (Emmett et al. 1991). However, they are often caught in beach seines over intertidal and pelagic habitats in estuaries and over shallow habitats such as eelgrass meadows and tideflats. Coho are less dependent on benthic/epibenthic habitats, as evidenced by fewer cases of diet dominated by taxa such as gammarid amphipods (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000). Fresh et al. (1981) found decapod larvae (over 30 percent of the prey biomass), herring, amphipods, and polychaetes in diets of juvenile coho collected in sublittoral habitats.

Adults

Coho salmon spawn in Puget Sound tributaries in winter. Up to 5 percent of the wild coho of Puget Sound may reach maturity within the Strait of Juan de Fuca (Weitkamp et al. 1995). Food web linkages for adult Puget Sound coho salmon are similar to those for chinook, with larger fish feeding on herring and other forage fish (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000).

Historical Distribution and Use

Catches of coho salmon in Puget Sound fisheries have substantially decreased from 1896 to the early 1940s, but this is largely attributed to the prohibition of some fishing practices targeting this species. Overall catch within Puget Sound has increased gradually since that time, but has not returned to earlier levels, possibly as a result of greater interceptions of coho salmon in ocean fisheries (Weitkamp et al. 1995). The size of coho salmon adults in Puget Sound/Strait of Georgia is declining at a much faster rate than in other areas. Coho salmon caught in in-river fisheries in Puget Sound decreased in weight by about 50 percent between 1972 and 1993, from average weights of approximately 4 kg to about 2 kg (Weitkamp et al. 1995).

WRIA 8 – A compilation of distribution data for Puget Sound fishes through 1973 documents shapshots of observations of coho salmon throughout the nearshore area of WRIA 8 (Miller and Borton 1980). Many of these observations were clustered around Edwards Point and northward (reach 1), near Meadow Point and off Golden Gardens beach (reach 2), and in Shilshole Bay at the mouth of the ship canal into Lake Washington (reach 3). Juvenile coho salmon were rare to common (165 fish total) in monthly beach seine collections made off West Point in 1975 (Miller et al. 1976).

WRIA 9 – A compilation of distribution data for Puget Sound fishes through 1973 documents shapshots of observations of coho salmon within much of the WRIA 9 nearshore area (Miller and Borton 1980). Most catch records were clustered around West Point, north Alki Point, and in Elliott Bay at the mouth of the Duwamish River (reach 4). Additional concentrations occurred in Seahurst Bay (reach 7), around Three Tree Point (reaches 7-8), Poverty Bay (reach 8), along the northeastern shore of Vashon Island (reach 9), and along the entire Colvos Passage (reach 12). Coho salmon (presumably juveniles) were rare in monthly beach seine collections made off Alki Point (reach 4, 3 fish total) and Three Tree Point (reach 8, 21 fish total) in 1975 (Miller et al. 1976). For additional information on historical Elliott Bay coho salmon distribution and use, see Section 11.

Sockeye Salmon (Oncorhynchus nerka)

Current abundance trends, estimated from historical harvest records, suggest fairly constant populations of sockeye salmon in this region (Gustafson et al. 1997). Sockeye spawn in Puget Sound watersheds from late September to late December, with small numbers of spawners present in the Cedar River into February (Gustafson et al. 1997). Three spawning populations of sockeye have been identified in WRIA 8 (WDFW 1992). The status of all of these introduced stocks is considered depressed due to long-term negative trends in escapement and freshwater survival. Some sockeye spawn in the WRIA 9 watershed, although it is unclear whether these are riverine forms or strays from other watersheds (J. Kerwin, WA Conservation Commission, pers. comm.).

Juveniles

In the Puget Sound area, sockeye smolts rear in lakes then outmigrate to the nearshore and open ocean under cover of darkness during the spring to early summer. Sockeye juveniles usually have a shorter residence time in estuaries and nearshore areas than other salmonids (Hart 1973; Emmett et al. 1991; Gustafson et al. 1997). In marine and estuarine waters, juvenile sockeye feed near the surface on fish larvae, juvenile shrimp, insects, amphipods, mysids, and euphausiids (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000). Sockeye juveniles use the nearshore in WRIAs 8 and 9 as a migratory corridor (probably also for feeding and refuge). Recent King County data (unpublished), indicate that sockeye do occur in the nearshore. Sockeye were found in beach seines at Fauntleroy on June 5, 2000 (n=1) and at Seahurst Park on June 5, 2000 (n=3) and June 27, 2000 (n=1).

Adults

Adult sockeye are expected to be present in the nearshore and estuarine portions of WRIAs 8 and 9 during June through August (Gustafson et al. 1997) as they begin their freshwater spawning migrations.

Historical Distribution and Use

WRIA 8 – A compilation of distribution data for Puget Sound fishes through 1973 documents that sockeye salmon were found along much of the WRIA 8 nearshore, from Elliot Point (reach 1) south to West Point (reach 3) (Miller and Borton 1980). Most of these records are likely attributable to sockeye that migrate through Shilshole Bay (reach 3), up the ship canal, and into Lake Washington.

WRIA 9 – Few historical records have documented juvenile or adult sockeye salmon in WRIA 9 nearshore marine habitats south of West Point. Sockeye adults have been observed in river systems of WRIAs 10 and 11 (Williams, et al. 1975). There may have been a historical sockeye run into WRIA 12 that is extinct.

Pink Salmon (Oncorhynchus gorbuscha)

Of the 15 populations of pink salmon identified by WDFW et al. (1992) in Washington State, nine are classified as healthy, two as critical, two as depressed, and two as unknown. All runs are classified as wild production and most are of native origin. Most are odd-year populations. Hard et al. (1996) found no evidence of sustained recent declines in abundance for most pink salmon populations in Washington and southern British Columbia. Many populations appear to be healthy, with overall abundance close to historical levels. No major stocks of pink salmon currently originate from WRIA 8 or WRIA 9 streams (WDFW 1992), however pinks currently use some of the Green River system. Pinks from other WRIA systems, especially those to the south, use WRIA 8 and 9 nearshore environments during migrations.

Juveniles

Like chum, pink salmon fry migrate almost immediately downstream after emerging from gravel. In the Puget Sound region, this migration occurs primarily in March and April, and may extend into May (Hard et al. 1996). Juveniles in this region rear extensively in shallow marine waters and nearshore embayments, feeding on small crustaceans and growing rapidly. They spend little time in estuarine areas, but may be abundant in estuarine tidal channels for a short time (Emmett et al. 1991; Levy and Northcote 1982; Hard et al. 1996). After reaching 60-80 mm in length (generally by May to June), pink salmon move offshore, where they migrate at sea for 12 to 18 months. An exception to this pattern appears in some pink salmon from Puget Sound (and possibly Hood Canal) that may spend their entire marine phase in the nearshore environment (Hard et al. 1996).

Adults

Maturing fish returning to streams in southern Puget Sound arrive at terminal areas primarily between mid-July and mid-August (Hard et al. 1996). Most Washington pink salmon stocks are odd-year fish.

Historical Distribution and Use

Presumably resident pink salmon (based on their small size of 35-45 cm) supported a sport fishery in southern Puget Sound in odd years from the late 1940s until the early 1960s (Hard et al. 1996).

WRIA 8 – A compilation of distribution data for Puget Sound fishes through 1973 documents scattered observations of pink salmon throughout the nearshore area of WRIA 8 (Miller and Borton 1980). Several observations were clustered south of Elliot Point (reach 1), near Meadow Point, near Golden Gardens beach (reach 2), and in Shilshole Bay at the mouth of the ship canal into Lake Washington (reach 3).

WRIA 9 – Pinks historically used the Green River system (Williams et al. 1975) but were extirpated in the 1930s. A compilation of distribution data for Puget Sound fishes through 1973 documents spotty observations of pink salmon within WRIA 9 nearshore areas, with most records clustered within Poverty Bay (reach 8) (Miller and Borton 1980). For additional information on historical Elliott Bay pink salmon distribution and use, see Section 11.

Cutthroat Trout (Oncorhynchus clarki)

Few data exist concerning current abundance and distribution of coastal cutthroat trout in the Puget Sound ESU region, and WDFW considers the status of most Puget Sound and coastal Washington cutthroat trout runs unknown (Johnson and J. Summers 1999). Cutthroat populations do occur in a variety of drainages within WRIA 8 and 9, although little data are available on current distribution or stock status.

Juveniles

Coastal cutthroat trout generally enter marine waters after 2-4 years in the freshwater environment. Outmigration in Washington occurs from March to July, and peaks in May (Emmett et al. 1991). Seaward migration of smolts to more protected areas in Puget Sound occurs at an earlier age (at 2 years) and smaller size (approximately 160 mm) than migration to more exposed areas (i.e., the outer Washington coast) (Johnson et al. 1999). Cutthroat trout coastal migration is not well understood; they reportedly move moderate distances along the shoreline but do not cross large bodies of open water (Johnson et al. 1999). Juveniles and adults can be found over a variety of substrates within nearshore marine and estuarine waters during the summer. Juveniles and adult cutthroat trout are piscivorous and feed on northern anchovy, kelp greenling, scorpaenids, salmonids, euphausiids, mysids, and crab megalopae (Emmett et al. 1991).

Adults

Anadromous forms of adult cutthroat trout, known as sea-run coastal cutthroat, return to freshwater in the winter to feed, seek refuge, or spawn. In Washington, sea-run cutthroat trout follow two run timings: early returning cutthroat peak in large streams in September and October, and late returning cutthroat peak in smaller streams draining directly to saltwater during December and January (King County Department of Natural Resources and R2 Resource Consultants 2000). Anadromous cutthroat trout may move up rivers with daily tidal fluctuations to feed. Their ability to physiologically handle transitions between saltwater and freshwater during this life phase is unique to cutthroat. Repeat spawners (iteroparous) may spawn up to five times during their life and are critical to the reproductive success of the species because they produce larger, more numerous eggs (Kerwin, pers. comm.). They also provide for the exchange of genetic material between brood years. They rarely overwinter in saltwater and can be found in tidal freshwater areas of estuaries as they await favorable conditions to go upstream (Emmett et al. 1991; Johnson et al. 1999). Gravel beaches with overhanging upland vegetation and nearshore habitats (<10 ft deep) with large woody debris are often used during the marine phase for feeding and migration (King County Department of Natural Resources and R2 Resource Consultants 2000).

Historical Distribution and Use

Few data exist concerning historical abundance of adult coastal cutthroat trout in the Puget Sound ESU region. Coastal cutthroat trout harvest in the Puget Sound region was probably significant in the past, but direct and indirect fishing pressure on coastal cutthroat trout has declined (Johnson et al. 1999).

WRIA 8 – A compilation of distribution data for Puget Sound fishes through 1973 documents observations of cutthroat trout throughout the nearshore area of WRIA 8 (Miller and Borton 1980). All of these records are confined to nearshore habitats, with continuous distributions from Elliot Point (reach 1) south to Point Wells (reach 2), and several records off Golden Gardens (reach 2) and Shilshole Bay (reach 3).

WRIA 9 – A compilation of distribution data for Puget Sound fishes through 1973 documents observations of cutthroat trout within several nearshore concentrations in WRIA 9 (Miller and Borton 1980). Catch records were clustered in Elliott Bay at the mouth of the Duwamish River (reach 4), in Poverty Bay (reach 8), along the entire shoreline of Quartermaster Harbor on Vashon Island (reach 11), and in Colvos Passage along the northwestern shore of Vashon Island (reach 12). Cutthroat trout (age class unidentified) were rare (8 fish total) in monthly beach seine collections made near Three Tree Point (reach 8) in 1975 (Miller et al. 1976). For additional information on historic Elliott Bay cutthroat trout distribution and use, see Section 11.

Steelhead (Oncorhynchus mykiss)

WDFW et al. (1992) identified 53 stocks of steelhead within the Puget Sound ESU, of which 31 were considered to be of native origin and predominantly natural production. The total recent run size for major stocks in the Puget Sound ESU was greater than 45,000 fish, with a total natural escapement of about 22,000. Based on these numbers, Puget Sound populations of steelhead were determined not to warrant protection under the ESA at this time (Busby et al. 1996).

Juveniles

Juvenile steelhead spend from one to four years in freshwater followed by one to five years in the ocean before returning to freshwater to spawn. In the Puget Sound ESU, steelhead generally smolt at 2 years (Busby et al. 1996). In estuaries, juvenile steelhead feed on gammarid amphipods, small crustaceans, insects, aquatic worms, fish eggs, and small fishes. In marine waters, juvenile and adult steelhead eat fish, crustaceans, squid, herring, and insects (Emmett et al. 1991). Juveniles usually move to sea from April through June (Busby et al. 1996) and appear to spend little time in estuaries (Emmett et al. 1991).

Adults

Two races of steelhead exist; winter-run stocks migrate upstream during fall through early spring, while summer stocks migrate during spring through early fall. Within the Puget Sound ESU, steelhead populations are primarily of the winter variety, with several summer stocks (Busby et al. 1996). Steelhead spawn in the spring. They are repeat spawners (iteroparous), and may spawn up to five times during their lives. Adults are epipelagic and are found in coastal neritic waters to a depth of 25 m (Emmett et al. 1991).

A single stock of winter steelhead was identified by WDFW et al. (1992) in WRIA 8. This stock is sustained by wild production and is considered depressed based on chronically low spawner escapements. WDFW et al. (1992) reported two stocks of steelhead in WRIA 9. The summer run is a non-native stock sustained by a mixture of artificial and natural production, while the winter run is a native stock, also sustained by a mixture of artificial and natural production. Both are considered healthy.

Historical Distribution and Use

No estimates of historical (pre-1960s) steelhead abundance specific to the Puget Sound ESU are available (Busby et al. 1996). Total run size for Puget Sound in the early 1980s was calculated as approximately 100,000 winter steelhead and 20,000 summer steelhead. Up to 70 percent of steelhead in ocean runs (for Puget Sound and coastal Washington combined) were of hatchery origin (Busby et al. 1996).

WRIA 8 – A compilation of distribution data for Puget Sound fishes through 1973 documents several observations of steelhead in the WRIA 8 nearshore (Miller and Borton 1980). Most of these observations are spotty and confined to nearshore habitats, with records south of Elliot Point (reach 1) and off Golden Gardens (reach 2) and Shilshole Bay into the Lake Washington ship canal (reach 3).

WRIA 9 – Distribution data from Miller and Borton (1980) documented that the only records of steelhead in WRIA 9 were within Elliott Bay at the mouth of the Duwamish River (reach 4). Steelhead (age class unidentified) were also rare (1 fish total) in monthly beach seine collections made off Alki Point (reach 5) in 1975 (Miller et al. 1976). For additional information on historic Elliott Bay steelhead distribution and use, see Section 11.

Bull Trout (Salvelinus confluentus)

Two native species of char, bull trout (*Salvelinus confluentus*) and Dolly Varden (*Salvelinus malma*), are potentially present in WRIAs 8 and 9. However, the species composition of native char will remain uncertain until genetic analysis of native populations is completed (King County Department of Natural Resources and R2 Resource Consultants 2000). For this review, we include distribution information for both species, but focus on life history aspects of bull trout. Little is known of the distribution and abundance of bull trout in Puget Sound estuaries and nearshore waters. They have been documented in the WRIA 8 (upper Cedar River Watershed) and WRIA 9 in the lower Green River and Duwamish River (King County Department of Natural Resources and R2 Resource Consultants 2000). Few data exist for nearshore distribution or habitat use in nearshore and estuarine habitats of WRIAs 8 or 9. However, in August and September 2000, a total of 8 bull trout were captured at Turning Basin number 3 in the Lower Duwamish (Taylor Associates unpublished data). Native char have also been observed in Shilshole Bay and Salmon Bay, and migrating upstream and downstream at the Ballard Locks.

Juveniles

Fry emerge from the streambed in late winter to early spring and juveniles grow in the stream for two years or longer (King County Department of Natural Resources and R2 Resource Consultants 2000). Captures of subadults in the Duwamish were documented between 1994-2000, and within the Duwamish turning basin during the summer of 2000. Juveniles feed on insects, crustaceans, and small fishes. Anadromous char in the Snohomish system have been shown to overwinter in the lower river and in tidal freshwater areas with light to moderate currents and gravel/sand bottoms (J. Houghton, Pentec Environmental, unpublished data). The size range of these fish (257 to 420 mm; mean 344 mm) suggests that they are non-spawners.

Adults

Bull trout may have both non-migratory freshwater and anadromous forms. Anadromous native char outmigrate from Puget Sound rivers, including the Skagit and Snohomish Rivers, into nearshore areas typically as subadults. Bull trout mature at 5 to 7 years of age, with spawning in Puget Sound streams peaking in September and October (King County Department of Natural Resources and R2 Resource Consultants 2000).

Adults are known to feed on marine forage fish species, and locations of recreational fishing for char usually coincide with surf smelt spawning beaches. Bull trout appear to favor forage fish species (smelts, Pacific herring, and Pacific sand lance) over juvenile salmonids when both are abundant in the nearshore—most likely because of the larger size of the forage fish species. Bull trout are known to be cannibalistic; a 10-inch specimen was caught on hook and line that had a 4-inch char in its throat (K. Kraemer, WDFW, pers. comm.).

Historical Distribution and Use

WRIA 8 - Information on the historical presence, abundance, distribution, use, and life history of bull trout in WRIA 8 is limited. Distribution data for Puget Sound fishes through 1973, however, documented records of native char in nearshore habitats of WRIA 8 near Golden Gardens (reach 2) and Shilshole Bay (reach 3) (Miller and Borton 1980).

WRIA 9 - In WRIA 9, information on the historical presence, abundance, distribution, use, and life history of bull trout in the Green River basin is extremely limited. Suckey first observed native char in the Duwamish River during June 1856. He observed specimens as large as two feet in length in the Duwamish and another individual fish was captured approximately 35 miles upstream in June 1856 (Suckey and Cooper 1860). These fish were described as "red-spotted salmon trout" with the scientific name of *Salmo spectablis*. Pautzke and Megis (1940) described the presence of a "few" Dolly Varden during the 1930s in the Green River. More recently, Mongillo (1993) suggested the need for additional data collections. Investigations (Watson and Toth 1994; Tacoma Water HCP 1999) have not provided any evidence of bull trout spawning in the Green River Basin. However, native char have been captured as far as RM 40 in the Green River (Watson and Toth 1994). Recreational anglers have reported sightings of native char in the lower Green River (H. Boynton, pers. comm.). Native char have not been observed or captured upstream of Howard Hanson Dam as a part of surveys conducted by Plum Creek Timber Company (Watson and Toth 1994). Distribution data from Miller and Borton (1980) also documented several records of Dolly Varden (*Salvelinus malma*) within Elliott Bay at the mouth of the Duwamish River (reach 4). Dolly Varden (age class unidentified) were rare in monthly beach seine collections made off Alki (reach 4; 1 fish total) and Three Tree Point (reach 8; 1 fish total) in 1975 (Miller et al. 1976).

All Salmonids

Reasons for Change

Numerous causes have been forwarded to explain salmon population declines in the Puget Sound region. These include natural and anthropogenic alteration of marine habitats, harvest activities, and alteration of freshwater habitat.

One major factor affecting Puget Sound salmon abundance over the last 25 years is ocean growth/survival conditions. Cycles in climate change are believed to favor success of populations in Alaska in recent decades, with low survival of Washington and Oregon populations (Beamish and Bouillon 1993). Recent reductions in regional prey resources (forage fish) have also been offered as one reason for reduced catches of adult chinook and coho in Puget Sound (Appleby and Doty 1995).

Many of the declines in salmonid populations are likely attributable to urbanization and anthropogenic activities in nearshore marine and estuarine habitats (Schmitt et al. 1994). Loss of over 70 percent of Puget Sound coastal wetlands and estuaries to urban or agricultural development (diking, dredging, and hydromodification) has resulted in a massive reduction in rearing habitat for juveniles, especially estuarine-dependent chum and chinook salmon and cutthroat trout (Myers et al. 1998). Degradation and loss of shallow vegetated habitats may alter sheltered migration corridors for juveniles of all species (Simenstad et al. 1982). Declines in woody debris in estuaries and shoreline alterations have likely resulted in detrimental effects to many resident and migratory stages due to a reduction in refuge and feeding sites (Johnson et al. 1999). Shoreline armoring, over-water structures that shade marine vegetation and primary productivity, filling, channel dredging, and pollution from upland commercial, industrial, and residential development have also contributed to the declines.

Harvest impacts on Puget Sound chinook salmon stocks have been relatively high; ocean exploitation rates on natural stocks average 56-59 percent, but on some stocks have exceeded 90 percent (Myers et al. 1998).

In addition, within freshwater portions of watersheds in WRIAs 8 and 9, urbanization and anthropogenic activities have limited salmon access to historical spawning grounds, altered downstream flow and thermal conditions, increased sedimentation, decreased LWD and gravel recruitment, and reduced river pool and spawning areas (Myers et al. 1998). Water diversion and hydroelectric dams have also prevented access to portions of several rivers, and domestic and industrial wastes impact local water systems. Water withdrawals for irrigation and flood-control structures may negatively influence the quality of spawning and incubation habitat (Hard et al. 1996). The WRIA 9 Habitat Limiting Factors and Reconnaissance Assessment

(Nelson and Kerwin, 2000) and the forthcoming WRIA 8 Habitat Limiting Factors Report discuss these items in more detail.

Stressors

Salmonids use a variety of habitats throughout their life history, a fact that complicates any assessment of the primary reason for population reductions (Schmitt et al. 1994). However, stressors to salmon populations in WRIAs 8 and 9 are undoubtedly similar, and include loss of estuarine and nearshore marine rearing areas. Habitat impacts in the central Puget Sound have been substantial, and include loss of estuarine wetlands and shallow marine habitats due to diking and armoring (i.e., construction of bulkheads, piers, and docks), urbanization, and degradation of water quality (WDFW 1992; Johnson et al. 1997).

High temperatures in estuaries may be a stressor on juvenile salmonids. Associated localized depletion of oxygen can cause mortalities of salmonids and forage species in nearshore environments where there is little tidal flushing.

Diseases are natural stressors of fish at all ages. When salmonids are affected by other natural or human-caused stressors they will be more susceptible to disease.

The loss of coastal wetlands to urban or agricultural development may directly reduce the productivity of estuarine habitats to the detriment of highly dependent chinook, chum, and cutthroat populations. Primary losses in estuarine habitat can be attributed to the ditching, draining, diking, and filling associated with agricultural and urban development (Schmitt et al. 1994; Johnson et al. 1999). Within Puget Sound, extensive historical changes in intertidal and nearshore marine habitats due to shoreline armoring may have a cumulative environmental impact that eventually results in loss of riparian vegetation, burial of the upper beach areas, altered wave interaction with the shoreline, and obstruction of sediment movement (Thom et al. 1994; Shipman and Canning 1993). Loss of beach habitat from shoreline armoring and other modifications can degrade or destroy forage fish spawning habitat, adversely affecting these important salmonid prey resources. Alteration of marine shorelines may alter migration corridors and make juvenile pink and chum salmon more susceptible to predation (Heiser and Finn Jr. 1970).

Construction activities in, or close to, the nearshore environments of WRIAs 8 and 9 can interrupt salmonid migration and feeding. The range of sound magnitude from the faintest to the loudest the human ear can hear is so large that sound pressure is expressed on a logarithmic scale in units called decibels (dB). Environmental noise is commonly “A-weighted” to simulate how an average person hears sounds. A-weighted sound levels are expressed in units of A-weighted decibels (dBA). U.S. Environmental Protection Agency (EPA) research found that noise associated with normal operation of construction equipment (trackhoe) is typically 75 to 92 dBA at 46 feet (EPA 1971). Pile driving can be louder. These measurements are based on sound movement through air. Decibel conversion from air to water is approximately 26 dBA higher (Walter 1999). Underwater noise associated with normal operation of construction equipment would be in the 101 to 118 dBA range. Point-source noise dissipates at approximately 6 dBA per distance doubled (i.e., 45, 90, 180 feet) through water. According to Feist (1991), salmonids do not detect sound below about 97 dBA. The estimated distance salmonids would perceive noise from construction activities could range from approximately 650 to over 1,000 feet from a project site.

Fishing should be considered a stressor because it clearly affects stocks by adult mortality and removal of eggs.

Ship and boat traffic may be a stressor to salmonids in industrial waterfronts of WRIAs 8 and 9. Noise and physical displacement may cause interruptions of migration and feeding of salmonids and forage species.

Data Gaps

There is a definite need for development of standardized methodologies to assess nearshore habitat quality and function for salmonids. Relationships need to be established to link the physical, chemical, and biological processes with what forms and maintains properly functioning conditions in the nearshore. Proper assessment of nearshore habitats would provide estimates of current nearshore carrying capacity, and form the scientific basis of a habitat protection and restoration program.

There is limited historical distribution and abundance by time of year data for most salmonids in the nearshore and open waters of Puget Sound. More information is needed to determine preference for various habitat conditions and timing of utilization by each species. Similarly there is a need for annual surveys and stock assessments for forage fish (surf smelt, Pacific sand lance, and Pacific herring) spawning areas along the nearshore. All life history stages beyond the egg stage of forage fish are used as food for juvenile, resident, and adult salmonids.

Coastal cutthroat trout are the least studied of the Pacific Northwest salmonid species, and are characterized by a pervasive lack of quantitative population information (Johnson et al. 1999). Likewise, most of what we know about char use of nearshore and estuarine areas in Puget Sound is characterized by significant data gaps.

Issues of estuarine and coastal productivity and carrying capacity limitations for Pacific salmon remains an untested dilemma (Wissmar and Simenstad 1998). Additional research needs to better link variation in production to salmon population dynamics and prey utilization in estuarine and nearshore marine habitats.

Water pollution in estuaries and the nearshore occurs in many forms, including inorganic and organic chemicals, sediments and turbidity, and thermal. Understanding the effects of individual pollutants on fitness and survival of juvenile salmonids and their food sources, as well as synergistic effects of these pollutants, are data gaps.

Little is known regarding survival of juvenile salmonids relative to avoidance of predators. Understanding the relationships of salmonid size, season, depth distributions of different habitats compared with species distribution and timing of salmonid predators will provide key information on survival in the nearshore environment. There have been no quantitative studies investigating the effects of shoreline armoring and associated shoreline steepening on the vulnerability of juvenile salmonids to predation. Such data would assist in understanding the ramifications of decisions to allow in water construction and what should be required for effective mitigation measures.

There are still data gaps in characterizing how new and existing over-water structures affect juvenile salmonids, and the relationship of these effects to long term survival.

Cumulative effects of shoreline alterations and watershed degradation are difficult to tease apart, and few studies have attempted to understand the direct impacts of shoreline modifications to salmon or other nearshore-dependent species (Thom et al. 2000). Furthermore, the impact of losses in connectivity between these habitats is unknown.

Data gaps for salmonids are summarized in Table 23.

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

Forage fish, as the name implies, are a significant part of the prey base for marine mammals, sea birds, and fish populations, including salmonids, in Puget Sound. They rely upon a variety of shallow nearshore and estuarine habitats and are a valuable indicator of the health and productivity of our marine environment (Table 24).

The five species of forage fish are herring, surf smelt, longfin smelt, eulachon, and sand lance. These small, schooling fish most likely use shorelines within WRIAs 8 and 9. One herring stock is known to spawn at Quartermaster Harbor. Pacific herring is a candidate species for listing under the Endangered Species Act.

Table 24: Forage Fish: Washington State/Federal status in South Puget Sound and indication of nearshore marine and estuarine habitat use

Common Name	Scientific Name	WDFW/Federal Stock Status	Nearshore and Estuarine Habitat Use		
			Spawn	Adult Resid.	Juven. Rear.
Pacific Herring	*Clupea harengus pallasi*	Variable	●	●	●
Surf Smelt	*Hypomesus pretiosus*	Unknown/None	●	●	●
Longfin smelt	*Spirinchus thaleichthys*	Vulnerable/None	●	●	●
Eulachon	*Thaleichthys pacificus*	Unknown/None			
Sand Lance	*Ammodytes hexapterus*	Unknown/None	●	●	●

Source: Lemberg et al. 1997; Musick et al. 2000

Notes: Filled circles represent extensive use of these areas.

Anadromous eulachon pass through nearshore and estuarine habitats during spawning migrations; patterns of habitat use are poorly known.

Pacific Herring (Clupea harengus pallasi)

Juveniles

After transformation from their larval form, juvenile Pacific herring usually stay in nearshore marine waters until fall, when they disperse to deeper marine waters (Emmett et al. 1991). They feed primarily on euphausiids (J. Brennan, pers. comm.), copepods and small crustacean larvae (Hart 1973; Emmett et al. 1991).

Adults

Pacific herring do not make extensive coastal migrations, but rather move onshore and offshore in schools as they feed and spawn (Emmett et al. 1991). Some Puget Sound herring may summer off Cape Flattery (W. Palsson, WDFW, pers. comm.). Adult Puget Sound herring stocks move onshore during winter and spring to holding areas prior to moving to inshore spawning grounds (O'Toole 1995; Lemberg et al. 1997). Adults appear to consistently return to their natal spawning grounds, and during spawning migrations may greatly reduce or stop feeding (Emmett et al. 1991; Lemberg et al. 1997). Most spawning in Puget Sound takes place from late January through early April in lower intertidal and upper subtidal habitats (O'Toole 1995). Adhesive eggs are primarily deposited on native eelgrass and a variety of marine algae (Lemberg et al. 1997). Pacific herring in shallow nearshore habitats of Puget Sound feed primarily on copepods, decapod crab larvae, (Fresh et al. 1981) and euphausiids (D. Penttila, WDFW, pers. comm.).

Current Distribution and Use

At least 18 Pacific herring stocks, defined by spawning ground, occur inside Puget Sound (Lemberg et al. 1997). Pacific herring use the nearshore environment for feeding and spawning. Currently, there are two commercial herring fisheries in Washington; the principal one is in south-central Puget Sound and has annual average landings (1992-96) of 510 tons (Lemberg et al. 1997). Currently, Puget Sound herring are fished at a conservative level

(O'Toole 1995). Although Puget Sound herring stocks have declined over the past 20 years, the National Marine Fisheries Service decided they did not warrant listing under ESA in 2001. It is probable that Pacific herring of all ages pass through WRIA 8 and 9 nearshore habitats, especially as juveniles rearing during the summer months and as adults migrating to holding areas near natal spawning grounds. Figure 18 shows the distribution of documented forage fish spawning areas in WRIAs 8 and 9. These data almost certainly are conservative because not all beaches have been surveyed, and not all surveyed beaches have been monitored in multiple years. Therefore, lack of documented spawning in an area does not mean that spawning does not occur there.

WRIA 8 – There are no documented herring stocks that spawn within the nearshore of WRIA 8 (Figure 19). However, herring are widespread within Puget Sound and use these habitats for feeding and migration.

WRIA 9 – A single stock of Pacific herring spawns within WRIA 9 at Quartermaster Harbor, located between Vashon and Maury Islands (reach 11) (Figure 19). This stock's spawning activity occurs from January through mid-April (Lemberg et al. 1997). During spawning of large year classes (i.e., 1975 and 1995), spawning may extend around the harbor mouth into reaches 10 and 12 (Lemberg et al. 1997; EVS Environmental Consultants 2000).

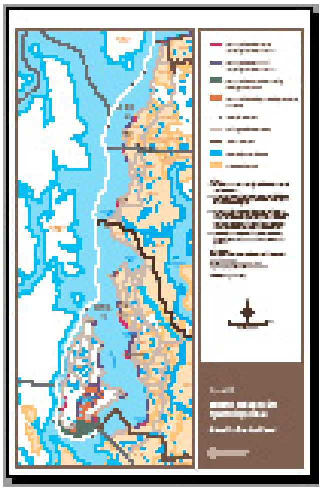
Pre-spawn herring holding areas occur outside of the harbor (reach 11) and along the eastern shoreline of Maury Island (reach 10) (Lemberg et al. 1997) (Figure 19). WDFW currently estimates spawning biomass of about 12 of the known herring stocks each year (O'Toole 1995), and recent summaries of the Quartermaster Harbor stock list it as stable and healthy (Lemberg et al. 1997).

Historical Distribution and Use

Pacific herring stocks in Puget Sound have undergone significant fluctuations, and some stocks have declined over the past 20 years.

WRIA 8 – Distribution data for Puget Sound fishes compiled through 1973 show clusters of Pacific herring records within the nearshore area of WRIA 8 (Miller and Borton 1980). According to several isolated records, Pacific herring occurred near Edwards Point (reach 1), with a group off Meadow Point and Golden Gardens beach (reach 2), and in Shilshole Bay (reach 3). Pacific herring were rare to common (331 fish total) in monthly beach seine collections made off West Point in 1975 (Miller et al. 1976).

Figure 19 Known Forage Fish Spawning Areas



Click here to view figure

WRIA 9 – Historical records of Pacific herring within the WRIA 9 nearshore area were clustered around West Point, north Alki Point, and Elliott Bay at the mouth of the Duwamish River (reach 4), with additional concentrations in Quartermaster Harbor (reach 11) and along the entire Colvos Passage (reach 12) (Miller and Borton 1980). Herring (no size class indicated) occurred infrequently in monthly beach seine collections made off Alki Point (reach 4; 13 total fish) and Three Tree Point (reach 8; 2,284 total fish) in 1975 (Miller et al. 1976).

Surf Smelt (Hypomesus pretiosus)

Juveniles

Juvenile surf smelt reside in nearshore waters and may use estuaries for feeding and rearing (Emmett et al. 1991; Lemberg et al. 1997).

Adults

Adult surf smelt are pelagic, but remain in nearshore habitats over a variety of substrates throughout the year (Emmett et al. 1991). They feed on a variety of zooplankton and epibenthic organisms, including planktonic crustaceans and fish larvae (Emmett et al. 1991; Fresh et al. 1981). Spawning occurs during much of the year on mixed sand-gravel beaches at a tidal elevation between approximately +2 m and the mean higher-high water line (Lemberg et al. 1997), or higher. Adults school offshore and may return to the same spawning ground each year (Lemberg et al. 1997). Surf smelt are an important trophic link in nearshore marine food webs.

Current Distribution and Use

Surf smelt are a widespread and important member of the nearshore fish community throughout Puget Sound. Although surf smelt movements within Puget Sound are unstudied, a number of genetically distinct stocks are thought to occur. Because no stock assessment studies have been done, the status of Puget Sound surf smelt populations is currently unknown (Lemberg et al. 1997). The initial studies of surf smelt in the Puget Sound basin in the 1930’s mapped no spawning beaches in WRIA 8, WRIA 9, or the Vashon – Maury Island area. Subsequent discoveries of spawning sites in these regions are presumably due to increased sampling effort, not an expansion of the range of this species (D. Penttila, WDFW, pers. comm.). Limited periodic surveys of surf smelt spawning beaches have documented about 210 linear miles of spawning habitats (D. Penttila, WDFW, pers. comm.).

WRIA 8 – Four surf smelt spawning beaches have been documented along the WRIA 8 shoreline; the north side of Picnic Point; north of Point Edwards, the south shore of Point Wells, and Richmond Beach (Lemberg et al. 1997; D. Penttila, WDFW, pers. comm.) (Figure 19). Lack of documented spawning in an area does not mean that spawning does not occur there. Not all beaches have been surveyed and those that have do not always include data for multiple years. All currently known surf smelt spawning beaches in WRIA 8 have been discovered since 1991 (D. Penttila, WDFW, pers. comm.).

WRIA 9 – Surf smelt spawning beaches are more widespread along the WRIA 9 shoreline, and occur in every shore reach (4-11) from north of Alki Point to Quartermaster Harbor; no spawning has been documented on the western shore of Vashon Island (reach 12) (Lemberg et al. 1997) (Figure 19). Washington Department of Fisheries forage fish staff members were first aware of surf smelt spawning habitat in Quartermaster Harbor in 1975, and the full extent of the spawning habitat in the harbor was not known until 1988. All additional surf smelt spawning sites known to occur in WRIA 9 have been found since 1991 (D. Penttila, WDFW, pers. comm.). As in WRIA 8, however, the lack of documented spawning habitat may reflect the lack of spawning survey effort.

Historical Distribution and Use

No reliable estimates of historical surf smelt distribution and habitat use exist for Puget Sound since spawning beach surveys were begun in 1972 (Penttila 1978; Lemberg et al. 1997).

WRIA 8 – Historical distribution data for Puget Sound fishes compiled through 1973 shows clusters of surf smelt records within the nearshore area of WRIA 8 (Miller and Borton 1980). Most records indicate surf smelt occurrence near Edwards Point (reach 1), with some off Meadow Point and Golden Gardens beach (reach 2), and in Shilshole Bay (reach 3). Surf smelt were rare to common (54 total fish) in monthly beach seine collections made off West Point in 1975 (Miller et al. 1976).

WRIA 9 – Historical records of surf smelt within the WRIA 9 nearshore area were sparse, with several clusters around West Point, north Alki Point, and the mouth of the Duwamish River (reach 4) (Miller and Borton 1980). Surf smelt were rare in monthly beach seine collections made off Alki Point (reach 4; 1 fish total) and Three Tree Point (reach 8; 2 fish total) in 1975 (Miller et al. 1976).

Longfin Smelt (Spirinchus thaleichthys)

Juveniles

Juvenile longfin smelt are most commonly associated with pelagic estuarine habitats. They are carnivorous planktivores and eat a variety of small crustaceans (Emmett et al. 1991).

Adults

Adult longfin smelt are abundant in estuarine habitats from Puget Sound to San Francisco Bay. Spawning occurs in freshwater areas at night during winter over sandy areas with aquatic vegetation; most adults die soon after spawning (Emmett et al. 1991). Adults are carnivorous zooplanktivores and are consumed by numerous marine and estuarine vertebrates (Emmett et al. 1991).

Current Distribution and Use

Little information exists on longfin smelt habitat distributions and use in Puget Sound. However, longfin smelt are likely found in estuarine habitats within WRIAs 8 and 9. There are anecdotal reports of the possible existence of a longfin smelt population in the Duwamish River (L. Moulton to D. Penttila, pers. comm.). Confirmation of longfin smelt spawning sites, timing, substrate, and early life history requirements may be critical for its survival, and for its habitat needs to be taken into account in the Lower Duwamish River management plans.

Historical Distribution and Use

WRIA 8 – One historical record of longfin smelt exists within WRIA 8 nearshore habitats. Longfin smelt were rare (2 total fish) in monthly beach seine collections made off West Point in 1975 (Miller et al. 1976).

WRIA 9 –Historical records of longfin smelt within WRIA 9 nearshore habitats are very limited. One study (Malins et al. 1980) found that longfin smelt were among the 10 most common fishes caught in Elliott Bay during the fall and winter.

Eulachon (Thaleichthys pacificus)

Juveniles

Newly hatched eulachon larvae are 5-7 mm long and rapidly drift out of rivers and estuaries to marine waters (Hart 1973; Emmett et al. 1991). Juveniles eat planktonic crustaceans such as euphausiids and copepods (Hart 1973; Emmett et al. 1991). They are found at various depths in marine habitats.

Adults

The eulachon is an anadromous species, and adults spawn in freshwater rivers once a year during the late winter/early spring (Emmett et al. 1991; Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000). Adults spend most of their lives in the marine environment before making spawning migrations, when they may be found near the bottom of river and estuarine channels (Emmett et al. 1991).

Current Distribution and Use

Eulachon are considered rare within Puget Sound (Emmett et al. 1991) and little current information exists on their nearshore distributions within WRIAs 8 and 9. Puget Sound eulachon populations were designated a candidate species for listing under the ESA in 1999 (National Marine Fisheries Service 1999).

Historical Distribution and Use

Few records document the historical distribution and use of Puget Sound nearshore habitats by eulachon.

WRIA 8 – Historical distribution data for Puget Sound fishes compiled through 1973 show only three records of eulachon within the nearshore area of WRIA 8, and all of these occur near Meadow Point (reach 2) (Miller and Borton 1980).

WRIA 9 – No historical records of eulachon exist within the WRIA 9 nearshore area (Miller and Borton 1980).

Pacific Sand Lance (Ammodytes hexapterus)

Juveniles

Pacific sand lance juveniles are pelagic and schooling, but may burrow into unconsolidated sediments at night to rest and escape predators (Emmett et al. 1991). Juvenile sand lance are primarily planktivorous carnivores (Emmett et al. 1991). Juveniles rear in bays and nearshore waters (Lemberg et al. 1997) and are commonly found in eelgrass beds (King County, unpublished data).

Adults

Adult sand lance likely move into coastal and estuarine waters during spring and summer for feeding and refuge from predators (Emmett et al. 1991). Spawning occurs once a year from November to February at tidal elevations from +1.5 m to about the mean higher-high water line on sand to gravel beaches (Penttila 1995a; Lemberg et al. 1997). Adult sand lance are planktivorous carnivores and prey heavily upon calanoid copepods (Fresh et al. 1981). In turn, sand lance are a highly important prey item for many marine vertebrates and seabirds.

Current Distribution and Use

The Pacific sand lance (known locally as "candlefish") is a common but poorly known nearshore schooling baitfish in Washington waters (Penttila 1995a). However, they are highly abundant and widely distributed throughout Puget Sound bays and nearshore habitats (Emmett et al. 1991, Penttila 1995a). Over 140 miles of Puget Sound shoreline have been documented as sand lance spawning habitat (D. Penttila, WDFW, pers. comm.).

WRIA 8 – Within WRIA 8, documented sand lance spawning beaches exist near Elliot Point, north Picnic Point, and north Edwards Points (reach 1), south Point Wells (reach 2), and south of Meadow Point (reach 3) (Lemberg et al. 1997; D. Penttila, WDFW, pers. comm.) (Figure 19). However, just because spawning is not documented in an area does not mean it does not occur there.

WRIA 9 – Pacific sand lance spawning beaches are more widespread along the WRIA 9 shoreline, and occur in shore reaches 4, 6, 7, 8, 10, and 12 (Lemberg et al. 1997) (Figure 19). Large schools of sand lance have been observed along the eastern shore of Maury Island (EVS Environmental Consultants 2000).

Historical Distribution and Use

No data were available regarding sand lance spawning habitats in Puget Sound before 1989 (Penttila 1995a). No sand lance spawning sites were documented in WRIA 8 prior to 1991. Historical abundance and habitat distribution and use are virtually unknown.

WRIA 8 – Historical distribution data for Puget Sound fishes compiled through 1973 show sand lance distributed throughout the nearshore area of WRIA 8 (Miller and Borton 1980). Sparse records of sand lance occur from Elliot Point (reach 1) south past Edwards Point and Richmond Beach (reach 2), with a higher frequency of sand lance catches near Golden Gardens (reach 2), Meadow Point, and Shilshole Bay (reach 3). Sand lance occurred rarely (240 fish total) in monthly beach seine collections made off West Point in 1975 (Miller et al. 1976). During 1975-76 beach seine netting, 247 sand lance were caught off West Point (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000).

WRIA 9 – Historical records of Pacific sand lance within the WRIA 9 nearshore area were infrequent, with several observations around West Point, the mouth of the Duwamish River, north Alki Point (reach 4), and near Three Tree Point (reach 7) (Miller and Borton 1980). Beach seine collections made in 1976-1977 netted 1,250 sand lance from eelgrass habitats off Alki Point (reach 4) (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000). Sand lance were also collected infrequently in monthly beach seine collections made off Three Tree Point (reach 8; 208 fish total) in 1975 (Miller et al. 1976). Sand lance occurred frequently in spring and summer 1992-1993 beach seines made near Seahurst Bay (reach 7; 4 fish/haul), and east of Point Vashon (16 – 231 fish/haul) on eastern Vashon Island (reach 9) (Donnelly et al. 1984).

All Forage Fish

Reasons for Change

Increased natural mortality for herring over the last 20 years has been attributed to increased predation pressure (Lemberg et al. 1997). Individual herring stocks vary greatly in relative size and may undergo significant fluctuations in recruitment and adult survival due to variations in marine ecological conditions and prey resources, alterations in nearshore habitats, and fishery overharvest (Lemberg et al. 1997; West 1997).

No data are available for smelt, longfin, eulachon, and sand lance.

Stressors

Commercial overharvest of herring to supply bait needs and for sac-roe occur and have resulted in fisheries closures (Bargmann 1998). There is a relatively consistent *in situ* egg mortality at certain locations in Quartermaster Harbor (Lemberg et al. 1997). The causes of these egg mortalities are as yet unknown. Surf smelt also are affected by large commercial and recreational harvests that average more than 200 tons annually (Lemberg et al. 1997). Pollution, thermal stress, and desiccation can result in egg and larval mortality (Emmett et al. 1991).

Herring, surf smelt, and sand lance have specific spawning habitat requirements, which make them especially vulnerable to shoreline development activities (Lemberg et al. 1997; Penttila 1978; Penttila 2000). For example, shoreline armoring has been implicated in the loss and alteration of beach substrate that supports eelgrass and forage fish spawning (Thom and Hallum 1990; Thom and Shreffler 1994). Loss of overhanging riparian vegetation along shorelines may reduce shading and result in reduced survival of these species' eggs and larvae (Penttila 2001).

Longfin and eulachon are affected by the loss of estuarine habitats and alteration of freshwater flows (Emmett et al. 1991). All life stages are sensitive to changes in temperature and industrial pollution (Emmett et al. 1991).

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

Groundfish live in marine waters and spend their lives near or on the bottom; they include rockfish, which are covered in the next section. In Washington State, groundfish are legally defined as food fishes, and most are the focus of important fisheries (Palsson 1997). Groundfish include Pacific cod, walleye pollock, Pacific hake, lingcod, English sole, and rock sole. Populations of several species are at historic lows (Palsson 1997), particularly Pacific cod and hake.

While many adult groundfish reside within the deeper waters of Puget Sound, some rely on shallow nearshore marine and estuarine habitats during part of their life history (Table 26). Groundfish in nearshore marine and estuarine areas of WRIAs 8 and 9 are considered a component of South Puget Sound stocks (Palsson 1997). This stock delineation has been adopted because habitats in South Puget Sound, as compared to North Puget Sound, are generally more protected, more influenced by freshwater, closer to several large cities, and have less reef habitat. Fisheries in this region are less focused and tend to occur throughout the year (Palsson 1997).

Table 26: Groundfish: Washington State/Federal status in South Puget Sound and indication of nearshore and estuarine habitat use

Common Name	Scientific Name	WDFW/Federal Stock Status	Nearshore Marine and Estuarine Habitat Use		
			Spawn	Adult Resid.	Juven. Rear.
Pacific Cod	*Gadus macrocephalus*	Critical	●	●	●
Walleye Pollock	*Theragra chalcogramma*	Critical	●	●	●
Pacific Hake	*Merluccius productus*	Critical	●	●	●
Lingcod	*Ophiodon elongatus*	Stable/Candidate	●	●	●
English Sole	*Pleuronectes vetulus*	Unknown/None	●	●	●
Rock Sole	*Lepidopsetta bilineata*	Unknown/None	●	●	●

Source: Palsson 1997; Musick et al. 2000
Notes: Filled circles represent extensive use.

Pacific Cod (Gadus macrocephalus)

Juveniles

After hatching, Pacific cod larvae spend several months in the water column. In late summer, juvenile cod metamorphose and settle to shallow vegetated habitats where they find shelter and prey resources, which include copepods, amphipods and mysids (Matthews 1989).

Adults

General reviews of Pacific cod life history, distribution, and migration are contained in Matthews (1989), Beschta et al. (1987), and Palsson (1990). Pacific cod are widely distributed in relatively shallow marine waters (50-200 m) throughout the northern Pacific Ocean; populations in Washington's inland marine waters are considered the southern limit of fishery-exploitable populations (West 1997). Adult Pacific cod live over soft unconsolidated sediments at depths ranging from 50 to 200 m. They are large demersal carnivores that feed on sand lance, herring, pollock, sculpins, flatfishes and invertebrates such as euphausids, crabs, and shrimp (Palsson 1990; West 1997; Schmitt et al. 1994). In Puget Sound, Pacific cod concentrate in shallow embayments such as Port Townsend Bay and Agate Passage during the winter to spawn, but disperse to deeper waters to feed during the remainder of the year. They are highly fecund broadcast spawners, with eggs that sink to the sea floor where they adhere to the substrate.

Current Distribution and Use

Currently, the population of Pacific cod in North Puget Sound is described as "depressed" and the southern Puget Sound population is considered "critical or near extinct levels" (Table 26) (Palsson et al. 1997). Catch rates have been on a long-term decline since the mid 1970s. Pacific cod are found throughout Puget Sound, with abundance declining from north to south (Schmitt et al. 1994).

WRIA 8 – Schools of young-of-the-year Pacific cod have been observed on several dates (1991, 1993) in nearshore eelgrass and macroalgae habitat near Carkeek Park (reach 1) (Doty 1993). WDFW trawl surveys have collected Pacific cod primarily over sand habitat at depths from 30-360 ft near Edmonds (reach 1) and Meadow Point (reach 2-3) (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000).

WRIA 9 – Quartermaster Harbor (reach 11) is considered an important spawning, feeding, and/or nursery area for Pacific cod (Schmitt et al. 1994).

Historical Distribution and Use

Three separate stocks, or populations, of Pacific cod existed historically in Puget Sound: a stock in the Gulf of Georgia region, a stock in the eastern Strait of Juan de Fuca, and a stock in South Sound centered around Agate Pass (Palsson 1990). Pacific cod once supported commercial fisheries in Puget Sound before precipitous declines in catches during the 1980s (Palsson 1990; Schmitt et al. 1994; Palsson et al. 1997).

WRIA 8 – According to historical records, Pacific cod occurred in clusters off Edwards Point (reach 1) and around Meadow Point, Shilshole Bay, and West Point (reaches 2 and 3) (Miller and Borton 1980).

WRIA 9 – Pacific cod within the WRIA 9 nearshore area were sparse, with several groupings around West Point, Elliott Bay, and north Alki Point (reach 4) (Miller and Borton 1980). Isolated records also documented Pacific cod on the east side of Vashon Island (reach 9) within Quartermaster Harbor (reach 11) and in Colvos Passage (reach 12). Juvenile Pacific cod were rare (<30 percent of samples) in monthly beach seine collections south of Alki Point (reach 5) in 1975 (Miller et al. 1976).

Walleye Pollock (Theragra chalcogramma)

Juveniles

As juveniles, walleye pollock settle near the bottom and become semi-demersal, migrating to inshore, shallow habitats for their first year (Schmitt et al. 1994). They are found in eelgrass and over gravel and cobble substrates. Juvenile walleye pollock feed primarily on small crustaceans (mysids, calanoid and harpacticoid copepods, gammarid amphipods, and juvenile shrimp), progressing to small fishes as they grow larger.

Adults

Walleye pollock is a northern cold water species at the southern extent of its fishery-exploitable population in Puget Sound. Pollock inhabit mid-water or near-bottom cold water environments over a variety of substrate types (Matthews 1989). They form spawning aggregations from February to April in localized deep water areas (Schmitt et al. 1994). As with Pacific cod, walleye pollock are carnivorous predators and are highly fecund, broadcast spawners.

Current Distribution and Use

Walleye pollock in South Puget Sound have experienced severe declines in recent years and its status is considered "critical" (West 1997; Palsson et al. 1997).

WRIA 8 – WDFW trawl surveys have collected walleye pollock at depth (126-360 ft) near Edmonds (reach 1), south of Point Wells (reach 2), and Meadow Point (reach 2-3) (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000).

WRIA 9 – No current data were available on walleye pollock distribution and habitat use in WRIA 9 nearshore habitats.

Historical Distribution and Use

In southern Puget Sound, walleye pollock were once the most common species taken in the recreational fishery (West 1997). Historically, anglers harvested a majority of pollock in South Sound, but after 1986 catches diminished before finally collapsing after 1988.

WRIA 8 – According to historical records, walleye pollock occurred in all reaches (1-3) of WRIA 8, with a dense cluster from Golden Gardens to West Point (Miller and Borton 1980). Juvenile walleye pollock were rare (<30 percent of samples) in monthly beach seine collections made off West Point (reach 3) in 1975 (Miller et al. 1976).

WRIA 9 – Walleye pollock exhibited historical distribution patterns similar to Pacific cod within the WRIA 9 nearshore area. Pollock were recorded primarily within Elliott Bay (reach 4), with isolated records south of Alki Point (reach 5), Poverty Bay (reach 8), the eastside of Vashon Island (reach 9), within Quartermaster Harbor (reach 11), and in Colvos Passage (reach 12) (Miller and Borton 1980). Juvenile walleye pollock were rare (<30 percent of samples) in monthly beach seine collections made south of Alki Point (reach 5) and Three Tree Point (reach 8) in 1975 (Miller et al. 1976). In seasonal beach seines made throughout WRIA 9 nearshore habitats in 1982-1983, walleye pollock (presumably juveniles, no size class information provided) were most abundant during fall collection periods (Donnelly et al. 1984). They were collected in Seahurst Bay (reach 7; 7.5 – 17.5 fish/haul), south of Three Tree Point (reach 8; 5.5 - 37 fish/haul), Tramp Harbor (reach 9; 0.5 – 19 fish/haul), and east of Point Vashon on eastern Vashon Island (reach 9; 5 - 191 fish/haul) (Donnelly et al. 1984).

Pacific Hake (Merluccius productus)

Juveniles

After hatching, larvae of Pacific hake are found throughout the mid-water from April to May. By June, larvae disappear from mid-water habitats, possibly moving inshore as they metamorphose and begin active schooling (Schmitt et al. 1994). Juvenile and immature hake may aggregate in inshore waters and mainland inlets, where they feed and grow away from concentrations of adults.

Adults

Pacific hake, also known as Pacific whiting, is considered a warm water species that has abundant populations off the coasts of California and Baja California, Mexico. Hake is a mid-water schooling species that undergoes northward feeding migrations in the summer to Washington and British Columbia, before returning to southern waters for winter spawning (West 1997). A small genetically distinct resident hake population in southern Puget Sound migrates seasonally between Port Susan and Saratoga Passage. Spawning occurs from March to May at mid-water depths of 50 to 350 m (Schmitt et al. 1994). They are opportunistic carnivores and feed primarily on small forage fishes.

Current Distribution and Use

Currently, the status of Pacific hake in South Puget Sound is considered "critical" because of the sharp decline in abundance observed in annual hydro-acoustic surveys (Palsson et al. 1997). The commercial fishery is now closed in Puget Sound due to low abundance.

WRIA 8 – WDFW trawl surveys have collected low densities of Pacific hake at depth (126-360 ft) near Edmonds (reach 1), Edwards Point (reach 1-2), south of Point Wells (reach 2), and Meadow Point (reach 2-3) (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000).

WRIA 9 – No current data are available on Pacific hake distribution and habitat use in WRIA 9 nearshore habitats.

Historical Distribution and Use

At one time, Pacific hake comprised the largest fishery by weight in Central Puget Sound. In the mid-1980s, the annual exploitation rate reached 40 percent of the adult population (Palsson et al. 1997).

WRIA 8 – Historical records of Pacific hake occurred in all reaches (1-3) of WRIA 8, with a cluster of records spanning from Golden Gardens to Shilshole Bay (Miller and Borton 1980).

WRIA 9 – Pacific hake exhibited historical distribution patterns similar to other codfish species (family Gadidae) within the WRIA 9 nearshore area. Hake records occurred primarily within Elliott Bay (reach 4), with isolated records at the mouth of Quartermaster Harbor (reach 11) (Miller and Borton 1980). Pacific hake were never collected in seasonal beach seines made throughout WRIA 9 nearshore habitats in the mid-1970s (Miller et al. 1976) and early 1980s (Donnelly et al. 1984).

Lingcod (Ophiodon elongatus)

Juveniles

Lingcod require several different habitats throughout their life cycle. After hatching and dispersing from their nests, larvae spend two months in pelagic nearshore habitat as surface-oriented larvae (West 1997). In late spring-early summer, juveniles move to benthic habitats, settling in shallow water, vegetated (kelp or eelgrass) habitats (Buckley et al. 1984; Cass et al. 1990). Juveniles (age 1-2) are commonly observed in high-current, soft bottom, or shell hash habitats near the mouths of bays and estuaries (Doty 1993). Juveniles are carnivorous, feeding on crustaceans and small fishes (Emmett et al. 1991).

Adults

The lingcod is a large (up to 45 kg) predatory fish native to the west coast of North America. They are top-level carnivores, preying on other fish and some molluscs (Schmitt et al. 1994; Emmett et al. 1991). Adult lingcod have a relatively small home range and are typically found associated with rocky reefs or other complex substrata with high current velocities (West 1997). They are found from the intertidal zone to 200 m, but are most abundant at depths between 10 and 100 m. Adult lingcod spawn between December and March, laying adhesive eggs in nests found in rocky crevices in shallow areas with strong water circulation. After the eggs are fertilized the nests are guarded by the males (West 1997).

Current Distribution and Use

Lingcod are found throughout Puget Sound. They are considered non-migratory, with mostly self-replenishing local stocks (Cass et al. 1990). Lingcod catches have steadily and substantially declined in Puget Sound since the early 1980s. Stocks in both North and South Puget Sound are considered fully used, with populations considered below average to depressed (Palsson et al. 1997).

WRIA 8 – Lingcod have been observed by video in shallow nearshore habitats off Point Wells and north of Meadow Point (reach 2) (Woodruff et al. 2000). Likewise, WDFW video surveys have documented lingcod associated with structures at 34- to 41-ft. depths north of Edwards Point (reach 1), around Point Wells (reach 2), and Meadow Point (reach 2-3) (Striplin Environmental Associates, Battelle Marine Sciences Laboratory, and King County Water and Land Resources Division 2000).

WRIA 9 – Few current quantitative data are available on lingcod distribution and habitat use in WRIA 9 nearshore habitats.

Historical Distribution and Use

Historically, lingcod have supported large important fisheries in Puget Sound since prehistoric times (West 1997). Strong year-classes in the early 1980s supported the fishery for several years before more recent declines.

WRIA 8 – Historical data for Puget Sound fishes compiled through 1973 show lingcod occurred in all reaches (1-3) of WRIA 8, with clusters of records at Edwards Point, Golden Gardens, and Shilshole Bay (Miller and Borton 1980).

WRIA 9 – According to historical records, lingcod distribution within the WRIA 9 nearshore area occurred primarily within Elliott Bay and Alki Point (reach 4-5) and at the south end of Vashon Island near Neill Point (reach 11-12) (Miller and Borton 1980). Lingcod were not collected in seasonal beach seines made throughout WRIA 9 nearshore habitats in the mid-1970s and early 1980s (Miller et al. 1976; Donnelly et al. 1984).

English Sole (Pleuronectes vetulus)

Juveniles

Patterns of juvenile and larval English sole distribution suggest active migration or directed transport to estuary or shallow nearshore marine areas for settlement (Gunderson et al. 1990). Pelagic English sole larvae are transported to these nursery areas by tidal currents between March and May. After metamorphosis, they assume a demersal existence and remain in protected coastal and estuarine areas where they feed on abundant prey resources. Juvenile English sole use a variety of shallow nearshore marine and estuarine habitats, and tend to prefer shallow (<12 m deep) muddy substrates in Puget Sound (Emmett et al. 1991). Juvenile English sole exhibit distinct patterns of depth segregation, with smaller fish generally restricted to shallow waters and larger fish found progressively deeper. Emigration from the estuaries is also length-dependent, beginning at 75-80 mm length (Gunderson et al. 1990). Juvenile English sole are opportunistic benthic carnivores, feeding on harpacticoid copepods, gammarid amphipods, polychaetes, small bivalves and siphons, and cumaceans (Emmett et al. 1991; Williams 1994).

Adults

English sole occur over flat-bottom coastal habitats, primarily at shallow depths during the summer and down to 250 m during the winter (Schmitt et al. 1994). They feed by day on benthic invertebrates, such as polychaetes, amphipods, molluscs, and crustaceans (Emmett et al. 1991). Females are larger than males at maturity and make up the bulk of commercial trawl landings. Adults spawn buoyant pelagic eggs over soft bottom substrates at depths of 50 to70 m. Puget Sound stocks spawn primarily from March to April (Emmett et al. 1991).

Current Distribution and Use

English sole in central Puget Sound exhibit significant homing and tend to remain within localized geographic regions (Schmitt et al. 1994). Recreational catch rates of flatfish show an increasing population trend during the last five years, and trawl survey data indicate the adult population is underused (Palsson et al. 1997). They are currently found throughout all reaches of WRIAs 8 and 9, with smaller fish more commonly associated with shallow waters and larger fish with deeper habitats.

Historical Distribution and Use

English sole were once one of the primary species targeted in commercial bottom trawl fisheries (Palsson et al. 1997). Landings data peaked in 1970 and then began a general decline until 1989, when the South Sound trawl fishery was closed by the Washington State Legislature. English sole have been found throughout all reaches of WRIAs 8 and 9 (Miller and Borton 1980; Miller et al. 1976; Donnelly et al. 1984).

Rock Sole (Lepidopsetta bilineata/Lepidopsetta polyxystra)

Juveniles

Eggs of rock sole have recently been identified from sand-gravel upper intertidal beaches at a number of sites in Puget Sound (Penttila 1995b). Juveniles and adults are abundant in nearshore marine habitats at depths ≤ 15 m (Donnelly et al. 1984). Little information on food habits and ecological requirements of juvenile rock sole has been documented in the literature.

Adults

Adult rock sole are a right-eyed flatfish commonly found throughout Puget Sound, primarily over cobble, gravel, and sand substrates. They usually occur in waters shallower than 200 m (Eschmeyer et al. 1983). Rock sole feed on molluscs, polychaete worms, crustaceans, brittle stars, and fishes (Simenstad et al. 1979). Adults may spawn on upper intertidal beaches, but may also spawn at subtidal depths as well (Penttila 1995b). Additional information is needed to determine spawning habitat requirements.

Current Distribution and Use

There are two recognized species of rock sole that occur in Puget Sound; Northern rocksole (*Lepidopsetta bilineata*) and Southern rocksole (Lepidopsetta polyxystra) (W. Palsson, WDFW pers. comm.). Rock sole are generally abundant and widespread throughout Puget Sound. However, documented intertidal rock sole spawn occurrences are largely confined to the region south of Seattle and are relatively infrequent (Penttila 1995b). Rock sole are one of the more common flatfishes harvested by recreational anglers, and catch trends indicate that stocks in South Puget Sound are above average levels (Palsson 1997). Trawl survey data indicate they are under-used (Palsson 1997).

WRIA 8 – At the current level of sampling effort, no intertidal rock sole spawning beaches have been documented in WRIA 8 (Penttila 1995b).

WRIA 9 – According to Penttila (1995b), rock sole spawning beaches occur throughout WRIA 9, with isolated sites in reaches 6 and 8, and concentrations in Quartermaster Harbor (reach 11).

Historical Distribution and Use

Rock sole has been the second most common flatfish in South Sound; they comprised about 5 percent of the commercial catch from the bottom trawl fishery before it was closed in 1989

(Palsson et al. 1997). During a period from the early 1970s to the mid 1980s, commercial catch rates in this region were at or above the 20-year mean. Rock sole have been found throughout all reaches of WRIAs 8 and 9 (Miller and Borton 1980; Miller et al. 1976; Donnelly et al. 1984).

All Groundfish

Reasons for Change

Overharvest by commercial and recreational fisheries is likely a leading cause in the decline of all groundfish populations, though no data are available for rock sole. For hake and lingcod, this decline is compounded by high predation by marine mammals, which may be preventing the recovery of these populations (Palsson et al. 1997).

In addition to overharvest, severe declines for walleye pollock since the 1980s are likely influenced by progressively lower recruitment of year classes born between 1975 and 1984 (Schmitt et al. 1994). Numerous physical and biological parameters combine to affect year-class strength (Emmett et al. 1991) in pollock and English sole.

Water temperatures and the presence or absence of herring have been found to affect cod recruitment and abundance in British Columbia (Palsson 1990). In Puget Sound a severe decline in abundance during the 1980s coincided with warm water conditions, intense fishing effort, and increased marine mammal abundance (Schmitt et al. 1994). Fisheries targeting spawning concentrations of cod in Agate Passage and Port Townsend Bay were closed as a result of low cod abundance. Trawl survey information indicates that cod stocks are reduced in both North and South Puget Sound.

Stressors

Stressors for groundfish are generally unknown. Changing water temperatures, decreases in prey availability, marine mammal predation, as well as overharvest are considered the primary stressors to these species. Pacific cod, walleye pollock, and Pacific hake are short lived and susceptible to overfishing that reduces age class diversity and abundance; stocks are then susceptible to collapse during years of naturally poor recruitment (West 1997). Losses and alteration of shallow nearshore habitats throughout Puget Sound may affect juvenile stages, but have generally not been considered in the literature.

Natural variability in recruitment, predation by marine mammals, and overharvest by human fisheries are likely stressors to lingcod populations. Estuarine dredging may alter natural open-sand rearing areas, while reductions in water circulation reduce embryo survival (Emmett et al. 1991).

English sole in contaminated areas of Puget Sound exhibit high rates of disease, increased parasite loads, and impaired reproductive success (Schmitt et al. 1994). Alteration and pollution of estuarine rearing habitats have adversely affected this species (Emmett et al. 1991). Similarly, shoreline development has altered intertidal spawning beaches for rock sole.

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

Key Findings

- 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

Rockfish (*Sebastes* sp.), as their name implies, are often associated with subtidal rocky reefs, although some are found associated with flat muddy bottoms. More than 20 species of rockfish inhabit Puget Sound, but only five are commonly caught by recreational or commercial fisheries (Palsson et al. 1997). Copper, quillback, and brown rockfish are the three most common species found in Puget Sound's shallow nearshore marine habitats, generally near kelp or rocky habitat (West 1997). Juveniles, in particular, utilize eelgrass and kelp as nursery areas. Like other groundfish, rockfish populations are at below-average levels.

Other, less common rockfish species in Puget Sound exhibit similarly distinct habitat specificity (Table 31). Black and yellowtail rockfish form pelagic schools of 10-40 fish around kelp or rocky habitats, and bocaccio use localized areas characterized by steep drop-offs to 90 m Canary and yelloweye rockfish occupy deep (>37 m) rocky habitats (Schmitt et al. 1994). Little is known about the ecology and stock status of most other species, although some may use shallow nearshore marine and estuarine habitats during part of their life history (Table 28).

Table 28: State/Federal status and nearshore habitat use of rockfish species in Washington State

Common Name	Scientific Name	WDFW/Federal Stock Status	Nearshore Marine Habitat Use		
			Spawn	Adult Resid.	Juven. Rear.
Black Rockfish	*Sebastes melanops*	Vulnerable/None	●	●	●
Blue Rockfish	*Sebastes mystinus*	Unknown			
Bocaccio	*Sebastes paucispinis*	Vulnerable/Candidate			●
Brown Rockfish	*Sebastes auriculatus*	Below Average/ Candidate	●	●	●
Canary Rockfish	*Sebastes pinniger*	Vulnerable/None			
China Rockfish	*Sebastes nebulosus*	Unknown			
Copper Rockfish	*Sebastes caurinus*	Below Average/ Candidate	●	●	●
Greenstriped Rockfish	*Sebastes elongates*	Unknown			
Quillback Rockfish	*Sebastes maliger*	Below Average/ Candidate	●	●	●
Redstripe Rockfish	*Sebastes proriger*	Unknown			
Tiger Rockfish	*Sebastes nigrocinctus*	Vulnerable/None			
Widow Rockfish	*Sebastes entomelus*	Vulnerable/None			
Yelloweye Rockfish	*Sebastes ruberrimus*	Vulnerable/None			●
Yellowtail Rockfish	*Sebastes flavidus*	Unknown	●	●	●

Source: Palsson 1997; Musick et al. 2000.
Notes: Filled circles represent extensive use.

Rockfish spp. *(Sebastes* sp.*)*

Juveniles

Born as free-swimming pelagic larvae, rockfish spend two to four months in the water column feeding on small zooplankton. When the planktonic larvae reach a specific size they move to shallow, benthic nursery habitats (West 1997). Drift material in the pelagic zone, including dislodged nearshore vegetation, provides prey resources and refugia that links some larval rockfish (i.e., tiger and splitnose) settlement to the nearshore environment (Shaffer et al. 1995; Buckley 1997). Studies of the more common copper, quillback, and brown rockfish species indicate that shallow areas with eelgrass, kelp beds, and other vegetation on cobbles and boulders are used as nursery habitats (West 1997). These nearshore habitats provide juvenile rockfish shelter from predation and increased access to prey resources. Limited availability of such habitat is thought to impose a demographic bottleneck on stock recruitment (West et al. 1995). Temperature affects juvenile rockfish growth during their first year, with warmer temperatures such as those found in the nearshore areas producing higher growth rates and possibly increasing their food assimilation efficiency (Buckley 1997). Juvenile rockfishes are commonly found in Puget Sound nearshore habitats throughout the summer and fall.

Adults

Upon reaching adult size, rockfish move to rocky reefs, boulders, offshore pinnacles, and other hard, high relief substrates. Most species are relatively sedentary and generally do not venture over 30 m^2 from preferred high-relief habitat (West 1997). However, seasonal variation in low-relief vegetated habitats may be reflected in dramatic density differences (Buckley 1997). Matthews (1989) found the highest fish densities in low-relief rocky reef and sand-eelgrass habitats occurring in summer, with fish densities declining in these habitats as vegetation dies off in the fall. High rockfish densities in physically complex, high-relief habitat during winter is likely correlated to refuge functions. Rockfish feed on a variety of small fish, molluscs, and crustaceans, with prey presence likely reflecting seasonal distribution and abundance (Schmitt et al. 1994). Summer feeding plays an important role in storing fat reserves for winter maintenance. All species of rockfish (genus *Sebastes*) have internal fertilization and bear live young (Hart 1973). Spawning probably occurs once a year, but may occur more than once in some species; copper, quillback, and brown rockfish release young during the spring (March–April). Most species of rockfishes display slow growth, late maturation (>4 years), and long life spans; females' fecundity increases with increasing size. A dominant feature of rockfish reproduction is a pattern of infrequent and irregular years with successful recruitment during periods with favorable environmental conditions, and many years with poor recruitment (Leaman and Beamish 1984; Botsford et al. 1994; Ralston and Howard 1995).

Current Distribution and Use

In South Puget Sound, rockfish stocks are currently considered overutilized, with populations depressed (Palsson et al. 1997). Rockfish may be locally abundant in some locations in Puget Sound, but are prone to severe depletion from overfishing due to their habitat specificity (West 1997). There is currently no targeted commercial fishery for demersal rockfish; however, target recreational fisheries have shown catch rates and sizes are declining, especially in South Sound (PSAT 2000). Copper rockfish are common throughout Puget Sound, and quillback rockfish are more common in North and Central Sound (north of Tacoma Narrows). Brown rockfish are more prevalent in South Sound (West 1997; Pacunski and Palsson 1998).

WRIAs 8 and 9 – Much of our recent (1990s) knowledge of rockfish distribution and abundance within WRIA 8 and 9 nearshore areas has been clarified by dive, video, acoustic, and trawl surveys conducted by WDFW and others (Table 29). Most of this information has focused on copper, quillback, and brown rockfish species, which are the most common species in WRIA 8 and 9 nearshore marine habitats. For example, copper and quillback rockfish occurred in 7-9 percent of video surveys conducted in central Puget Sound (Pacunski and Palsson 1998). Within WRIA 8, the Edmonds Underwater Park and marine refuge (reach 1) and Boeing Creek artificial reef complex (reach 2) have been the subject of considerable research into rockfish population dynamics, distribution, and habitat use (Palsson and Pacunski 1995; Matthews 1989; Buckley 1997).

Table 29: Distribution, habitat type, and density of rockfish spp. observed within WRIA 8 and 9 nearshore habitats

Common name	Distribution (reach #)	Habitat	Density	Reference #
Copper Rockfish	Carkeek Park (2)	Kelp, Macroalgae	2.5/m^3	1
	Picnic Point, Brown's Bay (1)	Sand, Eelgrass	8.5/100m^2	2
	Edmonds Underwater Park (1)	Sunken Dry Dock	Mod.-High	5, 9
	Boeing Creek (2)	Art. Rocky Reef	Low-Mod.	5, 8, 9, 10
	East Maury Island (10)	Pilings	Occasional	6
	N. Edwards Pt. (1), Pt. Wells (2), Meadow Pt. (2)	Rock Reef, 20-40 m depth	0.8/m^2	7
Quillback Rockfish	Carkeek Pk (1), Edwards Pt (2)	Kelp, Macroalgae	2.5/m^3	1
	Shilshole Bay (3)	Kelp	n/d	1
	West Point S. (4)	Kelp	n/d	1
	Picnic Point, Brown's Bay, N. Carkeek Park (1)	Sand, Eelgrass, Kelp Kelp	8.5 – 37.7 / 100m^2	 2
	South Magnolia (3)			2
	N. of Edwards Point (1), Boeing Creek area (2)	Eelgrass, Rock Sunken Dry Dock	 Mod.-High	 4
	Edmonds Underwater Park (1)	Art. Rocky Reef	Mod.-High	5, 9
	Boeing Creek (2)	Rocky Reef, 20-65 m		5, 8, 9, 10
	N. Edwards Pt. (1), Pt. Wells (2), Meadow Pt. (2)	depth	0.6/m^2	7
Brown Rockfish	Picnic Point, Brown's Bay, N. Carkeek Park (1)	Sand, Eelgrass, Kelp Pilings	 n/d	 2
	East Maury Island (10)	Art. Rocky Reef	Common	6
	Boeing Creek (2)	Sunken Dry Docks	Low	8, 9, 10
	Edmonds Underwater Park (1)		Low	9
Common RF sp. (3 above)	Boeing Creek (2)	Art. Reef - Rock, Macroalgae, Kelp	0.1– 0.5/m^2	3, 10
Black Rockfish	Edmonds Underwater Park (1)	Sunken Dry Docks	1.9/90m trans	9
	Boeing Creek (2)	Art. Rocky Reef	0.6/90m trans	9

Reference codes: 1 – (Doty and Norris 1992), 2 – Doty and Bookheim 1993], 3 – (West et al. 1995), 4 – (Woodruff et al. 2000), 5 – Palsson and Pacunski 1995], 6 – (Jones and Stokes Aquatic Research 1999), 7 – (WDFW unpublished data - W. Palsson), 8 – (Matthews 1989), 9 – (Palsson 1998), 10 – (Buckley 1997).

Historical Distribution and Use

Recreational fishers have historically harvested the majority of rockfish in South Puget Sound, with catches ranging from 100,000 to 400,000 pounds between 1970 and 1993. Based on recreational catch records and independent trawl and scuba surveys, rockfish stocks have undergone long-term declines in abundance since 1977 (Palsson et al.1997).

WRIA 8 – Historical data for Puget Sound fishes compiled through 1973 show various patterns of rockfish species distribution throughout the nearshore area of WRIA 8 (Miller and Borton 1980). Copper rockfish were common throughout WRIA 8 reaches 1-3, with dense catch records off Edwards Point, Golden Gardens, Shilshole Bay, and West Point. Quillback rockfish records reflected similar distributions. Black rockfish occurred in dense clusters off Elliot Point (reach 1), Edwards Point, and Point Wells (reaches 1-2), and Meadow Point and Shilshole Bay (reaches 2 and 3). Sparse catches of brown, greenstriped, bocaccio, yellowtail, redstripe, canary, and yelloweye rockfish have been collected off Meadow Point and Shilshole Bay (reaches 2 and 3). Miller and Borton (1980) did not observe widow, blue, China, and tiger rockfish in WRIA 8 nearshore habitats. Brown, copper, and quillback rockfish (no size/age class provided) were rare (occurred in <30 percent of samples) to common (30-70 percent of samples) in 25 m depth otter trawls made monthly off West Point in 1975 (Miller et al. 1976).

WRIA 9 – Historical records of rockfish species within the WRIA 9 nearshore area are well summarized through 1973 by Miller and Borton, and reflect some of the same relative abundance and distribution patterns as WRIA 8 (Miller and Borton 1980). Copper rockfish were common throughout the WRIA 9 nearshore, with records in all reaches except 10. Areas with particularly dense copper rockfish records include Alki Point (reach 4-5), Three Tree Point (reach 8), and Colvos Passage (reach 12). Quillback rockfish were less common in WRIA 9 nearshore habitats; several catches occurred at Alki Point (reach 4-5), Tramp Harbor (reach 9), the mouth of Quartermaster Harbor (reach 11), and Colvos Passage (reach 12). Brown rockfish have been observed south of Alki Point (reach 5) and in Seahurst Bay (reach 7). Bocaccio, redstripe, black, yellowtail, and yelloweye rockfish were observed south of West Point in Elliott Bay (reach 4), and greenstriped rockfish have been noted off Alki Point (reach 4-5). Miller and Borton (1980) did not record widow, blue, China, tiger, and canary rockfish in WRIA 9 nearshore habitats. Brown rockfish were rarely collected (<30 percent of samples) in monthly beach seine and shallow (5 m depth) otter trawls made off Alki Point (reach 4) in 1975; brown, copper, and quillback rockfish were also rare in similar collections made off Three Tree Point (reach 8) (Miller et al. 1976). In seasonal beach seines made throughout WRIA 9 nearshore habitats in 1982-1983, juvenile rockfish spp. (no species identification) occurred exclusively during summer and fall collections (Donnelly et al. 1984). Juvenile rockfish were collected in Seahurst Bay (reach 7; 3 – 23 fish/haul), south of Three Tree Point (reach 8; 1.5 – 19.5 fish/haul), Tramp Harbor (reach 9; 0.5 – 19 fish/haul), and east of Point Vashon on eastern Vashon Island (reach 9; 43.5 – 94.5 fish/haul) (Donnelly et al. 1984).

Reasons for Change

Rockfish in Puget Sound have been depleted due to growth overfishing, the chronic harvest of the largest fish in a population, which affects population fecundity and the quality of eggs and larvae produced (West 1997). Rockfish in Puget Sound harvest refugia were larger, more abundant, and had greater reproductive potential than those from nearby fished areas (Palsson and Pacunski 1995). Recruitment overfishing, which occurs when adult populations are reduced to such low levels that production is insufficient to maintain stocks, is also a suspected reason for decline in rockfish populations.

Stressors

Adults are susceptible to overfishing (see above) and habitat degradation due to their requirements for specific habitats. Populations may take longer to recover than other marine species because of their slow growth rate and late maturation. Juveniles are susceptible to the loss of critical nearshore habitat for settlement, feeding, and refuge. Rockfishes are likely susceptible to fragmentation of the links between nearshore marine habitats that are critical to various life history stages.

Data Gaps

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.