Chapter 4
Factors Affecting Species

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Chapter 4 — Factors Affecting Species

Chapter 4 describes the direct and indirect effects of covered activities on species and their habitats; the level of effects associated with the activities; and how the extent of the impact is calculated. The information in the following sections of Chapter 4 is from the “Potential Effects and Expected Outcomes Technical Paper” (November 2007)

Section 4.1 describes the life history, habitat use, and distribution of covered species.

Section 4.2 explains the analysis that was completed to arrive at the qualitative descriptions and quantitative values of potential effects presented.

Section 4.3 explains the potential effects on habitat types of covered activity on state-owned aquatic lands.

Section 4.4 addresses potential effects and expected outcomes specific to covered species if conservation measures are applied.

4.1 Covered species: life history, habitat use, and distribution

The Aquatic Lands Habitat Conservation Plan has identified a list of covered species that depend on habitats available on state-owned aquatic lands for a significant portion of their life history. Chapter 1 presented information on the species selection process and described the types of habitat they use. It also described geographic ecoregions throughout the state of Washington. These ecoregions are used throughout this section to describe distribution ranges of covered species.

Amphibians and turtles

Columbia spotted frog *(Rana luteiventris)*

Life history

Columbia spotted frogs range between 5 and 10 centimeters (2–4 inches) in length and reach sexual maturity between the ages of 2 and 6 years, with females breeding every 1 to 3 years in the spring (Johnson & O'Neil, 2001; NatureServe, 2005a). The species has a maximum life span of 10 to 12 years and lives near permanent water (Bull, 2005; Johnson & O'Neil, 2001; Lannoo, 2005; NatureServe, 2005a; Nussbaum et al., 1983; Stebbins, 1966). Clutch sizes range between 150 and 2,400 eggs, with the larvae (tadpoles) emerging within 8 to 21 days. While most tadpoles metamorphose in mid- to late summer, northerly populations or those at higher elevations may metamorphose as late as October or November (Lannoo, 2005). Tadpoles feed on algae and other vegetation, organic debris, and zooplankton, while adult frogs feed on insects, mollusks, crustaceans, and spiders (Johnson & O'Neil, 2001; Nussbaum et al., 1983). This frog hibernates during the winter, after burrowing into mud at the bottom of ponds and lakes (Pilliod et al., 2002).

Habitat use

Spawning and incubation occur in permanent waters, 10 to 20 centimeters in depth (4–8 inches), of most aquatic habitats occupied by the species, although only slow-moving reaches of riverine habitat are used for this purpose (Johnson & O'Neil, 2001; Lannoo, 2005; Nussbaum et al., 1983). Spawning is temperature-dependent and generally occurs from March through June, with egg masses deposited as free-floating clusters (Bull, 2005; Hallock & McAllister, 2005a; NatureServe, 2005a). Adults move overland between ephemeral and permanent water sources, with juveniles moving greater distances than mature adults (Funk et al., 2005; Johnson & O'Neil, 2001; Stebbins, 1966). Research indicates that females move up to 1,030 meters (0.5 miles) from breeding habitats, while males move less that 200 meters (0.1 miles) (Pilliod et al., 2002). Maximum distances recorded are equal to 5,750 meters (3.5 miles) (Funk et al., 2005).

Columbia spotted frog. Photo: Lisa Hallock

Distribution

The historic range of the Columbia spotted frog extends from southern Alaska through British Columbia and western Alberta to Washington, Oregon, Nevada, and Utah (Stebbins, 1966). In Washington, the species occurs on the eastern side of the Cascade Mountains in the Okanogan and Columbia Plateau ecoregions. While populations in the Columbia Plateau are small and scattered, this frog is common in the northern and eastern portions of its range in Washington (Hallock & McAllister, 2005a).

Northern leopard frog *(Rana pipiens)*

Life history

Northern leopard frogs grow to 5 to 10 centimeters (2–4 inches) in length and have a maximum life span of 5 to 9 years, with females becoming sexually mature at 2 to 3 years of age (AmphibiaWeb, 2007a; Lannoo, 2005; McAllister et al., 1999; NatureServe, 2005b). The northern leopard frog deposits between 645 and 7,648 eggs per spawning event, with tadpoles emerging within 2 to 17 days and undergoing metamorphosis within 3 to 6 months (Lannoo, 2005). Although little is known about overland movements in Washington, these frogs migrate to and from breeding ponds and overwintering water bodies (Johnson & O'Neil, 2001; Hallock & McAllister, 2005b; McAllister et al., 1999).

Adults of this species are entirely carnivorous and regularly feed on beetles, flies, ants, damselflies, dragonflies, grasshoppers, spiders, and small vertebrates such as birds, snakes, and other frogs (Johnson & O'Neil, 2001; Nussbaum et al., 1983). While developing in shallow nearshore waters, leopard frog tadpoles graze on periphytic (attached) algae; metamorphosis is completed during the summer of the first year (Zeiner et al., 1988). After metamorphosis, young frogs may emigrate from their natal ponds to permanent waters, such as a lake or stream. Leopard frogs usually overwinter underwater among stones, sunken logs, or leaf litter at the bottom of ponds, lakes, and streams (Hallock & McAllister, 2005b; McAllister et al., 1999)

Habitat use

While this species depends on upland vegetation as *refugia* from predators, it ranges widely across a variety of habitats, including wet meadows, grassy woodlands, and hay fields (McAllister et al., 1999; Nussbaum et al., 1983; Stebbins, 1966). Northern leopard frogs spawn from April through June in shallow water with emergent or submerged vegetation, such as cattails and sedge marshes (Johnson & O'Neil, 2001; Nussbaum et al., 1983; Zeiner et al., 1988). Northern leopard frogs lay egg masses, which they attach to emergent vegetation, in water depths of less than 65 centimeters (26 inches) and exposed to sunlight (McAllister et al., 1999; Zeiner et al., 1988).

Northern leopard frog. Photo: K. McAllister

Breeding ponds are generally greater than 1.5 meters (5 feet) in depth, with gradually sloping shorelines. They are characterized by substantial amounts of emergent and submerged vegetation for egg masses, shelter from predators, and tadpole grazing, and open waters that warm quickly and dry up periodically, thereby eliminating fish. Adult foraging habitat is generally associated with un-mowed pastures, shallow marshes, or meadows (McAllister et al., 1999).

Distribution

In Washington, the northern leopard frog historically occurred on the eastern side of the Cascade Mountains in both the Columbia Plateau and Okanogan ecoregions. Reports of the northern leopard frog include sites near the Pend Oreille River, the Potholes Reservoir, and Alder Creek (Klickitat County), and the Columbia, Snake, Spokane, and Walla Walla rivers.

Oregon spotted frog *(Rana pretiosa)*

Life history

Adult Oregon spotted frogs reach lengths of 4 to 10 centimeters (1.5–4 inches) and live to approximately 5 years of age (Hallock & McAllister, 2005c; Lannoo, 2005). Males reach sexual maturity in their second year, while females mature at 2 to 3 years. Females frequently lay their eggs in communal masses of 10 to 75, with individual masses containing between 500 and more than 1,000 eggs. Larvae hatch within 18 to 30 days, and tadpoles undergo metamorphosis 3 to 4 months later (Lannoo, 2005; McAllister & Leonard, 1997).


Oregon spotted frog. Photo: W.P. Leonard

The Oregon spotted frog has two types of annual migration pattern: Wet-season migrations occur infrequently and between widely separated breeding pools. In contrast, dry-season migrations are likely a response to changing water levels, with the migrations occurring more frequently and between pools that are closer together (Watson et al., 2000).

Adults forage in and under water, primarily consuming beetles, spiders, flies, and ants, although the species has been observed eating newly metamorphosed red-legged frogs and juvenile western toads (Johnson & O'Neil, 2001; Pearl & Hayes, 2002). Tadpoles graze on algae and plant detritus. Oregon spotted frogs overwinter in waters generally free of ice, burying themselves in the sediment at the base of plants during the coldest periods (Hallock & McAllister, 2005c; Lannoo, 2005; Watson et al., 2000).

Habitat use

The Oregon spotted frog is found in marshy edges of ponds and lakes or overflow pools associated with streams (Nussbaum et al., 1983; Stebbins, 1966). In Washington, the species occurs in large, shallow, wetland systems associated with streams and beaver impoundments. Breeding occurs from February to March in seasonally flooded margins of wetlands, with unattached egg masses laid in areas with little or no vegetative shading (Hallock & McAllister, 2005c; Johnson & O'Neil, 2001; Nussbaum et al., 1983). Adults prefer deeper waters, under open canopies, and rarely venture further than 2 meters (6.5 feet) from surface water. Tadpoles prefer warm shallow water, with dense emergent and submerged vegetation (Lannoo, 2005).

Distribution

The historic range of the Oregon spotted frog extends from British Columbia southward through the Puget Trough and the Willamette Valley, and along the Cascades to the Pit River watershed in northern California (Green et al., 1997; Hallock & McAllister, 2005c). In Washington, the frog is found in both the Puget Trough and East Cascade ecoregions at elevations from sea level to 610 meters (2,000 feet) (Johnson & O'Neil, 2001). Only six populations are currently known to exist in Washington: four in Thurston County in the Black River watershed and two in Klickitat County (Hallock & McAllister, 2005c) .

Western toad *(Bufo boreas)*

Life history

Adult western toads reach lengths of 5 to 14 centimeters (2–5.5 inches) and live to be about 10 years of age, with sexual maturity occurring at 2 to 6 years (AmphibiaWeb, 2007b; Lannoo, 2005). One toad lays an average of 5,200 eggs in double stranded strings during each spawning event. Embryos hatch within 3 to 10 days, and tadpoles undergo metamorphosis during their first summer (Lannoo, 2005; Leonard et al., 1993).

Although little is known about the migration behavior of this species, females have been observed up to 2,600 meters (1.6 miles) from breeding sites, with the documented movements of males covering shorter distances (Johnson & O'Neil, 2001). Adults of this species feed primarily on insects, but they also eat spiders, centipedes, sowbugs, crayfish, and earthworms. Tadpoles graze on algae and detritus. Hibernation typically occurs from November through April, but the length of time varies with location and temperature (Johnson & O'Neil, 2001). Observations of some toads reveal that they hibernate in terrestrial locations, although little information is available in the general literature regarding hibernation (Nussbaum et al., 1983).

Habitat use

In Washington, spawning and incubation occur in almost any standing water from February through July (Zeiner et al., 1988). Strings of eggs are attached to submerged and emergent vegetation or laid directly on the substrate in shallow ponds, lakes, slow-moving reaches of streams, springs, reservoirs, stock ponds, canals, and roadside ditches (Hallock & McAllister, 2005d; Johnson & O'Neil, 2001). When not breeding, this species is found primarily in terrestrial habitats, including grasslands, scrublands, woodlands, forests, and mountain meadows (Nussbaum et al., 1983; Stebbins, 1966; Vander Haegen et al., 2001). It can also occur in low-density urban habitats with irrigated landscaping (Ferguson et al., 2001). Western toads depend on loose soils for protection from predators and to prevent dehydration; they are known to use burrows of other animals for the same purposes (Vander Haegen et al., 2001).

Western toad. Photo: Lisa Hallock

Distribution

While the current and historic distribution of western toads includes the entire state of Washington, they appear to be absent from the south-central portion of the Columbia Plateau ecoregion (Hallock & McAllister, 2005d; Nussbaum et al., 1983; Stebbins, 1966). The species occurs from sea level to elevations as high as 2,255 meters (1.4 miles) in the mountains (Martin 2001; Stebbins 1966).

Western pond turtle *(Actinemys marmorata)*

Life history

Western pond turtles (also known as Pacific pond turtles) have an estimated lifespan of between 50 and 70 years, reaching reproductive maturity at over 10 years of age or at a carapace length of 135 to 140 millimeters (5.3–5.5 inches) (Hays et al., 1999). They nest from May to mid-July, with females burying between 2 and 13 eggs in soils with little or no vegetative covering (Hays et al., 1999; Johnson & O'Neil, 2001; Nussbaum et al., 1983; Stebbins, 1966). Incubation times range between three and four months. These turtles usually nest within 100 meters (328 feet) of water, but occasionally will nest up to 400 meters (1,312 feet) from water (Hays et al.,1999; Nussbaum et al., 1983). Similar to other turtles, the gender of the hatchlings depends on the temperature of the surrounding soils.

Western pond turtle. Photo: W. P. Leonard

Western pond turtles are opportunistic feeders, foraging in or under water for invertebrates (insects, earthworms, mollusks, and crayfish), vertebrates (fish, tadpoles, and amphibians), and carrion (small mammals, birds, amphibians, and turtles). Adults of the species overwinter in the muddy bottoms of lakes or ponds, or in upland habitats adjacent to water bodies (Nussbaum et al., 1983). Observation of juveniles in one study suggests they may also overwinter in the water (Hays et al., 1999).

Habitat use

This aquatic turtle occurs in streams, ponds, lakes, and both permanent and ephemeral wetlands (Nussbaum et al., 1983; Stebbins, 1966). Pond turtles will migrate overland, and may slow their metabolism to help conserve water during hot or dry periods (Johnson & O'Neil, 2001). Because they are *ectothermic*, pond turtles utilize floating vegetation, cattail mats, logs, rocks, mud flats, and sandbanks to bask in the sun (Hays et al., 1999). In large rivers, the pond turtle is located near the banks or in adjacent backwater habitats, where the current is relatively slow and basking sites are abundant (Stebbins, 1966).

A variety of substrates are found in the habitat range used by western pond turtles, including rocks, boulders, cobbles, gravel, sand, mud, decaying vegetation, and combinations of these (Stebbins, 1966). Vegetative cover used by pond turtles includes areas with little or no emergent vegetation; areas with abundant emergent vegetation; sites with no emergent vegetation, but with abundant submerged vegetation; and disturbed habitats where large mats of algae are the only aquatic vegetation present. Areas with dense shade generally lack basking sites are unsuitable habitat for pond turtles (Hays et al., 1999).

Distribution

Within Washington, western pond turtles historically occurred in the Puget Trough ecoregion and in the Columbia River Gorge from sea level up to elevations near 300 meters (984 feet) (Hays et al., 1999; Hallock & McAllister, 2005e). There are four populations in the Columbia River Gorge, two naturally occurring and two that have been established through reintroductions. There are two populations in Puget Sound that have been established through reintroductions.

Birds

Black Tern *(Chlidonias niger)*

Life History

Black terns are migratory birds that use eastern Washington as breeding grounds and as resting areas during their migration to and from their wintering grounds in Central and South America. In Washington, terns lay eggs between May and June. A clutch generally contains two to three eggs (Dunn and Agro 1995; NatureServe 2006b). Chicks hatch from late June to late July, with both parents tending the chicks until they *fledge* at 2 to 3 weeks. Adults and young both feed on insects, spiders, small crustaceans, and fish, with the proportions of insects to fish in the diet varying with availability (Dunn & Agro, 1995; NatureServe, 2006b).

Habitat use

Black terns are semi-colonial and generally nest in emergent vegetation (such as cattails and bulrushes) along prairie sloughs, rivers, lakes, impoundments, wet meadows, and marshes; occasionally, they nest on mats of floating vegetation or wood (NatureServe, 2006b). In northeastern Washington, the birds nest in major river valleys and other suitable habitats up to 914 meters (2,998 feet) in elevation (U.S. Fish and Wildlife Service, 1999). Black terns nest in areas with shallow water, usually within 1 to 2 meters (3.3–6.5 feet) of open water (NatureServe, 2006b). During fall and spring migrations between their wintering habitats in Central and South America and breeding habitats in North America, black terns use freshwater lakes, rivers, and interior wetlands in the U.S.

Black tern. Photo: Mike Yip

Distribution

Although this species is common in eastern Washington during migrations, nesting birds are less common (Wahl et al., 2005). Black terns breed primarily on the east slope of the Cascade Mountains within the Okanogan, Columbia Plateau, Canadian Rockies, and Blue Mountains ecoregions (Smith et al., 1997).

Common loon *(Gavia immer)*

Life history

Common loons breed in the summer. Both parents tend yearly clutches of one to three eggs. The chicks hatch within 29 days (on average) and are then transferred to the parents' backs for an additional 3 weeks. Adults continue to feed and defend their young until the chicks are roughly 11 weeks old and capable of flight (NatureServe, 2006c). Adults are flightless during a few weeks in mid-winter (February) and are therefore vulnerable to environmental disturbances (McIntyre & Barr, 1997).

Habitat use

Common loons generally nest on clear, *oligotrophic* lakes with complex rocky shorelines, numerous bays and islands, and deep inlets, but they will also use floating bogs if fish are present

(Richardson et al., 2000). Preferred nesting sites are on island or shoreline edges that are within 1.5 meters (5 feet) of water, sheltered from winds, and positioned within the vegetation to allow a view of the pairs' territory (McIntyre & Barr, 1997).

The species winters primarily in nearshore coastal marine waters—over shoals and in sheltered bays, inlets, and channels—with some individuals on freshwater lakes, reservoirs, and low-gradient river valleys. Winter distributions are variable, but are related to the abundance and stability of the forage base, protection from storms, and turbidity (Spitzer 1995). Birds in Washington are concentrated in Puget Sound and the Strait of Juan de Fuca (Richardson et al., 2000).

Common loon. Photo: U.S. Fish and Wildlife Service

Prior to their migration during April and again from late October to early December, this species aggregates on low-gradient river valleys and in littoral or limnetic zones of larger lakes and reservoirs. These staging areas are concentrated in habitats that combine abundant food with shelter from wind-generated waves (McIntyre & Barr, 1997).

Distribution

Within Washington, common loons nest on lakes and reservoirs in the Okanogan, North Cascades, East Cascades, and Puget Trough ecoregions, while non-nesting birds are found during the summer throughout the state (Richardson et al., 2000). Their winter distribution includes coastal and inland marine waters in the Northwest Cascade and Puget Trough ecoregions, with a few birds found on interior reservoirs, rivers, and lakes (Richardson et al., 2000).

Harlequin duck *(Histrionicus histrionicus)*

Life history

Harlequin ducks generally nest from mid-April through August, laying clutches of 5 to 7 eggs and incubating them for 27 to 30 days (Seattle Audubon, 2002). The chicks fledge within 5 to 6 weeks, whereupon both the young and their mother move to coastal wintering areas (Lewis & Kraege, 2004; NatureServe, 2006d; Robertson & Goudie, 1999). Males and non-breeding females are flightless during late July to mid-August, with breeding females generally flightless during September (Robertson & Goudie, 1999). Fall migration occurs from late June through mid-September.

Habitat use

Harlequin ducks build nests on the ground adjacent to relatively undisturbed fast-flowing streams with cobble- to boulder-size substrate and vegetated banks in riparian, subalpine, or coastal habitats (Lewis & Kraege, 2004). Preferred nesting habitat includes low-acidity streams with high invertebrate density, steep banks with vegetation, braided channels with small islands, and gravel and sand bars (Robertson & Goudie 1999). Prior to their spring migration (mid-March through May), many harlequin ducks aggregate at Pacific herring spawning locations (Vermeer et al., 1997), although it is unclear if these aggregations are pre-migratory staging or simply a response to an abundant food source. This species will also forage on a variety of mollusks (snails, periwinkles, limpets, chitons, and blue mussels) and fish, such as small sculpins and gunnels (Gaines & Fitzner, 1987; Vermeer, 1983).

In Washington, migratory harlequin ducks occur primarily in marine water less than 1 meter (3.3 feet) deep containing eelgrass (Zostera spp.) and kelp communities, and occasionally over sand or mudflats. Winter distributions are variable, but are related to the abundance of available intertidal and subtidal invertebrate forage species, with crustaceans, amphipods, isopods, and barnacles preferred.

Distribution

An estimated 400 harlequin duck pairs nest beside fast-flowing mountain streams in the Olympic and Cascade Ranges and in northeastern Washington (Robertson & Goudie, 1999; Wahl et al., 2005). Although there are questions surrounding the sightings, harlequin ducks may also occur in the southeastern corner of Washington in the Blue Mountains ecoregion (Lewis & Kraege, 2004). An estimated 3,000 harlequin ducks winter along the outer coast and in northern Puget Sound, northern Hood Canal, the Strait of Juan de Fuca, and the San Juan Archipelago (Lewis & Kraege, 2004; Robertson & Goudie, 1999.

Harlequin duck. Photo: L. Barnes

Many birds that nest in Washington molt and winter in the Strait of Georgia, British Columbia, while some harlequins that molt and winter in Washington nest in interior British Columbia, Alberta, Idaho, Wyoming, and Montana (Lewis & Kraege, 2004; Smith & Smith, 2003).

Marbled murrelet *(Brachyramphus marmoratus)*

Life history

Marbled murrelets breed in the early spring. Between April and July, each female lays a single egg, which is then tended by both parents. Incubation lasts for approximately 30 days, with the chick fledging in roughly 4 weeks (Miller et al., 1997). The birds forage in saltwater within 2 to 5 kilometers (1–3 miles) of shore in protected coastal and nearshore waters and within the top 50 meters (164 feet) of the water column (Thompson, 1999).

Habitat use

Although marbled murrelets are seabirds, they nest in old-growth coniferous forests and travel up to 80 kilometers (50 miles) to feed their young. The species feeds on small schooling fish, such as Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea pallasi*i), surf smelt (*Hypomesus pretiosus*), and shiner surfperch (*Cymatogaster aggregata*), as well as rockfish (*Sebastes spp.*) and a host of marine invertebrates, including squid and shrimp (Nelson,1997). During breeding season, they may also feed on juvenile salmon (*Oncorhynchus spp.*) in freshwater lakes (Nelson, 1997). Although foraging murrelets are generally solitary, individuals may aggregate where Pacific herring are spawning (Speich & Wahl, 1989).

Distribution

The remaining marbled murrelet populations in Washington occur mainly in northern Puget Sound and the northern Pacific Coast (Speich & Wahl, 1995). While at-sea distributions vary temporally and spatially, there is a general shift in winter abundance eastward from the Strait of Juan de Fuca to Puget Sound and the San Juan Islands during the fall and winter, with British Columbia populations moving south to Puget Sound (Speich & Wahl, 1995). Distribution and abundance during foraging may be influenced by distance from the nest—usually less than 20 kilometers (12 miles)—as well as physical and biological processes related to prey concentration, such as upwelling, outflow of large rivers, shelves at mouths of inlets, shallow banks, rip currents, tidal eddies, and kelp beds (Nelson, 1997). Abundance decreases with increasing distance from the shoreline, and juvenile birds tend to remain closer to shore (Speich & Wahl, 1995).

Marbled murrelet. Photo: Oregon State University

Western snowy plover *(Charadrius nivosus nivosus)*

Life history

Western snowy plovers have an average life span of 3 years, reaching sexual maturity at one year of age. Nesting occurs from late April to late June (Wahl et al., 2005), with females laying two to three clutches of three eggs annually (Page et al., 1995). Incubation lasts approximately one month, and the chicks fledge within 31 days (Warriner et al., 1986). Although both parents tend the eggs, females frequently abandon the chicks in search of a new mate, leaving the male to tend to the chicks until they fledge (NatureServe, 2006e; Warriner et al., 1986).

Western snowy plover. Photo: M. L. Baird

Habitat use

Pacific Coast western snowy plovers prefer flat, sandy areas with little or no vegetative cover, such as barrier beaches, dry lake beds, and salt flats (Palacios et al., 1994; Wilson-Jacobs & Meslow, 1984). The birds generally nest above the high-tide line on coastal beaches, sand spits, dune-backed beaches, and sparsely vegetated dunes; along beaches at creek and river mouths; and on saltpans at lagoons and estuaries. They secondarily nest on bluff-backed beaches, dredge-spoil piles, salt-pond levees, dry salt ponds and river bars (Palacios et al., 1994; Powell, 2001).

Distribution

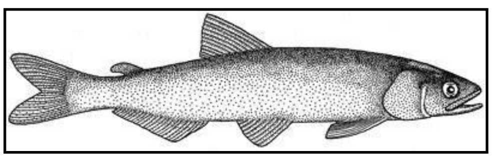
Western snowy plovers occur in several western states (Arizona, California, Colorado, Kansas, Nevada, New Mexico, Oklahoma, Oregon, Texas, Utah, Washington, and Wyoming), but only members of the Pacific Coast population (California, Oregon, and Washington) are listed as threatened (Code of the Federal Regulations, 1993). Historically, there were breeding snowy plovers in at least five areas in western Washington; however, there are now only three known active breeding grounds: the Damon Point/Oyhut Wildlife Area in Grays Harbor County and Midway Beach and Ledbetter Point/Gunpowder Sands in Pacific County (Richardson, 1995. All three breeding sites are federally designated critical habitat (Code of Federal Regulations, 2005). No nesting has been documented in eastern Washington, although several individuals have been observed there since 1967 (Richardson, 1995).

Fish

Eulachon/Pacific smelt *(Thaleichthys pacificus)*

Life history

Eulachon are important prey for many species of fish, marine mammals, and birds along the Pacific Coast (Sigler et al., 2004). The species is anadromous, becoming sexually mature at 2 to 5 years of age and returning to freshwater to spawn from late winter to early summer (Wydoski & Whitney, 2003). These fish are broadcast spawners: Each female deposits between 17,000 and 60,000 eggs, which hatch in approximately one month and wash out to sea (McLean et al., 1999; Wydoski & Whitney, 2003). Eulachon are thought to die after spawning, generally washing out to the ocean or being consumed locally by birds, mammals, and fish, such as sturgeon. Despite their widespread occurrence, very little is known about eulachon during their saltwater phase, except that they are known to prey heavily on euphausiid shrimp in shallow waters and are often bycatch in the shrimp fishery (Wydoski & Whitney, 2003).



Graphic: Alaska Fish and Game

Habitat use

Adult eulachon are *pelagic*, found throughout the Pacific Ocean water column at depths of 80 to 200 meters (262–656 feet). Eulachon generally spawn in lower gradient reaches with coarse sediments, during strong freshets, and at night (Fisheries and Oceans Canada, 2004; McLean et al., 1999; Wydoski & Whitney, 2003).

Distribution

Eulachon naturally occur from the Pribilof Islands in the Bering Sea south to Monterey Bay, California (Eschmeyer & Herald, 1983). In the Pacific Northwest, the species spawns in the Fraser and Nooksack rivers, with the strongest runs occurring in the Columbia River below Bonneville Dam and in the Cowlitz, Grays, Kalama, Lewis, and Sandy rivers (National Marine Fisheries Service, 2008a; Wydoski & Whitney, 2003). Listed federally as threatened in 2010, with critical habitat designated in 2011 (50 Code of Federal Regulations 226), the southern population of the species spreads across three states (California, Oregon, and Washington).

Pacific herring *(Clupea pallasi)*

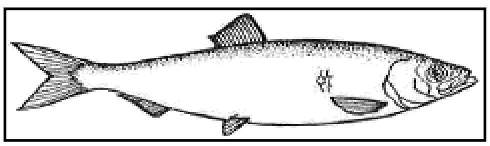
The Washington Department of Fish and Wildlife recognizes 18 distinct herring stocks in the Puget Trough ecoregion and two in the Northwest Coast ecoregion (Willapa Bay and Grays Harbor), with the populations delineated based on spawning grounds (Lemberg et al., 1997; Stick, 2005; Stout et al., 2001; Washington Department of Fish and Wildlife, 1997b).

Life history

Herring are primary and secondary consumers in all their habitats and are a critical keystone species with trophic links to a large number of other marine plants, fish and mammals. They reach sexual maturity at 2 to 3 years of age, spawning yearly until they die (Washington Department of Fish and Wildlife, 1997b). Total life span for this species is approximately 9 years, although some individuals have been aged at greater than 15 years (Lassuy, 1989).

Habitat use

Adult herring are pelagic, moving to holding areas adjacent to their spawning grounds shortly before spawning occurs. Depending on the stock, spawning can begin as early as January and last until June (Table 4.1), with the eggs deposited primarily on eelgrass at depths of up to minus 12 meters (40 feet) (Penttila, 2007; Washington Department of Fish and Wildlife, 1997b). Herring eggs hatch within 2 to 3 weeks, and larvae are distributed by local currents (Lassuy, 1989). Following metamorphosis, juvenile herring use the same ecosystem and habitats as adults.



Pacific herring. Graphic: Washington Department of Fish and Wildlife

Distribution

The geographic range of Pacific herring includes most of the waters over continental shelves in the northeast Pacific Ocean from Baja California, Mexico, to the Bering Sea and northeast to the Beaufort Sea, as well as the Asian coast from the Arctic Ocean to Japan (Washington Department of Fish and Wildlife, 1997b). Within Washington, the species occurs in all marine waters and uses both state- and privately owned shorelines for spawning.

Table 4.1. Pacific herring spawning season windows (Penttila, 2007). Shaded boxes indicate when spawning occurs.

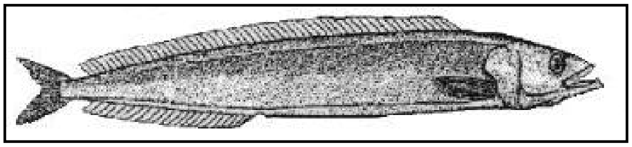
Region	Spawning Area	January	February	March	April	May	June
Puget Trough	Squaxin Pass	■	■	■			
	Wollochet Bay	■	■	■			
	Quartermaster Harbor	■	■	■	■		
	Port Orchard	■	■	■	■		
	South Hood Canal	■	■	■			
	Quilcene Bay	■	■	■	■		
	Port Gamble	■	■	■	■		
	Kilisut Harbor		■	■	■		
	Port Susan	■	■	■	■		
	Holmes Harbor		■	■	■		
	Skagit Bay		■	■	■		
	Fidalgo Bay	■	■	■	■		
	Samish/Portage Bay		■	■	■		
	San Juan Island	■	■	■	■		
	Semiahmoo Bay	■	■	■	■		
	Cherry Point			■	■	■	■
	Discovery Bay		■	■	■		
	Dungeness/Sequim Bay	■	■	■			
Northwest Coast	Willapa Bay	■	■	■			

Pacific sand lance *(Ammodytes hexapterus)*

Sand lance are especially important in the diets of juvenile salmon; the sand lance comprises up to 60 percent of the diet of juvenile Chinook salmon (Washington Department of Fish and Wildlife, 1997c).

Life history

Pacific sand lance spawn from November through February, with peak spawning occurring early in the period (Penttila, 2007). Wave action disperses eggs across the intertidal zone, and incubation lasts approximately 4 weeks (Lemberg et al., 1997). Currents disperse the larvae, which form schools when they reach approximately 22 millimeters (0.8 inches) in length (Washington Department of Fish and Wildlife, 1997c).



Pacific sand lance. Graphic: Washington Department of Fish and Wildlife

Habitat use

Sand lance spawn on sandy intertidal beaches with freshwater seeps at tidal elevations from mean higher-high water to plus 2 meters (7 feet) (Lemberg et al., 1997). Both adults and juveniles use sandy, nearshore substrates for burrowing at night, and open water areas for foraging during daylight (Penttila, 2007; Washington Department of Fish and Wildlife, 1997c).

Distribution

Pacific sand lance have a wide distribution and are common in Puget Sound, the Strait of Juan de Fuca, and Washington's coastal estuaries. Since 1989, the Washington Department of Fish and Wildlife has documented spawning activity along about 130 miles of Puget Sound shoreline (Lemberg et al., 1997; Washington Department of Fish and Wildlife, 1997c.

Surf smelt *(Hypomesus pretiosus)*

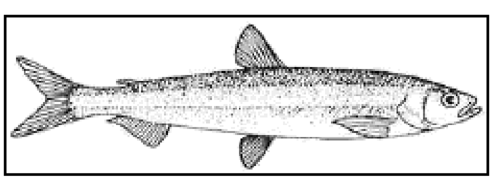
Although their movements are generally unknown, surf smelt are a common nearshore species (Penttila, 2007; Washington Department of Fish and Wildlife, 1997d).

Life history

Surf smelt life history is largely unknown. Thought to have maximum life spans of 4 to 5 years, smelt reside in the nearshore adjacent to their natal spawning grounds throughout their lives (Penttila, 2007; Washington Department of Fish and Wildlife, 1997d). Most adults spawn in their second year, but a small portion spawn after one year (Lemberg et al., 1997; Penttila, 1978; Washington Department of Fish and Wildlife, 1997d).

Habitat use

Surf smelt spawn throughout the year on intertidal beaches of mixed sand and gravel from about extreme high water to plus 2 meters (7 feet) in tidal elevation (Penttila, 2007). Spawning sites seem to be associated with areas containing freshwater seeps, with the eggs deposited near the waterline and hatching in one to two months (Washington Department of Fish and Wildlife, 1997d). Surf



Surf smelt. Graphic: Washington Department of Fish and Wildlife smelt larvae are planktonic and assume their adult body type after about three months. Juveniles continue to rear and school in nearshore areas (Penttila 2007; Washington Department of Fish and Wildlife, 1997d).

Distribution

Surf smelt range from Long Beach, California, north to Chignik, Alaska, with populations in Washington (Table 4.2) occurring throughout the nearshore ecosystem (Washington Department of Fish and Wildlife, 1997d).

Table 4.2. Surf smelt spawning season windows (Penttila, 2007)
Shaded boxes indicate when spawning occurs.

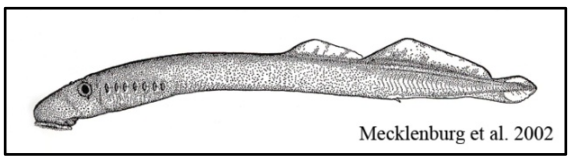
Region	Spawning Area	January	February	March	April	May	June	July	August	September	October	November	December
Puget Sound	Island County	■	■	■	■	■	■	■	■	■	■	■	■
	Birch/ Cherry Point	■	■	■	■	■	■	■	■	■	■	■	■
	Fidalgo Bay	■	■	■	■	■	■	■	■	■	■	■	■
	Dungeness Bay	■	■			■	■	■	■	■	■	■	■
	North Port Orchard	■	■							■	■	■	■
	Sinclair/ Dyes Inlet	■	■	■	■	■	■	■	■	■	■	■	■
	Quarter-master Harbor	■	■								■	■	■
	South Hood Canal	■	■							■	■	■	■
	South Puget Sound	■	■	■				■	■	■	■	■	■
	San Juan Islands	■	■	■	■	■	■	■	■	■	■	■	■

Region	Spawning Area	January	February	March	April	May	June	July	August	September	October	November	December
Northwest Coast	Pacific Coast												
	Grays Harbor												

Pacific lamprey *(Lampetra tridentate)*

Life history

Pacific lampreys are anadromous, and the adult form is parasitic, using its sucker-like mouthparts to remove body fluids from host organisms (marine fish and mammals). The species is the largest of the native lampreys, reaching a length of 76 centimeters (30 inches) and a weight of 450 grams (1 pound) (Wydoski & Whitney, 2003).



Pacific lamprey.

Adults spend 1 to 3 years in the ocean before returning to their natal streams to spawn. Migrations begin up to a year before spawning occurs, with the species overwintering in deep pools and reproducing in the spring (Wydoski & Whitney, 2003). Upon returning to freshwater, Pacific lamprey end parasitic feeding and rely exclusively on stored carbohydrates, proteins, and lipids until they spawn. Spawning occurs from February through July; lamprey that spawn in coastal streams do so earlier than lamprey further inland (Moser & Close, 2003).

Larvae (ammocoetes) hatch within approximately 20 days, burrowing into silty substrates and remaining within slow-moving reaches of streams, where they feed by filtering microscopic plants and animals out of the water (Moser & Close, 2003). Ammocoetes remain in freshwater for 4 to 7 years. They can reach a size of up to 17 centimeters (7 inches) before metamorphosing into their parasitic adult phase (Moser & Close, 2003). Metamorphosis occurs from July until November, and the newly metamorphosed lamprey may either move immediately to sea or remain in fresh water for up to 10 months (Wydoski & Whitney, 2003).

Habitat use

Pacific lamprey have been found from 9 to 100 kilometers (6 to 62 miles) offshore in waters as deep as 800 meters (2,645 feet), although they are more commonly located in water depths of 70 to 250 meters (230–820 feet) (Wydoski & Whitney, 2003). Nests are generally located in riffles or the tails of pools in moderate- to high-flow streams at depths of less than 1 meter (3 feet) (Moser & Close, 2003).

Distribution

Pacific lamprey range from Baja California to the Aleutian Islands in Alaska, and they are found along the eastern coast of Asia as far south as Japan (Wydoski & Whitney, 2003). In Washington

State, the species is found in most large rivers and streams along the coast, Strait of Juan de Fuca, and Puget Sound, and it occurs far inland in the Columbia, Snake, and Yakima rivers (Moser & Close, 2003; Wydoski & Whitney, 2003). Historically, Pacific lamprey were found as far upstream as Kettle Falls on the Columbia River and Spokane Falls on the Spokane River, but passage was blocked with the completion of Grand Coulee Dam in 1941, and in 1955, Chief Joseph Dam blocked an additional 52 miles of the Columbia (Wydoski & Whitney, 2003). Pacific lamprey are also located in streams along the southern, western, and northern boundaries of the Olympic Peninsula.

Rockfish *(Sebastes spp.)*

Rockfish are associated with rocky outcroppings and walls in both coastal and inland waters. Species frequently occupy the same location, but use different depths. This genus of fish is ovoviviparous, with females producing live young that undergo a pelagic phase before metamorphosing to juvenile life forms and beginning their gradual descent to their adult habitat. Although long-lived, the species distributions, life histories, and status are frequently not well documented or understood, and available data are generally the result of fishery trawls and recreational dives. No spatial data are available for the three species discussed here.

Bocaccio *(Sebastes paucispinis)*

Life history

The maximum life span for bocaccio is unknown. An estimated lifespan is up to 50 years; the fish reaches sexual maturity between 3 and 8 years of age (Love et al., 2002; National Marine Fisheries Service, 2008b). Mating generally occurs once a year: females store sperm for 4 to 6 weeks while their eggs develop (Wyllie-Echeverria, 1987). They produce between 20,000 and 2.3 million eggs per season (Phillips, 1964; Stanley et al., 2001). Bocaccio release larvae offshore during the winter months and remain in the water column for several months while transitioning to juvenile life form (Garrison & Miller, 1982;Wyllie-Echeverria, 1987).

Habitat use

Bocaccio most commonly inhabit steep slopes with sand and rocky substrates at depths between 50 and 250 meters (164–820 feet); larger fish occupy the deeper habitats (Love et al., 1990; Love et al., 2002; National Marine Fisheries Service, 2008b; Palsson et al., 2008; Starr et al., 2002). Bocaccio larvae remain in the water column for several months while transitioning to pelagic juveniles, and the juveniles then settle in shallow vegetated rocky areas (Garrison & Miller, 1982; National Marine Fisheries Service, 2008b). As they grow, they move to deeper water habitats with crevices and rocky holes (Garrison & Miller, 1982). Juveniles have been observed occupying areas of high relief and have also been associated with anthropogenic structures, including offshore oil platforms in southern California (Love et al., 2002). Bocaccio co-occurs with several other species of semi-pelagic rockfish, including yellowtail and widow rockfish, often caught in mid-water trawls.

Bocaccio *(Sebastes paucispinis)*. Photo: M. Conlin

Distribution

Bocaccio have been found on rocky outcroppings in the offshore waters of Washington, Central Puget Sound, Ports Gardner and Susan, and the Strait of Juan de Fuca (Love et al., 2002; Miller & Borton, 1980; Palsson et al., 2008). Canadian assessments have shown bocaccio to be abundant along the northwest coast of Vancouver Island (Committee on the Status of Endangered Wildlife in Canada, 2002). NOAA Fisheries listed Puget Sound bocaccio as endangered in 2010.

Canary Rockfish (*Sebastes pinniger*)

Life history

Canary rockfish can live more than 80 years (Wilkins et al., 1998). They reach sexual maturity between 7 and 8 years of age in Washington State. Mating occurs from September to March, with the peak off the Washington coast occurring in December and January (Methot & Piner, 2001). Females produce from 250,000 to over 2 million eggs per year (Love et al., 2002). The young are released into the water column from January to March (Westrheim, 1975).

Canary rockfish. Photo: Fisheries and Oceans Canada

Habitat Use

Adult canary rockfish are benthopelagic, forming loose schools in the water column over cobble, mud, and sand habitats interspersed in rocky structures from 80 to 200 meters (262–656 feet) in depth (Love et al., 2002; National Marine Fisheries Service, 2008b). Larvae are thought to remain in the plankton for up to four months, and juveniles gradually settle into benthic habitats associated with kelp beds or other high relief nearshore areas (Love et al., 1991; Love et al., 2002; Sampson & Stewart, 1994). Similar to other rockfish, juveniles move to deeper habitats as they grow larger (Boehlert, 1980).

Distribution

In Washington, canary rockfish were once common in Puget Sound, but now primarily inhabit the marine and the outer coast environments (Garrison & Miller, 1982). The Washington Department of Fish and Wildlife's current trawl, video, and scuba distribution data indicate that the species also inhabits the northern and central Sound and Northern Hood Canal (Palsson et al., 2008). NOAA Fisheries listed Puget Sound canary rockfish as threatened in 2010.

Yelloweye rockfish *(Sebastes ruberrimus)*

Life history

Yelloweye are among the largest and longest-lived of rockfish, with some individuals exceeding 100 years of age (Andrews et al., 2002). The species is slow growing and matures late, with both males and females reaching sexual maturity at about 20 years of age (Barss, 1989; Methot et al., 2002). Mating occurs once a year, generally in the winter, and females can produce between 1 and 3 million eggs per season (Garrison & Miller, 1982; Love et al., 2002). Females store sperm for 4 to 6 weeks while their eggs develop; after fertilization. The embryos develop for about 5 weeks before the young are released (Wourms, 1991) offshore between February and September, peaking at different times depending upon location in the range (Love et al., 2002).

Habitat use

Yelloweye rockfish occupy complex rock and wall habitats and are often associated with boulder fields, broken rock, overhangs, and crevices at depths ranging from 40 to 550 meters (131–1,804 feet) (Eschmeyer & Herald, 1983; Jagielo et al., 2003; Love et al., 2002; Yoklavich et al., 2000). As adults, they are sedentary demersal fish, generally found on or just above rocky substrates, and they are thought to possess strong site fidelity because of their sedentary nature (Love et al., 2002; Methot et al., 2002; Yamanaka et al., 2000). While little information exists for the early life-history stages of this species, larvae are thought to use the upper mixed zone of the ocean, where they are believed to be dispersed by physical transport processes (Love et al., 2002; Yamanaka et al., 2000). Yelloweye juveniles settle in shallow (50 to 100 meters or 164 to 328 feet) nearshore and offshore rocky areas (Yamanaka et al., 2000).


Yelloweye rockfish. Photo: G. McIntyre

Distribution

Yelloweye rockfish range from Unalaska Island in the Aleutian Islands of Alaska to the Baja California peninsula in northwestern Mexico; they are most abundant from central California to southeast Alaska (Hart, 1973; Love et al., 2002). In Washington, Yelloweye are found offshore along the outer coast and appear to be rare in Puget Sound (Love et al., 2002; Palsson et al., 2008). In 2010, NOAA Fisheries listed Puget Sound Yelloweye as threatened.

Salmonids

The life histories, habitat usage, and residency time of the eight salmonid species addressed by the Aquatic Lands Habitat Conservation Plan can differ greatly between and within species. Salmonids typically exhibit one or more of the following life history strategies:

- **Anadromous:** Spawning in freshwater; juvenile rearing in fresh- and saltwater; migrating to saltwater for adult rearing.
- **Adfluvial**: Spawning and juvenile rearing in freshwater tributaries; migrating to lakes or reservoirs for adult rearing.
- **Fluvial:** Spawning and juvenile rearing in small freshwater streams; migrating to larger rivers for adult rearing
- **Resident:** Entire life history occurs in smaller streams.

Anadromous, adfluvial, and fluvial life history types also exhibit distinct strategies (such as parr, fry, or yearling migration) for each life history type, as well as distinct life phases (upstream migration, spawning, incubation, emergence, juvenile rearing, downstream migration, and estuarine/marine/freshwater rearing to adult) (Beamer et al., 2005).

In general, migrating adult salmonids return to their natal streams to spawn. Each female excavates a pocket (redd) within the gravel substrate for her eggs, and one or more males fertilizes the eggs prior to the female covering them with loose gravel. The eggs incubate within the interstitial spaces in the gravel, with the larvae (alevins) feeding on their yolk sacks between hatching and emergence from the gravel as fry. Fry leave the gravel in search of food and protective cover, imprinting on the odor of their natal stream as they grow into juveniles.

Following their freshwater rearing period, juveniles begin their downstream migration. Anadromous species migrate to saltwater and acclimate through a process called smoltification. These smolts forage, rest, and grow in estuaries and nearshore habitats before they migrate to deeper water and the open ocean. Growth and development continues in the open ocean for a few months to several years, depending on the species. When mature, adult salmon migrate back to their natal streams, where they typically spawn and die (Salo & Cundy, 1987; Spence et al., 1996; Wydoski & Whitney, 2003). While fluvial and adfluvial populations exhibit behavior similar to that of anadromous forms, they remain in freshwater throughout their lives and generally spawn more than once.

Habitat requirements common to all salmonids

Clean gravels

Although the gravel size used for spawning and incubation varies by species, all salmonids require clean, stable gravel with interstitial spaces and low levels of fine sediment. In addition to providing *refugia* for *alevins*, gravel also increases stream productivity by providing habitat for plankton and aquatic invertebrates—an important food source for fish and other species.

Complex channel structure and large woody debris

Deep pools with vegetative cover and large woody debris are important as holding and resting areas for overwintering juveniles and migrating adults. Streams with more structure (logs, root wads, and undercut banks) support more fish, not only because they provide more usable habitat, but also because they provide more food and cover from predators (Scrivener & Andersen, 1982). Large woody debris also traps coarser sediment for spawning grounds and supports nutrient cycling by trapping fish carcasses and leaf litter (Meyer et al., 1988; Salo & Cundy, 1987; Spence et al., 1996).

Cool, well-oxygenated water

The preferred temperature range for most salmon and trout is 12 to 15° C (54–59° F), with juveniles susceptible to sublethal effects when the average stream temperature is above 15° C (59° F) (Bjornn & Reiser, 1991; Hicks, 2002). Areas of cold groundwater upwelling and *hyporheic* (river-influenced groundwater) exchange have been documented to be especially important for both bull trout spawning habitat and chum salmon (Baxter & Hauer, 2000; Frissell; 1999; Lister et al., 1980). Adequate riparian cover is also important for shading and maintaining cool stream temperatures (Frissell, 1999; National Research Council, 1996). In addition, cooler water temperatures help maintain adequate dissolved oxygen concentrations for all life stages: The Washington State Department of Ecology defines the minimum dissolved oxygen requirement for salmonids as 6.5 milligrams per liter (Washington Administrative Code 173-201A-200).

Estuarine and nearshore habitat

Beach seining surveys suggests that juvenile anadromous salmonids use estuarine/nearshore habitats year-round (Fresh, 2006; Redman et al., 2005). The abundant food supplies, wide salinity gradients, and diverse habitats associated with estuarine/nearshore areas are particularly valuable to anadromous fish for rearing, feeding, and *osmoregulatory* acclimation during the transition between freshwater and marine life stages (Healey, 1982; Macdonald et al., 1987; Simenstad, 1983). Estuarine/nearshore food webs are supported by abundant sources of detritus from submerged vegetation (such as eelgrass and kelp), salt marshes, and terrestrial vegetation, coupled with high levels of primary production in the shallow, nutrient-rich waters (Phillips, 1984). Forage fish species such as surf smelt, Pacific sand lance, and Pacific herring also depend upon beaches and intertidal areas for spawning (Hart, 1973; Washington Department of Fish and Wildlife, 1997b; 1997c; 1997d; Washington State Department of Ecology, 2007).

Functioning floodplains

In addition to helping dissipate floodwaters across the adjacent terrestrial landscape, functioning floodplains provide increased sediment storage capacity as well as a variety of aquatic habitats (such as sloughs, oxbow lakes, and wetlands). While some of these features have a permanent hydrologic connection to the main channel, many features exist only during seasonal connections or exposure during periods of higher flows. These slower water areas can provide seasonal spawning and rearing habitats outside of the main river channels, as well as foraging and overwintering habitat (Spence et al., 1996).

Habitat connectivity

While habitat connectivity is an important consideration for all species, the diversity of use of salmonid habitat makes connectivity a critical issue for their survival. Connectivity gives salmonids access to natal spawning grounds, the ability to move between different rearing habitats, and escape from adverse conditions (including high water temperatures, fluctuating flows, and high turbidity), and it allows populations to recolonize areas after catastrophic events. While both natural features (such as floods and logjams) and man-made structures (such as dams and roads) can change habitat connectivity, the degree to which natural features block access generally varies seasonally. Loss of connectivity from man-made structures is generally permanent and leads to the loss of large areas of previously available habitat.

Low turbidity

High concentrations of suspended solids reduce light penetration, leading to a reduction in algal productivity and nutrients for salmonids. Suspended particulate matter may also physically abrade fish gills, decreasing the ability of the fish to breathe (Spence et al., 1996).

Natural stream flows

Adult migration and spawning depends on the natural and unaltered stream flow regimes. Peak flows beyond natural levels may cause increased movement of large woody debris and bed materials (such as gravel, cobble, and boulders), decreasing egg and fry survival by increasing channel scour, bank erosion, and sedimentation. Low summer flows can also affect both adult migration and juvenile rearing due to decreased dissolved oxygen concentrations, increased water temperature, reduced availability of habitat as a result of decreased water depths, and increases in predation associated with migrating fish being concentrated in available habitat.

The changes associated with both high and low flow events are important for the persistence of salmonid populations. High-flow events redistribute sediments in streams, flushing fine sediments from spawning gravels and allowing recruitment of gravels to downstream reaches. In addition, high flows are essential in the development and maintenance of healthy floodplain systems through deposition of sediments, recharge of groundwater aquifers, recruitment and transport of large woody debris, and creation of side channels. Low flows may also be important for establishing riparian vegetation on gravel bars and along stream banks, providing additional terrestrial food sources and habitat complexity (Spence et al., 1996).

Shoreline/riparian buffers

Both fresh- and saltwater shoreline buffers are important for maintaining bank stability, shading, and organic matter, as well as for recruitment of large woody debris. In addition to contributing leaf detritus, riparian vegetation produces insects that fall into the water and supplement juvenile salmonid diets (Murphy & Meehan, 1991). Riparian buffers are especially important as the source of large woody debris and thereby directly influence several habitat attributes important to salmonids, such as pool formation and maintenance, refugia, prey availability, and sediment storage (Forest Ecosystem Management Assessment Team, 1993; Spence et al., 1996).

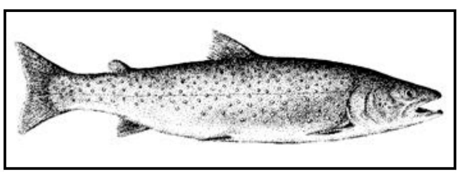
Wetlands

Wetlands play a vital role in watershed health as a whole, benefiting humans as well as other animals and plants. In addition to playing a key role in groundwater recharge, wetlands reduce flood events by slowing and storing storm flows. They also help convert inorganic nutrients into organic forms, breakdown pollutants, and store sediments (Mitsch & Gosselink, 1999; Reinelt & Horner, 1990; Richardson, 1994). Larger, deeper wetlands may also provide foraging and overwintering habitat for both resident and anadromous salmonids (Peterson, 1982).

Bull trout *(Salvelinus confluentus)*

Life history

Bull trout exhibit resident, fluvial, adfluvial, and anadromous life history forms, and individuals are capable of adopting more than one strategy during the course of a lifetime, as well as alternating strategies from year to year (Goetz et al., 2004). They reach sexual maturity at approximately 5 years of age, and they may live as long as 15 years (Donald & Alger, 1993; Wydoski & Whitney, 2003). Migratory forms of this species grow to lengths of 60 centimeters (23 inches), while lengths for resident forms range between 15 and 30 centimeters (6–12 inches) (Wydoski & Whitney, 2003).



Bull trout. Graphic: D. Pruett

Unlike salmon, bull trout are capable of spawning more than once (iteroparous). Females deposit between 100 and 10,000 eggs per spawning event. Spawning migrations of fluvial, adfluvial, and anadromous bull trout may begin as early as April, with spawning occurring in late summer and fall in small headwater streams at temperatures of 5 to 9° C (41–48° F) (Meehan & Bjornn, 1991). *Fecundity* ranges between 74 and 12,000, and often correlates with size and with resident fish having the fewest number of eggs (Wydoski & Whitney, 2003). Egg development is dependent on temperature: In colder waters, 6 months can pass before the alevins emerge (Meehan & Bjornn, 1991).

Although anadromous, adfluvial and fluvial bull trout typically rear in their natal streams for 2 to 4 years; resident fish may remain in their streams for their entire lives. Fluvial and adfluvial forms occupy a wide range of freshwater habitat types, including small, high-gradient and high-elevation streams; large, low-gradient and low-elevation streams; and the littoral zones of lakes. Anadromous bull trout migrate to saltwater. Approximately 84 percent of bull trout out-migrants captured in northern Puget Sound are 3 years old (Goetz et al., 2004).

Bull trout are opportunistic feeders, and their diet appears to vary seasonally with the availability of prey items (Goetz et al., 2004). Bull trout in lakes prey on invertebrates (such as chironomidae, ephemeroptera, trichoptera, and amphipods) and on smaller fish, such as mountain whitefish *(Prosopium williamsoni)*, lake whitefish *(Coregonus clupeaformis)*, and kokanee *(Oncorhynchus nerka)*. Exact diets depend on the availability of prey and on competitive pressures (Donald & Alger, 1993). While the resident form of this species may subsist entirely on insects, migratory forms become increasingly *piscivorous* as they increase in size.

Habitat use

Bull trout require cold, clean water. Although they are generally absent when temperatures rise above 18° C (64° F), bull trout have been observed in lakes with temperatures up to 20° C (68° F) (Donald & Alger, 1993). Increased stream temperatures negatively affect 11 of 34 subpopulations in the coastal Puget Sound population (U.S. Fish and Wildlife Service, 2004).

All bull trout spawn in small headwater tributaries, and resident forms often remain within a few hundred meters of their natal stream throughout their lives. Fluvial forms move into larger streams for growth and maturation, while adfluvial forms migrate to lakes and anadromous bull trout migrate to the more productive nearshore marine and estuarine wetland ecosystems for growth and maturation. *Young-of-the-year* use low velocity habitats, such as side channels and the lateral margins of streams, where they feed primarily on aquatic invertebrates and fish eggs (Wydoski & Whitney, 2003).

Bull trout in the nearshore ecosystem rely upon estuarine wetlands and favor irregular shorelines with unconsolidated substrates over rocky (consolidated) types of habitat (Goetz et al., 2004). Juveniles may rear within estuarine wetlands and tidally influenced distributary channels (Goetz et al., 2004). Juvenile bull trout have been observed using tidal sloughs in the Chehalis River and tidally influenced floodplain areas of Puget Sound (U.S. Fish and Wildlife Service, 2004). The distribution of bull trout in the nearshore ecosystem depends upon the abundance and distribution of food prey items, such as sand lance, juvenile salmonids, surf smelt, and Pacific herring.

Bull trout tend to use the nearshore ecosystem during the spring and late summer months, but do not forage exclusively in the marine environment. Observations of individuals show that bull trout migrate hundreds of kilometers through the nearshore ecosystem in order to forage in different river basins (Goetz et al., 2004).

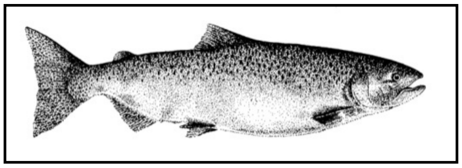
Distribution

Bull trout occur from the headwaters of the Yukon River in Alaska to the Klamath basin in Oregon (Dunham et al., 2003). In the Pacific Northwest, populations occur in the interior regions of the Columbia River and in parts of Montana, Idaho (the Wood River), Nevada (the Jarbridge River), and Canada (Bond, 1992). Bull trout are widely distributed in the state of Washington, and their current overall range is likely similar to their historical range (Washington Department of Fish and Wildlife, 2000). This habitat conservation plan covers both the Columbia River and coastal-Puget Sound evolutionarily significant units. In 2010, the U.S. Fish and Wildlife Service finalized critical habitat designations for bull trout in all of Washington State.

Chinook salmon *(Oncorhynchus tshawytscha)*

Life history

While the generalized life history of Chinook salmon is typical of anadromous Pacific salmon, the variety of life history types among Chinook salmon makes their habitat requirements particularly complex. The species is generally divided into three categories based on when the adults return to freshwater: spring run (March to May), summer run (June and July), and fall run (August and September) (Wydoski & Whitney, 2003). All Chinook spawn in the fall, with the spring runs spawning first in headwater streams, followed by



Chinook salmon. Graphic: D. Pruett

summer Chinook near tributary mouths, and fall types in main stem tributaries (Wydoski & Whitney, 2003). This species also exhibits one of two life history types or races: the stream-type and the ocean-type (Good et al., 2005). Stream-type Chinook tend to spend one or more years in freshwater environments as juveniles prior to migrating to saltwater and moving quickly into subtidal and offshore habitats (Beamer et al., 2005). Juveniles of the ocean-type Chinook depend more on estuarine habitats than any other species of salmon (Healey, 1991). They exhibit one of three post-emergence life history strategies:

1. A quick migration to saltwater and minimal use of tidal deltas (fry migrant).
2. A quick migration to saltwater, followed by several weeks or months in tidal deltas (tidal delta rearing migrants).
3. Rearing in freshwater for several months, followed by migration to saltwater and minimal use of tidal deltas (parr migration) (Beamer et al., 2005).

Pocket estuaries appear to play a critical role in the survival of fry and parr migrants and serve to relieve overcrowding in tidal deltas (Beamer et al., 2003, 2005).

With an average length of approximately 1 meter (3 feet) and weights ranging from 1 to 56 kilograms (2–123 pounds), adult Chinook are the largest of the Pacific salmon. The species spends between 2 and 6 years at sea prior to returning to freshwater to spawn, but this time varies between stocks and also depends somewhat on ocean conditions (Meehan 1991; Wydoski and Whitney 2003). Chinook tend to spawn in large river systems. In Washington, the species spawns at sites with escape cover, such as logs, undercut banks, and deep pools, that are dominated by large gravel or cobble between 2.5 and 15 centimeters (1–6 inches) in diameter (Healey, 1991; Meehan, 1991). As with other salmonids in Washington, fecundity correlates with size, and females produce between 3,385 and 5,504 eggs (Wydoski & Whitney, 2003). Chinook generally spawn at depths of less than 3 meters (3.3 feet), although Chinook have been observed spawning in the tailraces along the lower Snake River at depths of up to 9 meters (10 feet) (Wydoski & Whitney, 2003). Like other salmonids, Chinook often spawn in areas used by other salmon earlier in the year (Meehan, 1991). Male salmon die shortly after spawning, while adult females may spend 4 to 25 days guarding redds before dying (Healey, 1991).

While the length of time it takes for eggs to hatch depends heavily on water temperature, Chinook eggs generally hatch between 90 and 150 days after deposition. Optimal temperatures for incubation are between 7 and 10° C (45–50° F); although eggs hatch sooner in warmer water, the alevins that emerge are generally smaller and have lower survival rates (Healey, 1991). Alevins typically remain in the gravel for 2 to 3 weeks (Wydoski & Whitney, 2003). Newly emerged fry move to shallower pools where they establish and defend feeding areas (Meehan, 1991).

Young-of-the-year feed primarily on larval and adult aquatic insects, such as mayflies, caddisflies, and chironomids, as well as terrestrial insects (ants, spiders, and beetles), earthworms, and small crustaceans, such as Dungeness crab larvae and juveniles (Botsford & Lawrence, 2002; Healey, 1991). Their diets become more piscivorous with age: Adult Chinook feed primarily on larval and juvenile fish, as well as smaller species, such as Pacific herring, anchovy, and sand lance, while at sea (Healey 1991; Wydoski & Whitney, 2003).

Habitat use

Juvenile Chinook can occupy stream reaches with bottom current velocities of approximately 0.02 to 0.04 cubic meters per second (0.8–1.4 cubic feet per second) and depths ranging between 0.2 and 0.6 meters (0.7–2 feet) (Wydoski & Whitney, 2003). Younger juveniles seek out covered areas with lower flow near the edges of stream and river channels; they move to higher-velocity, midstream areas as they mature (Healey, 1991).

Ocean-type juveniles, which are typically the progeny of fall- and summer-run spawners, move slowly downstream after emerging from redds. Stream-type juveniles, meanwhile, overwinter in freshwater for at least 1 year and characteristically begin their downstream migration in the spring of the following year (Wydoski & Whitney, 2003). Stream-type juveniles in systems with higher percentages of large woody debris show higher overwinter survival rates (Murphy et al., 1986). Juvenile Chinook have also shown a preference for seasonally inundated floodplains in larger river systems (Sommer et al., 2001).

Ocean-type Chinook typically migrate to estuaries within 3 months of emergence, average about 50 to 70 millimeters (2–2.8 inches) in length, and make extensive use of estuarine and nearshore habitat for rearing (Healey, 1991). Stream-type (yearling) smolts, on the other hand, are much larger than ocean-type (sub-yearling) smolts and exhibit less reliance on estuaries for rearing (Beamer et al., 2005).

Because of their extended freshwater migration period, migrating adult spring Chinook salmon tend to prefer deep, cool “holding pools” with woody debris, over-hanging vegetation, and undercut banks to protect them from predators (Healey, 1991).

Distribution

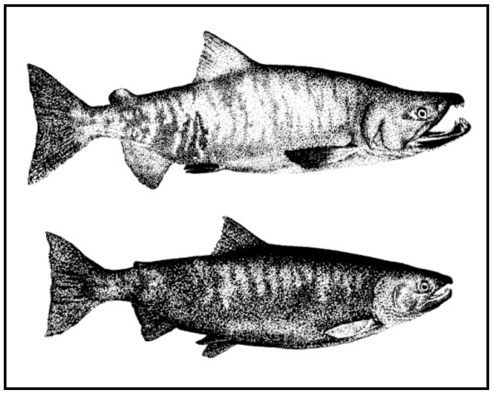
The historic range of Chinook within the state of Washington included most rivers, and fish migrated to the headwaters of the Columbia and Snake rivers (Good et al., 2005; Healey, 1991; Meehan, 1991; Wydoski & Whitney, 2003). Chinook inhabit the rivers and streams of Puget Sound (including Hood Canal and the Strait of Juan de Fuca), the Pacific coast, and the middle and lower Columbia River and its tributaries (Wydoski & Whitney, 2003). Some landlocked, resident populations occur in Lake Washington, Lake Cushman, and Lake Roosevelt (Wydoski & Whitney, 2003).

Washington stocks fall under nine federal evolutionarily significant units, with the lower Columbia River, Puget Sound, Snake River fall-run, Snake River spring/summer run, and upper Columbia River spring-run listed as threatened. In addition to those stocks, this plan also includes the middle Columbia River spring-run, Puget Sound Strait of Georgia, upper Columbia River fall-run, and Washington coast units. In 2000, NOAA Fisheries designated federal critical habitat for Puget Sound and lower and upper Columbia Chinook runs.

Chum salmon *(Oncorhynchus keta)*

Life history

In size and weight, chum salmon are second only to Chinook, reaching up to 1 meter (3 feet) long and about 20.8 kilograms (46 pounds). As with other Pacific salmon, chum are *anadromous* and *semelparous* (they perish after spawning). Adults return to spawn between 2 and 6 years of age, entering coastal streams from June to November (Froese & Pauly 2004; Neave et al., 1976; Wydoski & Whitney, 2003). Summer-run chum salmon enter Washington streams from June to August, spawning between mid-September and mid-October, while fall-run chum return from September to November, spawning between November and December (Johnson et al., 1997).



Chum salmon. Grapic: D. Pruett

Chum females produce between 2,000 and 3,600 eggs each. Spawning females typically favor sites with current velocities of 0.02 to 0.08 cubic meters per second (0.7–2.8 cubic feet per second) and depths of approximately 0.5 meters (1.6 feet), with substrates ranging from medium gravel to bedrock strewn with boulders (Johnson et al., 1971; Quinn, 2005; Scott & Crossman, 1973). Hatching time varies from approximately 45 to 182 days, depending on water temperatures (Salo, 1991).

Alevins emerge from the gravel 30 to 50 days after hatching and quickly migrate toward estuarine rearing habitat. In Washington, the fry migrate downstream from late January through June, with migration peaking between April and June (Wydoski & Whitney, 2003). Chum fry lack an obvious hiding response to disturbances, but congregate in the shade of aquatic and riparian vegetation for refuge from predators (Salo, 1991).

Although there is little information concerning feeding behavior during their downstream migration, chum fry have been observed to feed intensely upon chironomid and mayfly larvae, as well as other aquatic insects (Salo, 1991). Juveniles generally prey on epibenthic crustaceans, while larger juveniles may prey on terrestrial insects, copepods, amphipods, and other zooplankton (Simenstad et al., 1982). Migration timing along the nearshore seems linked to prey abundance; offshore migration occurs either when nearshore prey availability becomes low or when juveniles are large enough to feed on larger offshore zooplankton (Salo, 1991; Simenstad, 1983).

Habitat use

Chum salmon usually spawn in low elevation reaches, because they are unable to negotiate riverine blockages or falls due to a reduced ability to leap. However, in rivers that offer low gradients and relatively few obstacles, such as the Yukon River in Alaska and the Skagit River in Washington, they can migrate more than 2,500 kilometers (1,553 miles) and 170 kilometers (105 miles) upstream respectively (Johnson et al., 1997).

Since marine survival greatly depends on size, and chum fry arrive in estuaries earlier than most salmon, juvenile chum reside in estuaries longer than most other anadromous species (Healey, 1982; Quinn, 2005; Wydoski & Whitney, 2003). Estuarine wetlands are critical to chum salmon survival, because they provide an abundance of prey, an area of gradual transition from fresh to salt water, and an area with turbid water, shading, and vegetation to serve as refuge from predators and high temperatures (Quinn, 2005).

Juveniles enter nearshore estuarine wetlands between February and May, with a peak in late-March to early-May (Simenstad et al., 1982). Rearing occurs in productive and shallow eelgrass beds until the juveniles reach 30 to 66 millimeters (1.2–2.6 inches) in length and move offshore. Juvenile habitat usage may be due in part to possible overlap with returning adult chum salmon (Hood Canal summer-run), which may feed upon juveniles (Johnson et al., 1997). As major predators of chum juveniles in estuarine wetlands, returning chum salmon adults are joined by juvenile coho salmon *(Oncorhynchus kisutch)*, cutthroat trout *(O. clarki clarki)*, and aquatic birds. In addition to predation, causes of mortality in estuaries include cold temperatures, extreme changes in water flow, habitat degradation, disease, and *interspecific* competition from native and exotic species (Johnson et al., 1997).

Detailed studies of residence time in estuaries do not exist. Juveniles begin their seaward migrations in April, with larger fish leaving first. The young fish migrate northward through Puget Sound to the Strait of Georgia and have been observed along the coast of Washington and the west coast of Vancouver Island by mid-May. A study by Hartt and Dell in 1986 found that in their first year in the ocean, chum salmon tended to stay within 36 kilometers (22 miles) of the shore.

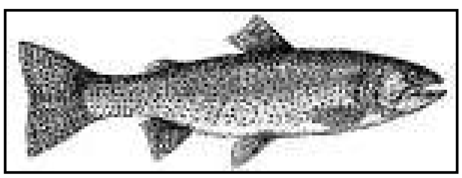
Distribution

In Washington state, chum salmon can inhabit the rivers and streams of the Washington coast, Hood Canal, Strait of Juan de Fuca, and Puget Sound. In the Columbia River Basin, their range does not extend above the Dalles Dam, and they are rarely found above Bonneville Dam (Wydoski & Whitney, 2003). The stocks are divided into four evolutionarily significant units: Puget Sound/Strait of Georgia, Hood Canal summer-run, Pacific Coast, and Columbia River (Johnson et al., 1997). Critical habitat designations were applied to the Hood Canal and Columbia River runs in 2000. Chum salmon have the most extensive distribution of all Pacific salmon. Their western reach encompasses Korea, Japan, and Russia, including the Arctic coast.

Coastal cutthroat trout *(Oncorhynchus clarki clarki)*

Life history

Similar to bull trout, coastal cutthroat trout are repeat spawners (iteroparous) and exhibit resident, fluvial, adfluvial, and anadromous life history forms. Although the species reaches sexual maturity between 2 and 3 years of age, many anadromous fish do not spawn upon their first return to freshwater (Wydoski & Whitney, 2003). Resident fish tend to be small as adults (15–30 centimeters or 6–12 inches in length), with anadromous individuals living to 10 years of age and attaining lengths of 43 to 48 centimeters (17–19 inches) (Pauley et al., 1989).



Coastal cutthroat trout. Graphic: D. Pruett

This species spawns from July through January in small tributaries with flows of less than 0.14 cubic meters per second (5 cubic feet per second) and total drainage areas of less than 1,300 hectares (3,212 acres) (Pauley et al., 1989). Females typically spawn upstream of salmon and steelhead spawning areas, depositing between 250 to 2,700 eggs in riffles at water depths of 15 to 45 centimeters (6–18 inches). Substrates selected for spawning typically range in size between 0.1 and 5 centimeters (0.04–2 inches) (Wydoski & Whitney, 2003).

Egg development depends on an optimal temperature of 10 to 11° C (50–52° F), with incubation lasting 6 to 7 weeks at those temperatures (Johnson et al., 1999; Pauley et al., 1989). Although cutthroat eggs and alevins tolerate fine sediment due to their relative smallness, the success rate for incubation and emergence decreases as the percentage of fine sediments in the interstitial spaces of the gravel increases.

Coastal cutthroat trout typically rear in their natal streams for up to 2 years, occupying streams with step-pool, plane-bed, pool-riffle and low gradient habitats (Connolly & Hall, 1999; Moore & Gregory, 1988a). Fluvial and adfluvial coastal cutthroat trout migrate out of their natal streams between 1 and 4 years of age (Wydoski & Whitney, 2003). Most anadromous forms migrate to saltwater during the spring at 2 to 4 years of age (Meehan & Bjornn, 1991). Resident fish may remain in their natal streams for their entire lives, while migratory fish move out to larger rivers, lakes, and estuaries.

Young fish feed primarily on aquatic invertebrates, but are opportunistic and will use other food sources, such as terrestrial invertebrates, zooplankton, and fish eggs (Pauley et al., 1989). Resident cutthroat trout may subsist entirely on insects, while their migratory counterparts become increasingly piscivorous as they increase in size.

Habitat use

Resident coastal cutthroat generally use small headwater and mid-size streams for all of their life-stages, residing within a few hundred meters of where they hatched or moving downstream to occupy larger habitat areas (such as deeper pools) as they grow larger. Fluvial cutthroat move out of their natal streams to larger rivers, and adfluvial fish extend their migration to downstream lakes. Although young-of-the-year typically use low velocity habitats (such as side channels and stream margins) associated with shallow, fast moving streams, adults prefer deeper pools with slower velocities. Moore and Gregory (1988a; 1988b) found that fry and juvenile fish in stream reaches with an abundance of low-velocity habitats attained larger sizes than fish in reaches with less cover. Adfluvial coastal cutthroat trout may use both littoral and limnetic habitats and feed openly in the water column in the absence of predatory and competitive pressures (Wydoski & Whitney, 2003).

After their downstream migrations, anadromous coastal cutthroat forage in estuarine wetlands, as well as nearshore coastal and inland waters, and typically occur in water less than 3 meters (10 feet) in depth. Available information indicates that this species will also occupy river deltas, distributary channels, and shallow shorelines, thereby demonstrating some preference for unconsolidated substrates (Johnson et al., 1999; Pauley et al., 1989). Although evidence suggests that coastal cutthroat trout rarely occur in marine waters greater than 3 meters (10 feet) deep, the species has been captured by fishing vessels in water up to 80 kilometers deep off the Oregon/Washington coast (Pauley et al., 1989; Wydoski & Whitney, 2003).

Distribution

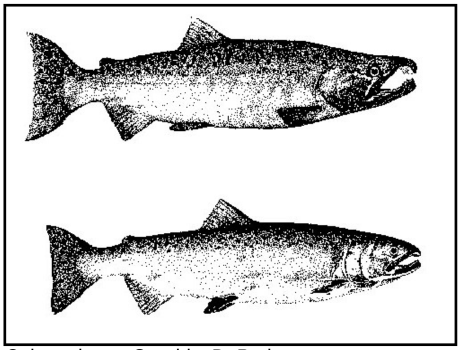
Three of the six defined evolutionarily significant units of coastal cutthroat occur in the state of Washington: Puget Sound, Olympic Peninsula, and southwestern Washington (Johnson et al., 1999). The fish are distributed in large rivers and small tributaries of the Columbia River up to the Bonneville Dam and drainage basins on the west side of the Cascade Mountains, including the Olympic Peninsula .

Coho salmon *(Oncorhynchus kisutch)*

Life history

While the life history of coho is typical of other Pacific salmon, this species tends to use a greater diversity of habitats than the other native anadromous species and can be found in headwater streams, small coastal creeks, and tributaries of major rivers (Meehan, 1991). Most coho spend between 1 and 2 years in the ocean before returning to spawn, although some males mature after only 5 to 7 months. At maturity, coho weigh between 3 and 6 kilograms (7–13 pounds), with lengths ranging from 50 to 75 centimeters (20–30 inches) (Wydoski & Whitney, 2003).

Although the timing is often unique for each run, in Washington, coho generally return to spawn beginning in August. Spawning occurs from September through January, with the adults entering freshwater earliest and moving the farthest upstream (Groot & Margolis, 1991; Meehan, 1991; Wydoski & Whitney, 2003). Females lay an average of 3,500 eggs in gravel areas that are free of heavy sedimentation and that have adequate flow and cool, clear water. Eggs hatch within 6 to 8



Coho salmon. Graphic: D. Pruitt

weeks and alevins remain in the gravel for an additional 2 to 3 weeks (Wydoski & Whitney, 2003). Upon emergence, fry move to shallow, protected areas of the stream, usually seeking pools formed by large woody debris or boulders, where they establish and defend feeding areas (Hartman, 1965; Meehan, 1991). Juveniles migrate to saltwater in the spring when they are 1 to 2 years of age.

Coho fry feed primarily on aquatic insects, such as mayflies, caddisflies, and chironomids, but they also eat terrestrial insects and earthworms. Both juveniles and adults feed on invertebrates, but become more piscivorous as they grow larger, commonly eating sand lance and other forage fish, smaller rockfish, pollock, and flatfish (Groot & Margolis, 1991; Wydoski & Whitney, 2003).

Habitat use

Juvenile coho exhibit a strong preference for freshwater structural components, such as undercut banks, large woody debris, root wads, and off-channel pools and channels, for protection from high winter flows (McMahon & Hartman, 1989; Nickelson et al., 1992). Bustard and Narver (1975a; 1975b) found that beaver ponds were an important overwintering area for juvenile coho, which have a survival rate roughly twice that of the entire stream system.

In their transition to ocean phase, migrating smolts depend upon estuarine and marine waters and are comparatively larger than juvenile Chinook and chum found in the same areas (Levy & Northcote, 1982; Weitkamp et al., 1995). Early out-migrating coho fry may feed and rear in productive estuarine habitats for several weeks, and they are often found in eelgrass meadows and tidal flats (Miller & Sadro, 2003). As adults, coho can be divided into two types: ocean and coastal, with ocean types occupying offshore waters and coastal types using nearshore waters (Groot & Margolis, 1991).

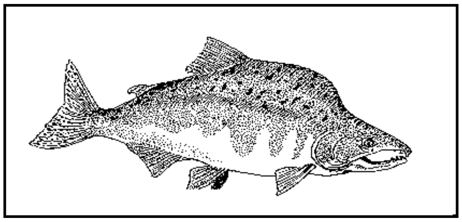
Distribution

Coho probably inhabited most of the coastal streams in Washington, and some extinct populations once spawned in tributaries of the upper Columbia River (Groot & Margolis, 1991; Nehlsen et al., 1991; Weitkamp et al., 1995; Wydoski & Whitney, 2003). Current populations occur throughout Puget Sound, Hood Canal, the Strait of Juan de Fuca, the Olympic Peninsula, and the Columbia River Basin. Washington stocks fall under three federal evolutionarily significant units: the lower Columbia River, Olympic Peninsula, and Puget Sound /Strait of Georgia.

Pink salmon *(Oncorhynchus gorbuscha)*

Life history

Pink salmon are the smallest of the Pacific salmon, maturing on a two-year cycle. In Washington, pink salmon spawn only in odd years, except in the Snohomish River, which has both odd- and even-year spawners. Adults range in length from 30 to 75 centimeters (12–30 inches) and weigh on average almost 2 kilograms (5 pounds) (Wydoski & Whitney, 2003). They spend a little over a year in the open ocean before returning to spawn.



Pink salmon. Graphic: R. Savannah, U.S. Fish and Wildlife Service

Spawning migrations in Washington typically occur in August and September (Hard et al., 1996; Wydoski & Whitney, 2003); however, arrival times can vary within and between river systems, leading to both an early and a late run (Hard et al., 1996). Unlike other Pacific salmon, pink salmon rarely make extended spawning runs and generally spawn near river mouths or a short distance upstream in fast-flowing current (Wydoski & Whitney, 2003). Spawners may remain in local bays for up to a month before migrating into the river; this delay allows for full gonadal development (Heard, 1991). Although intertidal spawning occurs, it is not common in Washington (Hard et al., 1996).

Pink salmon spawning behavior is similar to that of other salmonids, with females often digging redds in riffles with small- to medium-sized gravel; documented exceptions include the tail-ends of pools (Wydoski & Whitney, 2003). This species prefers to spawn in clear, fast-flowing streams. Pink salmon also spawn in rivers with substantial amounts of silt from glacial runoff, such as the Nisqually and Nooksack (Hard et al., 1996; Wydoski & Whitney, 2003). Females lay an average of 2,800 eggs, which hatch in 3 to 5 months (Hard et al., 1996; Wydoski & Whitney, 2003). Alevins may remain in the gravel for several months; emergence peaks during March and April (Heard, 1991; Quinn, 2005).

Habitat use

Out-migrant juvenile pink salmon move quickly to saltwater-nearshore habitats where they grow rapidly, feeding on small crustaceans, such as euphausiids, amphipods, and cladocerans (Hard et al., 1996). Prey may be benthic or pelagic in nature, although foraging usually occurs in the water column in nearshore areas along beaches or shorelines with complex structural characteristics (Heard, 1991). Juveniles form schools in nearshore habitats for several months during the summer, but move offshore by late summer or early fall (Hard et al., 1996; Wydoski & Whitney, 2003). Some Puget Sound populations spend their entire marine life in marine-nearshore habitats (Hard et al., 1996).

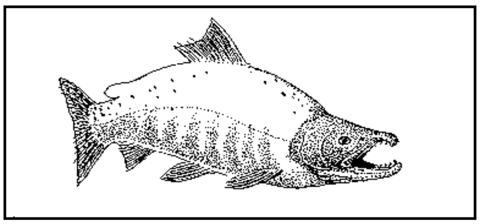
Distribution

Pink salmon are the most abundant species of Pacific salmon and are found throughout the north Pacific, including northern Asia. Thirteen stocks of pink salmon have been identified in Washington, with actively spawning populations occurring in the Nooksack, Skagit, Stillaguamish, Snohomish, Skykomish, Snoqualmie, Puyallup, Nisqually, Hamma Hamma, Duckabush, Dosewallips, Dungeness, and Elwha rivers (Wydoski & Whitney, 2003). Pink salmon have also been reported in other systems (for example, the Bogachiel River and Lake Washington), but these individuals are considered strays (Wydoski & Whitney, 2003).

Sockeye salmon/kokanee *(Oncorhynchus nerka)*

Life history

Sockeye is one of the most complex of any Pacific salmon species, both because of its variable freshwater residency (1 to 3 years) and because the species has several different forms. While most sockeye are anadromous and spawn in rivers or lakes, some (kokanee) remain in fresh water throughout their life spans (Wydoski & Whitney, 2003). Anadromous forms stay at sea for 2 to 4 years, reaching a maximum length of 83 centimeters (33 inches) and weighing between 1.5 and 3.5 kilograms (3.3–7.7 pounds) at maturity. Landlocked forms are generally smaller (lengths 20 to 40 centimeters or 8 to 16 inches) (Wydoski & Whitney, 2003).


Sockeye salmon/kokanee. Graphic: R. Savannah, U. S. Fish & Wildlife Service

Adult sockeye salmon home in and return to their natal stream or lake habitat, and stream fidelity is thought to be adaptive, ensuring that juveniles will encounter a suitable nursery lake (Hanamura, 1966; Quinn, 1984; Quinn et al., 1987). Spawning begins as early as August and may continue into February. Each female deposits up to 4,000 eggs in shallow water along lakes and rivers with gravel substrates (Wydoski & Whitney, 2003). Upon emergence, sockeye fry migrate downstream to the deep waters of nursery lakes and are particularly susceptible to predation because of their small size (25 to 32 millimeters or 1 to 1.3 inches).

Growth influences the duration of juvenile residency in nursery lakes. The growth rate is influenced by intraspecific and interspecific competition, food supply, water temperature, thermal stratification, migratory movements to avoid predation, lake turbidity, and the length of the growing season. Anadromous juveniles characteristically rear in lakes for 1 to 3 years before out-migrating (Burgner, 1991). Kokanee continue their lake residency and become sexually mature at ages 2 to 3 years (Wydoski & Whitney, 2003). The offspring of riverine spawners generally rear for 1 to 2 years in lower slow-velocity sections of rivers (river-type), although some populations migrate to estuarine environments after a few months in their natal stream (sea-type) (Burgner, 1991).

Juvenile forms and adult kokanee largely feed on zooplankton, while sockeye adults are generally piscivorous (Wydoski & Whitney, 2003).

Habitat use

Compared to other Pacific salmon, sockeye exhibit substantial diversity in selecting spawning habitat, timing in entering rivers, and the duration of holding in lakes prior to spawning. Although the species typically spawns in inlet or outlet tributaries of a nursery lake, they may spawn in suitable habitat between lakes or along the shore of nursery lakes on tributary outwash fans or submerged beaches where groundwater upwelling occurs. Sockeye also spawn along beaches where the gravel or rocky substrate is free of fine sediment and the wind-driven circulation provides oxygen to the eggs, or in main-stem rivers without juvenile lake-rearing habitat (Burgner, 1991).

Smolt migration begins in late April, with southern stocks migrating earliest. Northward migration of juveniles to the Gulf of Alaska occurs in a band relatively close to shore, and offshore movement of juveniles occurs in late autumn or winter. Sockeye salmon prefer cooler ocean conditions than do other Pacific salmon (Burgner ,1991).

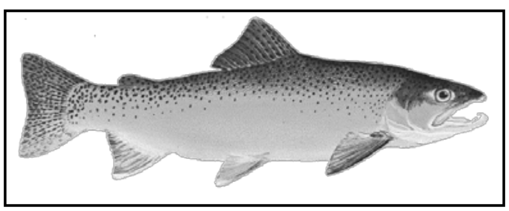
Distribution

Populations of sockeye occur in a number of lakes and rivers throughout the state of Washington, including the Snake River, Okanogan River, Lake Wenatchee, Lake Quinault, Lake Ozette, Baker River, Lake Pleasant, Lake Washington, and Big Bear Creek drainages. River sockeye regularly spawn in the north and south forks of the Nooksack River, the lower Samish, the upper Skagit and Sauk rivers, and the north fork of the Stillaguamish River, as well as the Wallace, Green, and Dungeness rivers. Although genetics are unclear, these river spawners are likely part of a wide-ranging west coast population. The landlocked form of sockeye (kokanee) occurs in many lakes throughout Washington, and many of these populations are the result of hatchery fish stocking. Some of the larger populations are in Banks and Loon lakes in eastern Washington, and lakes Whatcom, Washington, and Sammamish in western Washington (Wydoski & Whitney, 2003). The stocks fall under eight federal evolutionarily significant units: Baker River, Okanogan River, Lake Wenatchee, Quinault Lake, Lake Pleasant, Kokanee, Ozette Lake, and the Snake River. The NOAA Fisheries designated Ozette Lake as critical habitat in 2000.

Steelhead trout (Oncorhynchus mykiss)

Life history

During their ocean phase of life, steelhead range from Alaska to Japan and are generally found within 16 to 40 kilometers (10–25 miles) of the shore (McKinnell et al., 1997; Wydoski & Whitney, 2003). Steelhead generally rear in freshwater for 2 years, followed by 2 years at sea, before returning to spawn (Busby et al., 1996). They attain lengths of approximately 60 centimeters (24 inches) and weights of 2.5 to 5 kilograms (5.5–11 pounds) (Wydoski & Whitney, 2003). Similar to bull trout and coastal cutthroat, steelhead are capable of spawning more than once (semelparous) and return to the ocean after spawning (Wydoski & Whitney, 2003).



Steelhead trout. Graphic: Windsor Nature Discovery

Most steelhead spawn at least twice in their lifetimes, and many return to spawn three or four times (Wydoski & Whitney, 2003). However, in larger rivers where steelhead travel long distances to their natal spawning grounds, the proportion of returning adults who spawn more than once is considerably lower (Meehan, 1991). While steelhead typically spawn in the spring, there are two runs: a summer run that enters freshwater in August and September, and a winter run that occurs from December through February (Wydoski & Whitney, 2003). Females spawn at depths of 0.2 to 0.4 meters (0.6–1.3 feet) in mixed gravel (1 to 10 centimeters or 0.4 to 4 inches) and deposit an average of 3,434 eggs across several redds (Wydoski & Whitney, 2003).

Although time to hatching is temperature dependent, steelhead eggs generally hatch within 50 days at 10° C (50° F) (Wydoski & Whitney, 2003). Alevins typically remain in the gravel for another 4 to 6 weeks. Upon emergence, fry usually move to shallow, protected areas at the stream margins, where they establish and defend feeding areas (Wydoski & Whitney, 2003). Most juveniles move into riffles or to the head of shallow pools, although larger juveniles will move to deeper areas of pools or runs (Meehan, 1991). Out-migrating smolts typically leave their natal streams when they are between 2 and 4 years of age (Groot & Margolis, 1991).

Young-of-the-year feed primarily on aquatic insects, such as mayflies, caddisflies, and chironomids, although terrestrial invertebrates are important prey (Groot & Margolis, 1991). As steelhead grow larger, they become mainly piscivorous feeders on juvenile rockfish, sand lance, sculpin (Cottidae), and greenlings (Hexagrammidae). They also feed on invertebrates, especially euphausiids, amphipods, copepods, and squid (Groot & Margolis, 1991).

Habitat use

During their first summer, juvenile steelhead are typically found at the downstream end of relatively shallow areas with cobble and boulder bottoms or in riffles that are less than 0.6 meters (2 feet) deep (Meehan, 1991). Like other species of salmonids, juvenile steelhead trout generally prefer areas that include large woody debris, root wads, or boulders as cover from predators and as protection from both high and low stream-flow events. As juvenile steelhead grow, pools with an abundance of escape cover become more important as habitat (Stouder et al., 1997). Escape cover, such as logs, undercut banks, and deep pools are important for adult and young steelhead (Meehan, 1991).

Although steelhead trout use all types of freshwater riverine habitat for rearing, they prefer faster water (such as riffles) than do the coho and Chinook salmon rearing in the same streams (Meehan, 1991).

Distribution

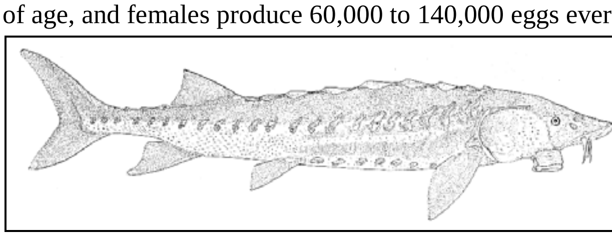
Steelhead populations in Washington are divided into five federal evolutionarily significant units: the upper Columbia River; middle Columbia River; lower Columbia River; Puget Sound, Olympic Peninsula, and southwest Washington; and the Snake River—and occur in all 10 reporting units. In 2000, NOAA Fisheries designated critical habitat for steelhead runs in the upper, middle and lower Columbia and Snake rivers.

Green sturgeon *(Acipenser medirostris)*

Characterized by large size, sturgeon have a long life expectancy and grow slowly. They are bottom feeders, and although they rely heavily on crustaceans (shrimp, crabs, and amphipods), mollusks (clams, mussels, and snails), and worms, they are also known to consume small fish (Adams et al., 2002; Hart, 1973; Wydoski & Whitney, 2003).

Life history

Adult green sturgeon reside in subtidal areas, moving from coastal marine waters into estuaries and rivers to feed and spawn (Emmett et al., 1991). Estimated to live up to 60 years, the green sturgeon can reach lengths of approximately 2 meters (6.5 feet) and weights of 136 kilograms (300 pounds) (Emmett et al., 1991; Hart, 1973). Reproductive maturity occurs between 15 and 17 years of age, and females produce 60,000 to 140,000 eggs every 3 to 5 years (Adams et al., 2002). There are no documented spawning locations for green sturgeon within the state of Washington; however, the species spawns in the Sacramento, Klamath, and Rogue rivers from March to July (Adams et al., 2002; Wydoski & Whitney, 2003).



Green sturgeon. Graphic: NOAA Fisheries

Optimal temperatures for incubation range from 10 to 18° C (50–65° F), with egg mortality occurring at temperatures exceeding 20° C (68° F) (Wydoski & Whitney, 2003). Larvae emerge within approximately 8 days and begin feeding about 10 days after hatching (Adams et al., 2002).

Larvae metamorphose into juveniles at approximately 45 days, remaining in the tidal freshwater areas of their natal rivers for 1 to 4 years before migrating out to nearshore marine waters (Emmett et al., 1991). Young sturgeon grow rapidly (up to 300 millimeters or 11 inches in one year) on a diet of benthic invertebrates (amphipods and mysid shrimp) (Adams et al., 2002; Wydoski & Whitney, 2003). Tagging studies suggest that many immature green sturgeon migrate north from their natal rivers in California and Oregon and concentrate in Washington and Oregon coastal estuaries during the summer (Adams et al., 2002).

Habitat use

Adult sturgeon make extensive use of coastal estuaries, where benthic organisms are plentiful. Eggs are broadcast spawn on mixed substrates (coarse sand to bedrock) in deep areas with swift currents, where the eggs settle into crevices and spaces in the substrate (Adams et al., 2002; Emmett et al., 1991).

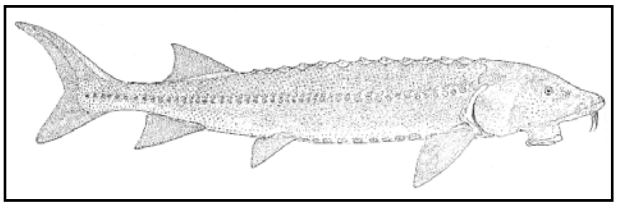
Distribution

While there are no known spawning populations of green sturgeon in Washington, they can be locally common throughout the state's saltwater habitats (Adams et al., 2002). Fisheries data show minor catches in Puget Sound and coastal Washington, with summer concentrations of green sturgeon found in Willapa Bay and Grays Harbor and in the Columbia River below Bonneville Dam (Adams et al., 2002). Recent telemetry data suggest that both the northern and southern distinct population segments migrate up and down the Pacific coast, with fish in Washington moving between Willapa Bay and the Columbia River (Moser & Lindley, 2006).[1] The northern distinct population segment spawns in the Klamath Basin, while the southern population spawns in the rivers of California's San Pablo Bay basin. The southern population of green sturgeon was listed as threatened in 2006 and critical habitat designated in 2009.

White sturgeon (Acipenser transmontanus)

Life history

White sturgeon are the largest fish in North America's freshwater environments (Wydoski & Whitney, 2003). Their life spans may exceed 100 years (Emmett et al., 1991). Although this species is anadromous, it is also capable of completing its entire life cycle in freshwater, and several stocks occur in the dam impoundments along the Columbia River. The majority of white sturgeon in the lower Columbia River do not become sexually mature until 16 to 35 years of age (Wydoski & Whitney, 2003).



White sturgeon. Graphic: NOAA Fisheries

Spawning typically occurs from early spring to early summer in large river channels with swift currents (0.7 to 2.8 meters per second or 2.3 to 9 feet per second in the Columbia River) and a substrate composed of cobble or boulders (Emmett et al., 1991). These habitats are often limited to areas

[1] Distinct population segments are those species subgroups that are either physically, behaviorally, or ecologically separated from other populations; or subgroups that use habitat across political boundaries with differing regulatory and management mechanisms (Federal Register, Volume 61, 4722; http://www.fws.gov/endangered/POLICY/Pol005.html)

below rapids or dams. Like other sturgeon species, white sturgeon will spawn multiple times over the course of their lives, with 3 to 11 years separating spawning events (Emmett et al., 1991; Wydoski & Whitney, 2003). Fecundity of white sturgeon is high: mature females produce between 100,000 and 300,000 eggs, and larger individuals may produce over a million eggs. Fertilized eggs settle to the river bottom, where they attach to cobble and hatch in 4 days to 2 weeks, depending on temperature (Emmett et al., 1991). Optimal temperatures for incubation range between 10 and 18° C (50–64° F), with egg mortality occurring at temperatures exceeding 20° C (68° F) (Wydoski & Whitney, 2003).

Larvae range in length from 8 to 19 millimeters (0.31–0.75 inches) and are found throughout the water column, becoming oriented to the bottom within 5 to 6 days after developing pectoral fins. Juveniles less than one year old are found only in freshwater habitats, where they feed on algae and small invertebrates (Emmett et al., 1991).

Habitat use

In freshwater systems, adult white sturgeon occur in large, low-gradient rivers and associated impoundments and are generally found in the larger, deeper pools and eddies of main river channels, where water velocity is lower. In the Columbia River, young-of-the-year white sturgeon were collected over unconsolidated sediments in water 13 to 27 meters (43–89 feet) deep, with an average velocity of 0.4 meters per second (1.3 feet per second) (Wydoski & Whitney, 2003). Sub-yearlings were also common during the summer over unconsolidated substrates in shallow freshwater areas of the San Joaquin Delta (Emmett et al., 1991). Habitat used by older juveniles (subadults) is similar to that used by adult white sturgeon.

White sturgeon are generally demersal (associated with the bottom) and use barbels (slender, whisker-like tactile organs) on their snouts to locate prey in turbid bottoms. Older juveniles and subadults in unimpounded river systems will move to estuarine habitats, where they consume a variety of benthic and epibenthic invertebrates, including tube-dwelling amphipods (Corophium sp.), bivalves, shrimp, and chironomids (Emmett et al., 1991; Wydoski & Whitney, 2003).

In the unimpeded reach of the Columbia River below Bonneville Dam, this species appears to migrate upstream into tidal freshwater habitats during the fall and downstream into marine-influenced habitats in the late winter and spring (Wydoski & Whitney, 2003). In marine systems, adult and subadult white sturgeon use a variety of unconsolidated estuarine and nearshore marine habitats, and may move onto intertidal flats to feed at high tide (Emmett et al.,1991). Adult and subadult white sturgeon may also spend time in the open ocean of the Pacific, and some individuals move among coastal river systems and estuaries.

Distribution

In Washington, white sturgeon are found in all coastal and inland nearshore waters and are considered common to abundant in Willapa Bay, Grays Harbor, and the lower Columbia River (Emmett et al., 1991). The species can also be found in several large freshwater rivers, although the only reproductive populations in the state are found in the Columbia River (Wydoski & Whitney, 2003). Dams along the Columbia River have changed the white sturgeon’s historic range, creating a number of landlocked, isolated populations that are functionally restricted to these impoundments. Columbia River populations are divided into those downstream of Bonneville Dam, with access to the ocean, and those present in the reservoirs and stretches of the river above Bonneville Dam. Observations of white sturgeon concentrations include other freshwater tributaries (such as Salmon Creek in Discovery Bay) of Puget Sound and the Strait of Juan de Fuca (Washington State Department of Natural Resources, 2007b).

Mammal

Southern resident killer whale (Orca) *(Orcinus orca)*

Life history

Killer whales are the largest species of dolphins currently in existence and can be found throughout the deep waters of the open ocean, as well as in shallow inland and intertidal waters planet wide (Baird, 2001; Wiles, 2004). The species is sexually dimorphic, with males reaching lengths of approximately 9 meters (30 feet) and weights of 5,600 kilograms (12,346 pounds) and females 8 meters (26 feet) and 3,500 kilograms (7,716 pounds) (Reeves et al., 2002). Killer whales are relatively long-lived: males have an average life span of 17 years (maximum age range 50 to 60 years) and females of 29 years (maximum age range 80 to 90 years) (Reeves et al., 2002; Wiles, 2004).

Orca. Photo: R. W. Baird

Males reach sexual maturity at about 15 years of age, and females typically give birth to their first calf at about 12 years of age, with an average of 5 years between calves (Reeves et al., 2002; Wiles, 2004). Mating probably occurs between May and October, but may take place year round (Wiles, 2004). Gestation lasts approximately 17 months. Southern resident populations give birth from October to March, and calves remain physically close to their mothers for at least their first year (Wiles, 2004). Although calves may nurse for 1 to 2 years, they develop teeth within their first 3 months and take solid food from their mothers (Wiles, 2004).

Resident killer whales have highly developed social frameworks, which are divided into four separate levels: matrilines, pods, clans, and communities. Matrilines are small groups related along maternal lines and are generally comprised of a female, her offspring, and the offspring of her daughters. Matrilines often contain up to 17 individuals from 3 generations. Members rarely separate for more than a few hours. Pods are larger groups related by a recent common maternal ancestor, while clans consist of pods with similar vocalizations and a more distant maternal ancestor, and communities are defined by pod and clan association patterns (Wiles, 2004). The community of southern resident killer whales are all members of the J clan, which consists of the J (4 matrilines), K (4 matrilines), and L pods (12 matrilines) (National Marine Fisheries Service, 2008c; Wiles, 2004).

Southern resident killer whale diets are likely similar to those of the northern population, with both populations preying predominately on Chinook salmon while they are in Washington’s waters (National Marine Fisheries Service, 2008c). Little information is available on diets during winter and spring outside of Washington’s waters (National Marine Fisheries Service, 2008c; Wiles, 2004).

Habitat use

Killer whales in the Georgia Basin do not generally enter water less than 5 meters (16 feet) deep, spending most of their time in deeper waters. Their distribution is strongly associated with salmon abundance, although there is some disagreement over specific feeding habitat. Baird (2001) described studies indicating that southern resident populations feed in high-relief areas, such as canyons, ridges, and steep slopes that increase feeding efficiency by limiting fish movements, while Ford et al. (1998) found no such association between feeding and bottom topography.

Distribution

Resident killer whales occur primarily in near-coastal and inland waters from central California to southeast Alaska, where they feed on salmon and other fish (Ford et al., 1998; Wiles, 2004). Southern residents live most of the year in inland areas around the Strait of Juan de Fuca, the Strait of Georgia, and Puget Sound (Krahn et al., 2002). They use core areas for summer rearing and migrate as far south as central California during the winter and early spring (Hauser, 2006; Krahn et al., 2004; Wiles, 2004). All three southern resident pods move back into Washington's waters beginning in the spring, with the K and L pods arriving first in May or June and staying until October or November (Wiles, 2004). The J pod frequents Puget Sound and the Georgia Basin sporadically during the summer and is the only group to swim among the San Juan Islands with any regularity. Southern resident killer whale were listed as endangered in 2005, with critical habitat designated in 2006.

4.2 Data analysis and methods

The Aquatic Lands Habitat Conservation Plan calculates potential impacts as the amount of area, in acres, that each covered activity may have on covered species habitat. Sections 4.3 and 4.4 describe these impacts as potential effects. Expected outcomes have been calculated and expressed as a percent decrease, or reduction, in the area of potential impact and are described in Section 4.4. These findings are a result of a complex review of GIS data, database analysis, and literature. The details of the review are described in this section. The calculations used to arrive at the findings are based on physical, chemical, and biological impacts associated with existing authorized activities and the habitats in which they reside. Calculations do not factor in the effects of historic uses prior to current use, effects from new uses, effects from unauthorized or illegal activities occurring on state-owned aquatic lands, or habitat altered through restoration or mitigation. To better convey how impacts were determined, this chapter is divided into two sections:

- The methods used to analyze and quantify potential effects from activities authorized by the Washington Department of Natural Resources (DNR) on aquatic habitats and species.
- The methods used to select applicable conservation measures and quantify the expected outcomes from applying the measures.

Many of the details resulting from this data analysis are not included in this overview. The information provided in this section is meant to explain the methods and reasoning for the calculations, rather than present all computational steps and values from the database. Additional information regarding how potential effects and expected outcomes were identified is located in the Aquatic Resources Program Endangered Species Act Compliance Project, Potential Effect and Expected Outcomes Technical Paper (Washington State Department of Natural Resources, 2007b) and the Aquatic Resources Program Habitat Conservation Plan Covered Species Technical Paper (Washington State Department of Natural Resources, 2007b).

4.2.1 Potential effects analysis

The potential effects analysis described here comprises three major steps:

- Step 1: Database construction—Compilation of the relevant information on the distribution of species, habitats, and activities (Washington Department of Natural Resources, 2007, 2005a) and standardization of data sources (Figure 4.1).
- Step 2: Spatial and temporal screening—Identification of potential interactions between species and activities in both space and time (Figure 4.1).
- Step 3: Determination of effect—Review of the available literature characterizing each activity sub-group, identification of potential controlling factors for ecosystem function, and quantification of the impacts on species habitat (Figure 4.1).

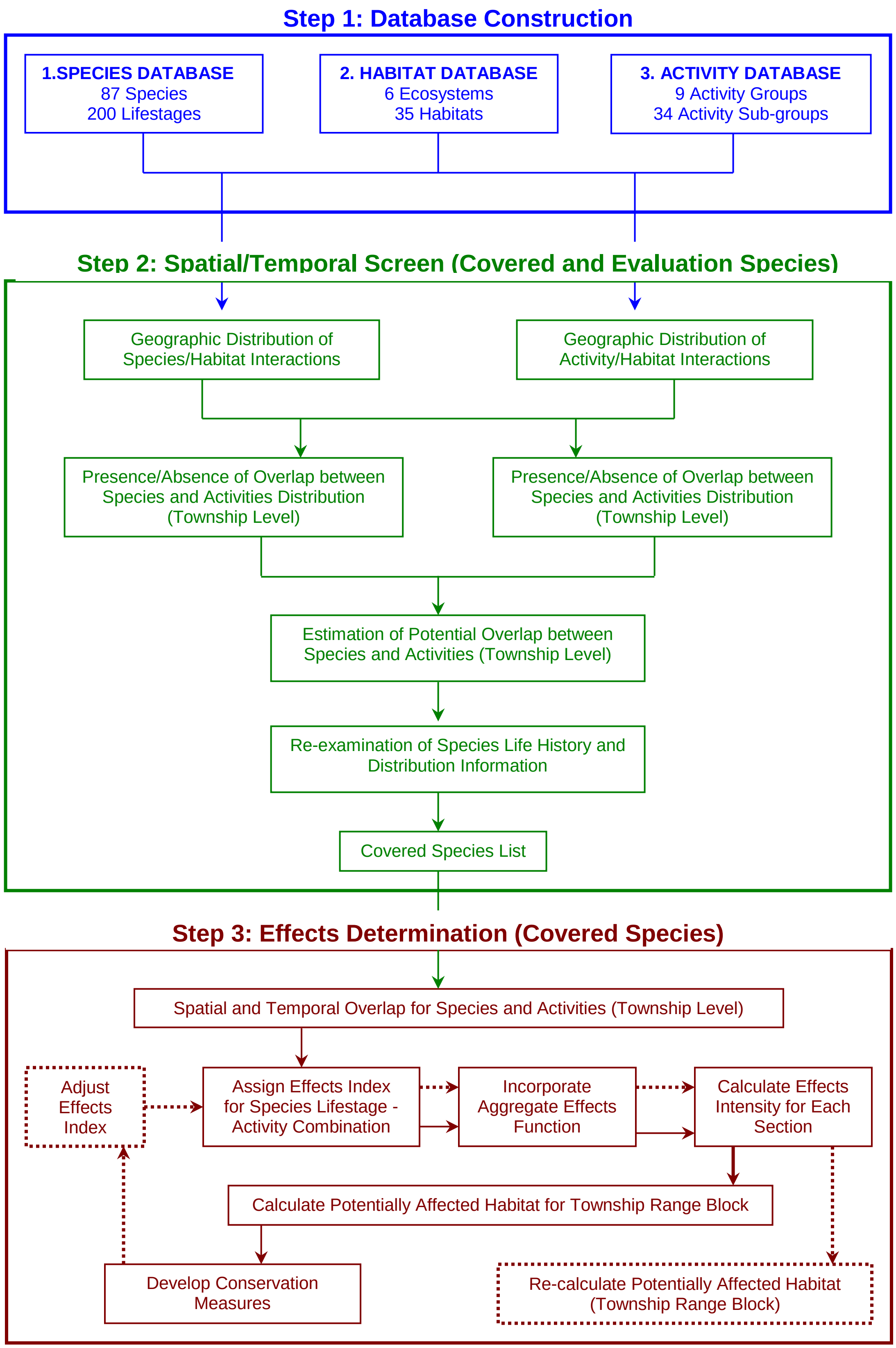
Covered activities, subgroups, and covered species

The baseline-effects analysis originally included eight activity groups and 42 species. Washington DNR is seeking Endangered Species Act coverage for only three activity groups: overwater structures, log booming, and aquaculture (Table 4.3). The selection process for these activities and the final list of covered species is described in Chapter 1 ("Introduction") and in Chapter 3 ("Description of Activities). Sub-groups were selected for various activities to identify which of Washington DNR's authorizations can be separated into a more detailed description or use type and fit within one of the three activity types. These are described in Chapter 3. Ecosystems and habitat types used in this analysis are described in Chapter 1.

Table 4.3 Activities covered and sub-groups identified

Activity Group	Sub-group	Covered Activity
Overwater Structures (single element)	Boat ramps, launches, hoists; docks & wharves; rafts & floats; floating homes; mooring buoys; nearshore buildings	All
Overwater Structures (multiple elements)	Marinas; shipyards & terminals	All
Aquaculture	Net pens; shellfish; commercial geoduck harvest; sand shrimp	Shellfish
Miscellaneous Nearshore	Public access; sediment removal; log booming & storage	Log booming and storage

Figure 4.1. Potential effects analysis, steps 1–3.
Dashed lines indicate feedback loop for implementation of conservation measures.



4.2.2 Step 1: database construction

Three key data types were used in constructing the database:

- **Species data:** Information regarding the spatial and temporal distribution of species.
- **Habitat data:** Spatial distribution of ecosystems and associated habitats.
- **Activities data:** Information about the spatial and temporal distribution of authorized activities on state-owned aquatic lands.

Each data type and its associated databases are discussed in the following pages. Figure 4.2 provides a conceptual illustration of the organization, content, and initial output.

1. Species data: database construction

The species database was developed as part of the literature review conducted for the 87 species and 200 lifestages addressed in the Covered Species Technical Paper (Washington Department of Natural Resources, 2007). The reviews and worksheets that document the timing and habitat usage of each life-stage occurrence for each species were compiled and incorporated into the species database (Figure 4.2). These data were not available for all stages or for all species. For example, very little is known about the juvenile habitat use of certain rockfish (*Sebastes spp.*). As a result, the three covered rockfish lack potential effects and expected outcomes outlined in Section 4.4.

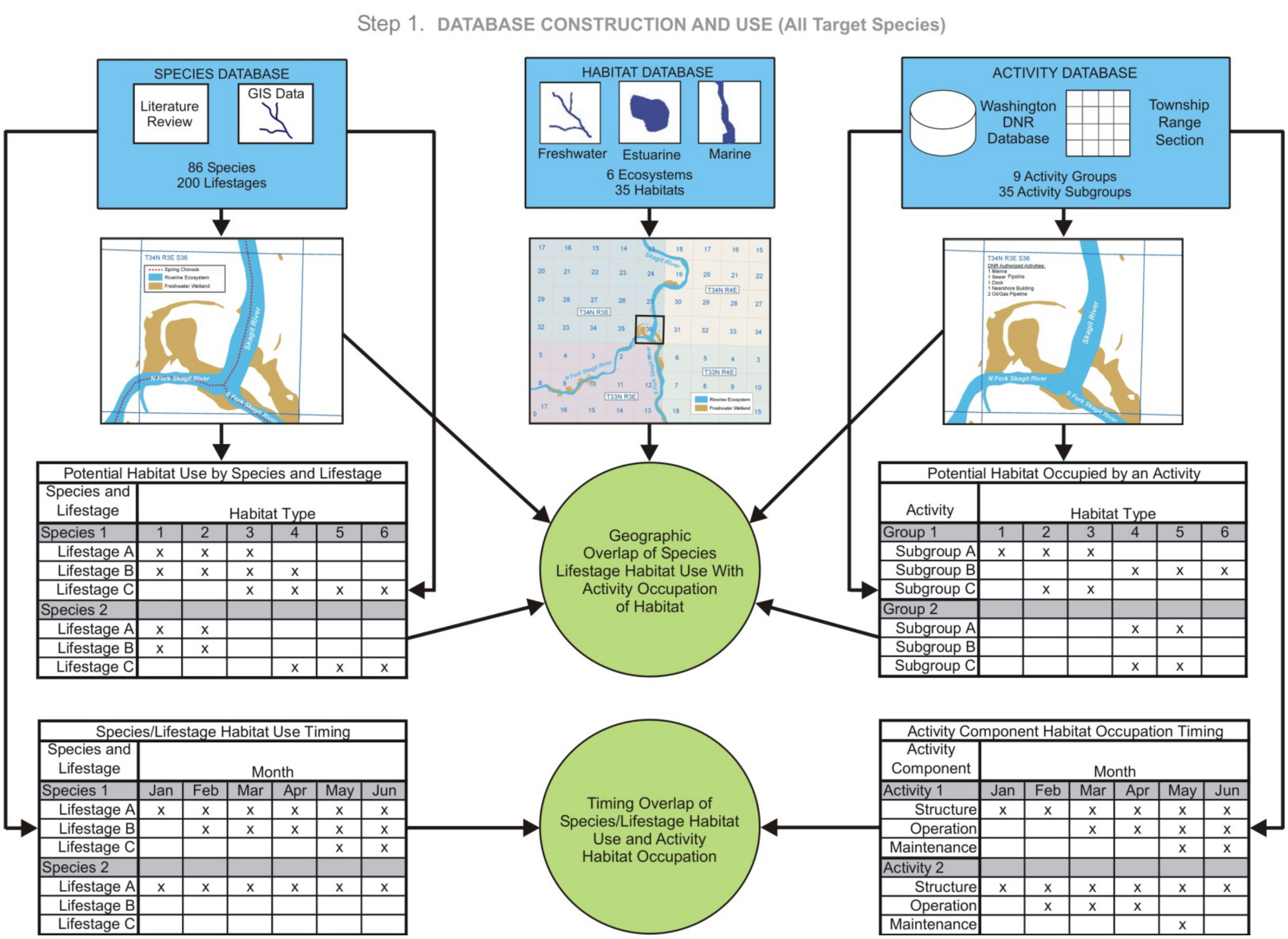
The spatial distribution of species was obtained in a geographic information system (GIS) shapefile or coverage format compatible with Environmental Systems Research Institute (ESRI) ArcGIS® mapping software. Because of the broad scope of this project, focus was placed on using widely available, standardized information. Data sources included the Washington Gap Analysis Project, Washington Department of Fish and Wildlife, Washington DNR, the Washington Nature Mapping Program, and the Interior Columbia Basin Ecosystem Management Project. For a number of the species reviewed, it was not possible to obtain data that adequately portrayed the species distribution for the entire life history (for example, salmonid use of saltwater environments). For all species, potentially suitable habitats identified in the literature reviews were selected from the GIS habitat classification datasets to spatially represent the areas where the species may occur. Any additional modifying information (such as a species only occurs in eastern Washington) was also incorporated into the potential habitat selection.

For many of the species reviewed, distribution information is portrayed as discrete point data that reflect actual field observations and likely underestimate the true range and movement of the species. To overcome this limitation in our input data sets, life history information was used for three covered species to create estimates around observation points of species' distribution range area (Table 4.4). For species that lacked sufficient information to estimate the species' distribution, no distribution map was created and no screening or potential effects determination was performed as these species were listed under ESA and added to the habitat conservation plan after the potential effects document was developed. The habitat protections provided in this plan for these species will provide substantial benefits for the habitat within the areas of assumed habitat overlap with the aquatic lands covered.

Table 4.4. Range area estimates: Applicable covered species

Species	Species Group	Data Source	Distance
Common loon	Bird	• Species predicted distribution: Washington Gap Analysis Program • Species observations: Washington Department of Fish and Wildlife, Puget Sound Ambient Monitoring Program	100 km (62 mi)
Harlequin duck	Bird	• Species observations: Washington Department of Fish and Wildlife, Wildlife Heritage	2 km (1.25 mi)
Marbled murrelet	Bird	• Species observations: Washington Department of Fish and Wildlife, Puget Sound Ambient Monitoring Program, Wildlife Heritage	5 km (3 mi)

Figure 4.2. Step 1: Database organization (squares), content, and initial output (circles).



2. Habitat data: database construction

Washington DNR used an ecosystem-based approach to organizing information, leading to a habitat-based perspective for addressing the conservation needs of species. This analysis calculates the take for each species as potentially affected habitat and is measured in hectares, but reported in acres. By relating species and lifestages to habitat-type, existing spatial and temporal aspects of habitat use can more directly relate to activities authorized by Washington DNR. The *Covered Habitat Technical Paper* (Washington Department of Natural Resources, 2005a) provides definitions of ecosystems and associated habitats used in the Washington DNR Endangered Species Act compliance process.

Although the definitions were founded on scientifically based and commonly used classification systems, they were simplified to address the broad geographic scope of state-owned aquatic lands (2.6 million acres); the large number and variability of both species and activities; and the differences in the resolution of available data. The *Covered Habitat Technical Paper* also provides a perspective on how Washington DNR's simplified use of the terms *ecosystem* and *habitat* within the Endangered Species Act compliance process compares to current use in ecology and systematic biology. This information is summarized in Chapter 1 of the Aquatic Lands Habitat Conservation Plan.

Six ecosystems (saltwater-offshore, saltwater-nearshore, tidal wetland, riverine, lakes, and freshwater wetlands) and 35 associated habitats were ultimately identified, with five basic criteria used in their selection:

1. Habitat types must have biological relevance to a broad array of species, including amphibians, aquatic invertebrates, birds, fish, and turtles.

2. Habitat types must be based on physical processes.

3. Habitat types must be based on a widely accepted classification system.

4. Habitat types must be categorized from existing data that are easily obtainable.

5. The spatial resolution of the habitat types must be consistent and compatible with other data sources used in the analysis (such as Washington DNR authorized activities), as well as adaptable to future refinements.

More information about habitats and associated habitats are in Chapter 1.

To assess the accuracy of the classifications, the GIS dataset was compared to field habitat observations (ground-truthing), and a report was generated (Washington Department of Natural Resources, 2005c). While the number of observations was small when compared to the overall dataset, there was a high degree of agreement with those projected in the GIS database.

3. Activities

Activities data used in the potential effects analysis were derived from the Washington DNR Revenue, Timber and Assets systems database. The *Potential Covered Activities Technical Paper* (Washington DNR 2005b) provides detailed descriptions of activities authorized by Washington DNR, the Revenue, Timber and Assets systems and the activities database developed from it, and the assumptions used to develop the information required for the potential effects analysis. Covered activity information used in this portion of database construction can be found in Chapter 3. The activities database used in this analysis consists of two main datasets:

- **Spatial data:** Spatially explicit representations of the locations of authorized activities on state-owned aquatic lands.
- **Descriptive data:** Descriptive information about temporal and spatial components of the activities.

Spatial data

The spatial data for the activities database is GIS based. Washington DNR currently uses the Public Land Survey System of geographic section-, township-, and range-blocks to track activities, rather than the exact location (that is, the GPS coordinate or equivalent) of the authorized activities. This means that the activity can occur anywhere within a particular geographic 1-square-mile (640-acres or about 260-hectares) section. Most sections end along the shoreline of navigable waterways and do not extend into the water. Sections indicated in the dataset are typically a waterward extension of the section nearest to the activity occurring on state-owned aquatic lands. Some activities extend across section lines and, by extrapolation, may also cross township and range blocks. The resulting level of geographic accuracy in the activities database created limitations for the analysis of effects from activities on the environment. While we assume that all species, habitats, and activities occurring in the same section co-occur or overlap in their distribution, overlaps that were identified as unlikely (such as fill or bank armoring in deep water) were eliminated.

Descriptive data

The original data contained in the Revenue, Timber and Assets systems are also limited by the lack of a standardized approach to how Washington DNR characterizes individual use authorizations. Consequently, two individual use authorizations that are similar in nature may have markedly different size or use characteristics, with some entries lacking size descriptors or any description beyond a billing code (Washington Department of Natural Resources, 2005b).

Addressing the lack of reliable spatial and temporal characteristics for over 4,000 individual use authorizations is beyond both the scope and the ability of Washington DNR's Endangered Species Act Compliance Project. As a result, a *typical activity* was defined for each of the 35 activity sub-groups that incorporates the average characteristics of a broad spectrum of use authorizations, thereby facilitating the development of descriptive statistics at the sub-group level. Typical activity assumptions are described in greater detail in Section 4.3 and in Chapter 3, with the descriptive data placed in one of two categories:

- **Size descriptors:** Data related to the size of the activity sub-groups.
- **Temporal descriptors:** Data characterizing the temporal aspect of the sub-groups.

Size descriptors

Two elements of an activity influence the spatial extent of effects on a species or habitat:

- The activity's footprint.
- The area of alteration that results from the activity's broader area of influence. To simplify the estimated area of alteration, it was assumed that habitat structure is correlated with ecological function. This allows spatial impacts to habitats to be extrapolated to impacts on ecological functions.

For each typical activity, the area of alteration was estimated by means of review of the literature, professional opinion, and field examination (Washington Department of Natural Resources, 2005c). To characterize the area of alteration, the footprint of the activity was first estimated based on a description of a typical structure. The structure's characteristics were drawn from a review of current leases in the Revenue, Timber and Assets systems and supplemented by input from land managers at Washington DNR and scientists with the Endangered Species Act Compliance Project who are familiar with the activities. Following an examination of the sources and controlling factors (mechanisms) for potential effects, the extent of habitat alteration (structure or process) was defined using one or more of the factors identified in Table 4.5 and estimated based on the area of the typical activity's footprint. Controlling factors listed in Table 4.5 are explained in greater detail in Section 4.3 (see the discussion of covered activity potential effects). The definitions and descriptions of covered activities in Chapter 3 and the covered activity footprint, or assumed area of alteration, in Section 4.3, were used to evaluate and determine controlling factors.

Table 4.5. Controlling factors potentially affecting ecosystem function.

Controlling Factors (Mechanisms)*	
• Loss of natural shade	• Wave energy
• Increased artificial shade	• Sediment supply
• Pollution (toxins, nutrients, thermal)	• Substrate type
• Physical disturbance (recurring human activity)	• Depth/slope
• Hydrology	•

* Adapted from Thom *et al.*, 2005.

Temporal descriptors

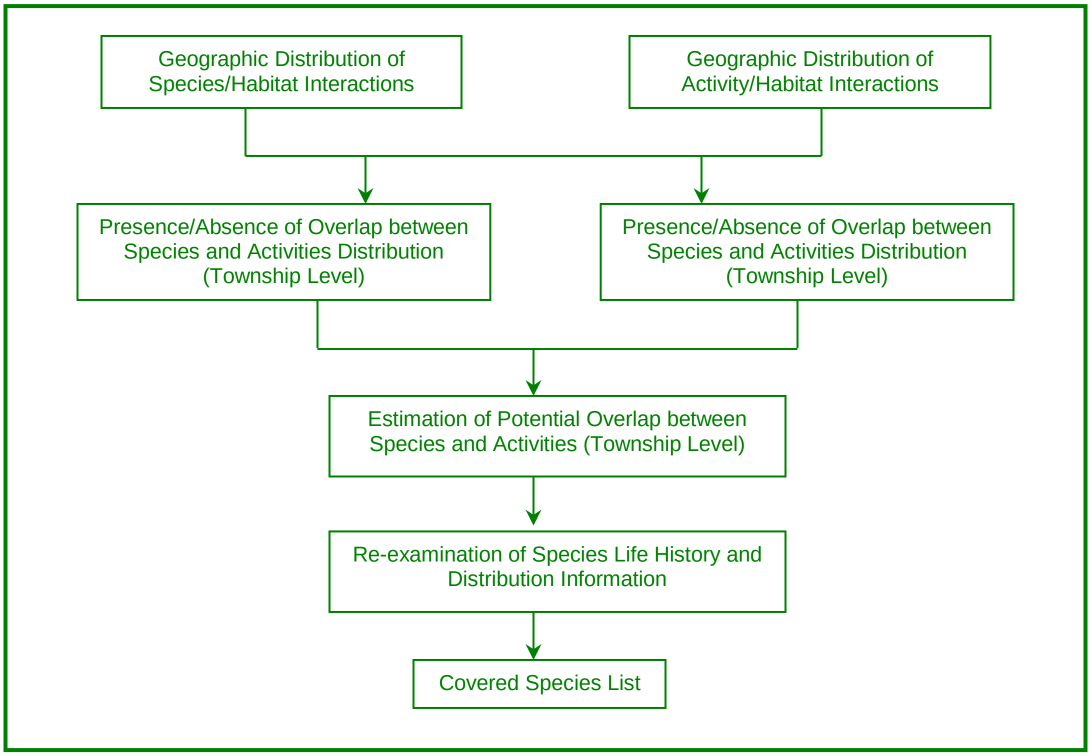
Temporal descriptors for typical activity sub-groups are presented in Chapter 3 and include the following information:

- **Structure:** The type of structures present in aquatic habitats (for example, log rafts, creosote pilings, and rip-rap).
- **Operation:** A description of the operational conditions associated with the activity.
- **Maintenance:** The period of time in which the maintenance activities occur.
- **Temporal:** The time period during which the structure or activity occurs.

4.2.3 Step 2: screening analysis

The second step in the potential effects analysis was the screening analysis used to identify intersections between species, habitats, and activities authorized by Washington DNR (Figure 4.3). To complete this analysis, it was necessary to divide the landscape into analysis units and determine which species, activities, and habitats occur within each analysis unit. As Washington DNR currently characterizes authorized activities by the Public Land Survey System section, township, and range, this dataset was used as the analysis unit and intersected with species distribution data, habitat distribution data, and activity data to identify overlaps.

Figure 4.3. Step 2: Potential effects analysis (spatial/temporal screen)



Information generated in the screen was used to confirm or deny any assumptions regarding overlap among species, life stages, and activities, and provides the basic information required for the calculation of potentially affected habitat provided in Sections 4.3 and 4.4. What follows is a description of the role of the screen in determining the likelihood of potential interaction between species/lifestages and Washington DNR activities. This screen is also how the covered species list from 2005 was confirmed. The species selection process is discussed in Chapter 1 in greater detail.

Spatial overlap analysis

The objective of the screen was to determine the degree to which the distributions of authorized uses potentially interact with covered species. This was accomplished using two techniques: First, a metric was developed that describes the number of activities authorized by Washington DNR that co-occur with each species' distribution. The number of activities overlapping with a species' distribution was then converted into a rank score of low (1), medium (2), or high (3), as described in Table 4.6. Second, the screen data were used to examine the spatial extent of the species distribution relative to the spatial extent of all authorized uses of state-owned aquatic lands. The calculated percentage of each species distribution coinciding with activities authorized by Washington DNR is referred to as *coincident habitat* and is used as an indicator of the likelihood of interaction. This is described in acres for each species in Section 4.4. Table 4.6 illustrates the ranking criteria and metrics used for the species/lifestage and activity overlap and coincident habitat metrics. This part of the process was used to confirm overlap of the covered species. Detailed tables of the data are available in the *Aquatic Resources Program Endangered Species Act Compliance Project, Potential Effect and Expected Outcomes Technical Paper* (Washington Department of Natural Resources, 2007b).

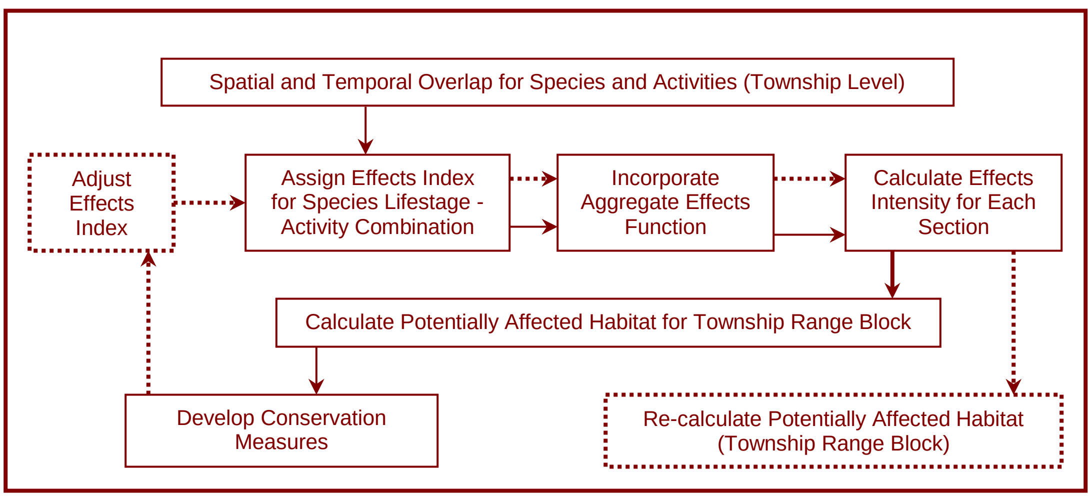
Table 4.6. Activity overlap ranking

Species/lifestage and Activity Overlap		Coincident Habitat	
Count	**Rank**	**Percent of Townships**	**Rank**
0–22	Low (1)	0–34	Low (1)
23–30	Medium (2)	35–66	Medium (2)
31–34	High (3)	67–100	High (3)

4.2.4 Step 3: Potential effects determination

The potential effects determination is the final step in the potential effects analysis (Figure 4.4) and was used to estimate the extent, magnitude, and intensity of effects from activities authorized by Washington DNR on habitats occupied by covered species and lifestages.

Figure 4.4. Step 3: Potential effects analysis (effects determination)

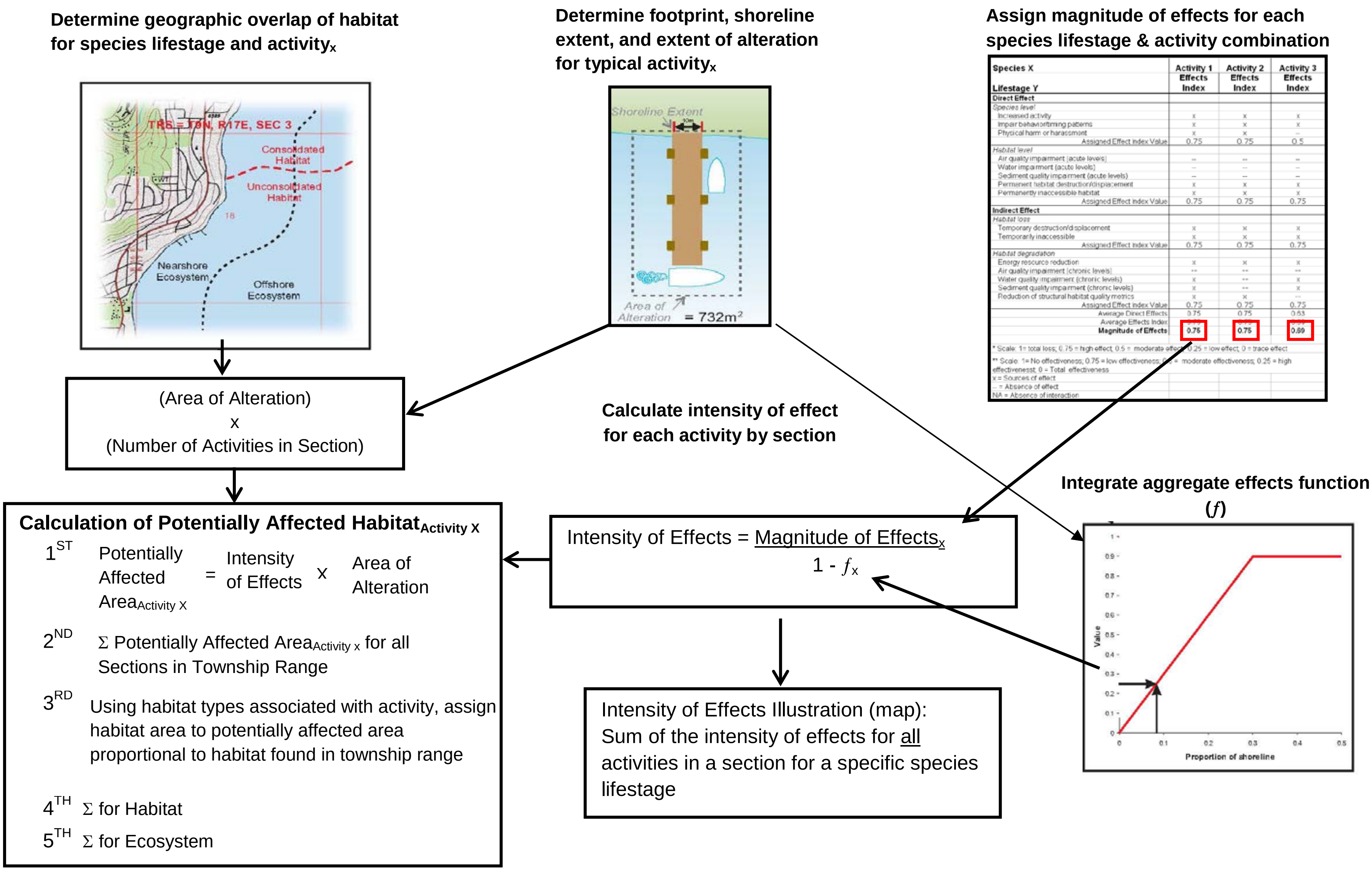


The determination of effects consists of four basic components:

- **Magnitude of Effect** (ME): A qualitative ranking of the magnitude of direct and indirect effects resulting from the physical presence, operation, and maintenance of each activity sub-group on covered species and lifestages.
- **Intensity of Effect** (IE): The adjustment of the magnitude of effect to reflect any additional impacts that may occur as a result of the density of authorized uses within a given area.
- **Potentially Affected Habitat** (PAH): The total habitat area affected by authorized uses. Potentially affected habitat is a function of the extent of alteration as well as the magnitude and intensity of the effect.
- **Intensity of Effect Distribution** (IED): A spatially explicit representation of the intensity of effect for all species, lifestages, and activity sub-groups within each section.

Detailed discussions of the components of the potential effects model are presented in the following sub-sections; Figure 4.5 on the following page illustrates the process used.

Figure 4.5. Process for determining potential effects



Magnitude of effect (ME)

The magnitude of effect is a qualitative ranking of the direct and indirect effects resulting from an authorized activity, including the physical presence of any structures, operation of facilities and infrastructure, and maintenance.

Regulatory basis for determining magnitude of effect

To meet the requirements of a Section 10 permit, the effects from the covered activities must meet the standards of both Section 10 (the effects do not appreciably reduce the likelihood of survival and recovery of the species in the wild) and Section 7 (the effects are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat). The effects of covered activities are typically described as direct or indirect, with direct effects including the immediate impacts of an activity on the species or its habitat (such as entrainment in surface water diversions), as well as the destruction of habitat (such as elimination due to the placement of a structure). Indirect effects are those ". . . that are caused by, or will result from, the proposed action and are later in time, but still are reasonably certain to occur. . ." (50 Code of Federal Regulations 402.02) and include chronic exposure to contaminants and reductions in prey.

Process for determining magnitude of effect

Effect indices were prepared for each unique species, lifestage, and activity sub-group combination, and composite scores characterizing the magnitude of effect were derived from individual rankings of direct and indirect effects. Fifteen mechanisms for potential effects were identified, with the mechanisms assigned to two categories for both direct effects (species and habitat level) and indirect effects (habitat loss and habitat degradation) (Table 4.7). For each mechanism, an "X" was used to indicate an overlap between the effect category, the species/lifestage being considered, and the particular activity. Justifications for the assumed overlap and the interpretation of the magnitude of the effect were based on a review of the literature and supplemented by professional judgment (Section 4.3: Assumed area of alteration).

Magnitude was determined by first having experts follow an ordinal ranking system ranging from 0 (no or trace effect) to 1.0 (total loss) for ranking direct and indirect effects, and then calculating the magnitude as the greater of either the average of individually ranked direct and indirect effects or the direct effect rank. Rankings for effects were created using effect indices for each of the covered species and lifestages for each activity sub-group (such as docks and wharves), with the indices providing a standardized method across species and activities to estimate the relative severity of effects associated with activity structure, operation, and maintenance.

Table 4.7. Effect index example (Assigned effects values are averages.)

Species X			
Lifestage Y	**Activity 1**	**Activity 2**	**Activity 3**
Direct Effect			
Species level			
Increased activity	x	x	x
Impair behavior/timing patterns	x	x	x
Physical harm or harassment	x	x	--
Assigned Effects Index Value	0.5	0.5	0.25
Habitat level			
Air quality impairment (acute levels)	--	--	--
Water impairment (acute levels)	x	x	x
Sediment quality impairment (acute levels)	x	x	x
Permanent habitat destruction/displacement	x	x	--
Permanently inaccessible habitat	--	--	--
Assigned Effects Index Value	0.25	0.25	0.5
Indirect Effect			
Habitat loss			
Temporary destruction/displacement	x	x	x
Temporarily inaccessible	x	x	--
Assigned Effects Index Value	0.5	0.5	0.25
Habitat degradation			
Energy resource reduction	x	x	x
Air quality impairment (chronic levels)	--	--	--
Water quality impairment (chronic levels)	x	x	x
Sediment quality impairment (chronic levels)	x	x	x
Reduction of structural habitat quality metrics	x	x	x
Assigned Effects Index Value	0.5	0.5	0.25
Average Direct Effects Index	**0.38**	**0.38**	**0.38**
Average Effects Index	**0.44**	**0.44**	**0.31**
Magnitude of Effects	**0.44**	**0.44**	**0.38**
Scale: 1= total loss; 0.75 = high effect; 0.5 = moderate effect;			
0.25 = low effect; 0 = trace effect			
x = Sources of effect			
-- = Absence of effect			
NA = Absence of interaction			
[1] Use direct effect value if greater			

Once it was determined that a category had a nexus and the potential magnitude of effect was identified, the potential effect value (score) for each of the four types of effect (direct—species and habitat level; indirect—habitat loss and habitat degradation) was estimated. Effects were evaluated in relation to the area of alteration and the severity of the potential impact and were assigned scores of 0 (trace effect), 0.25 (low effect), 0.5 (moderate effect), 0.75 (high effect), and 1 (total loss). Since the total area affected by a given activity is the product of the area of alteration and the magnitude of effect, activities with very large areas of alteration may have relatively low magnitude of effects values because the impacts are spread over a large total area. For example, if the entire area of alteration was considered a complete loss due to the specified mechanism, it was rated a 1 for that effects component. If half of the entire area of alteration was considered a complete loss with regard to a mechanism, it was scored a 0.5. Similarly, if it was determined that the entire area of alteration was moderately affected by the mechanism, then the assigned effect index (EI) value would equal 0.5.

The magnitude of effect is a composite score derived from the assigned effect index values for direct and indirect effects. The magnitude of effect for each activity sub-group and species lifestage is the greater of either the average of the two direct effect category scores or the average of the scores for all four (direct and indirect) categories. For example, the magnitude of effect for Activities 1 and 2 in Table 4.7 is equal to 0.44— the average of all four categories—whereas the magnitude of effect for Activity 3 is 0.38, which is the direct effect value.

Intensity of effect (IE)

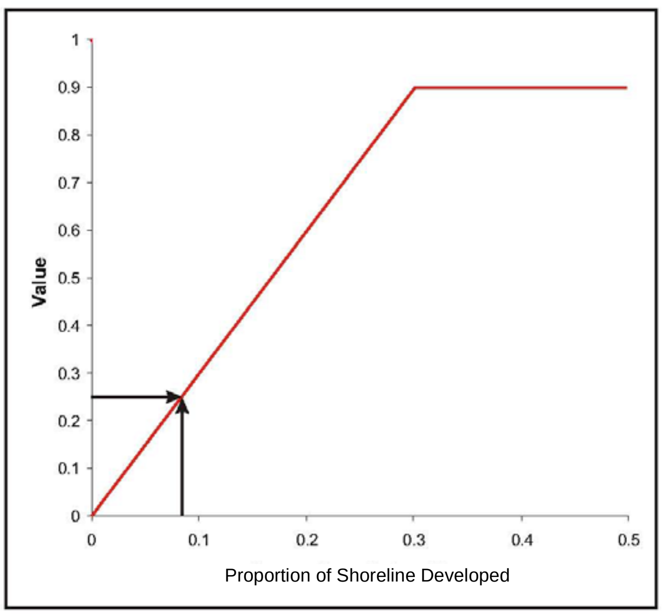
The intensity-of-effect (IE) metric is calculated as the ratio of the magnitude of effect over an aggregate effects function, described below.

Incorporation of aggregate effects (AE)

In estimating potentially affected habitat, it is important to incorporate an aggregate-effects factor to account for an increase in the magnitude of impacts in areas where activities authorized by Washington DNR are concentrated. For example, a single dock authorization may not significantly impact nearshore sediment supply and transport processes, but in all likelihood the combined presence of many docks along a shoreline will.

The role of aggregate effects in aquatic ecosystems is not well studied; however, research in upland watersheds indicates that a combination of factors influences the ecological integrity (physical, chemical, and biological measures) of aquatic resources. A science panel convened to evaluate ecological conditions in Puget Sound and the Georgia Basin concluded that ecosystem value declines rapidly with the percentage of developed shoreline (Puget Sound Action Team, 2005). The aggregate effects function used in this analysis (Figure 4.6) is based on the conclusions of the panel regarding nearshore ecosystem function and on a weight-of-evidence approach (Thom *et al.*, 2005). This function suggests that ecosystem value declines rapidly as the percentage of shoreline development increases until a threshold is reached (≈30 percent). At this limit, no additional density effect is observed, and activities achieve their maximum impacts.

Figure 4.6. Aggregate effects function



Process for incorporation of aggregate effects

Aggregate effects were incorporated into the analysis by calculating the ratio of the length of shoreline encumbered by uses authorized by Washington DNR to the total length of shoreline. This calculation was performed for each activity sub-group and was based on the assumed dimensions of each typical activity. The function consists of a line associated with the proportion of shoreline affected on the X-axis and an aggregate effect value of between 0 and 1 on the Y-axis (Figure 4.6). The line rises at a 45-degree angle from 0 for both axes until 30 percent of the shoreline was estimated to be affected and an aggregate effect of 0.9 was reached. The lack of further increases in the function is designed to reflect observations that substantial and increasing degradation of ecosystem function occurs when 0 to 30 percent of a shoreline is developed, after which ecosystem function changes very little.

The aggregate effects function was used to arrive at the intensity of effect, with the intensity of effect (IE) equal to the ratio of the magnitude of effect (ME) and the aggregate effects function (AE) (Equation 1). The ratio is used in determining the potentially affected area (PAA) for each activity (Equation 2), with AA being the assumed area of alteration for that activity.

Equation 1

$$IE = \frac{ME}{(1 - AE)}$$

Equation 2

$$PAA = (AA) \times \left(\frac{ME}{(1 - AE)} \right)$$

The value derived from the aggregate effects function increases with the percentage of shoreline development, decreasing the value of the denominator in the effects intensity ratio and resulting in a higher intensity of effect. When shoreline development is small, the intensity of effect is roughly equal to the magnitude of effect.

For example, assuming that approximately 5 percent of the shoreline in section X is disturbed, the aggregate effects (AE) function is equal to 0.1. If the area of alteration (AA) from activity Y is 100 meters^2 and the activity has a moderate (0.5) magnitude of effect (ME) on species B, the potentially affected area (PAA) is:

$$PAA = \left(100 meters^2\right) \times \left(\frac{0.5}{(1 - 0.1)} \right) = 55 meters^2$$

In contrast, if 25 percent of the shoreline is disturbed, the aggregate effects function is equal to 0.75 and the potentially affected area would quadruple:

$$PAA = \left(100 meters^2\right) \times \left(\frac{0.5}{(1 - 0.75)} \right) = 200 meters^2$$

Potentially affected habitat

As described in Section 4.2.1 (Database construction), the ecosystem and habitat data were referenced to the township and range block, while activities were referenced to a section, with the exact location of the activity within the section unknown. Therefore, the estimation of potentially affected habitat was calculated on the township/range scale. This was done by calculating the potentially affected area for a specific activity by section, adding all of the areas in a township and range block, and simply proportioning the habitat by the percentage of that habitat type found in the township and range (Figure 4.7). As described above in the screening analysis, only those habitats potentially associated with a particular activity are included in the habitat area calculation.

This also enables an estimation of the percentage of an ecosystem or habitat that is potentially affected by Washington DNR activities in relation to all that is available in the region/state. The data summaries assist in determining:

- What activities are having the greatest impacts on habitats and the species/lifestages they support.
- What ecosystems and habitats affected by Washington DNR authorized activities are contributing to, or limiting recovery of, a species on a regional scale.
- What conservation measures should be emphasized for an activity, ecosystem, habitat, and species/lifestage to encourage recovery.

Figure 4.7. Calculation of potentially affected habitat

Calculation of Potentially Affected Habitat$_{\text{Axtivity X}}$

1$^{\text{ST}}$ Potentially Affected Area$_{\text{Activity X}}$ = Intensity of Effects X Area of Alteration

2$^{\text{ND}}$ Σ Potentially Affected Area$_{\text{Activity x}}$ for all Sections in Township Range

3$^{\text{RD}}$ Using habitat types associated with each activity, assign habitat area to potentially affected area proportional to habitat found in township range

4$^{\text{TH}}$ Σ for Habitat

5$^{\text{TH}}$ Σ for Ecosystem

Intensity of effects distribution

As described above, potentially affected habitat was summarized by activity, activity sub-group, ecosystem, habitat, and species/lifestage. Although the coarseness of the locational datasets for habitats and activities prohibited defining the precise geographic distribution of affected habitat, the summaries provide an understanding of where potentially affected habitat occurs and where activities are concentrated, as well as a basis for developing and applying appropriate conservation measures.

The summary was accomplished by examining the intensity of effect (IE) values for all species-lifestage-activity combinations on a regional basis. Using the intensity of effect equation (Equation 1), the theoretical maximum intensity of effect value for an individual species-lifestage-activity combination (SLAC) in a section equals 10 and would occur only when both the magnitude of effect (ME) was very high (i.e., 1.0 = total loss) and the density of activities authorized by Washington DNR comprised at least 30 percent of the shoreline (AE = 0.9).

Equation 3

$$IED_{SectionX} = \sum_{SLAC=1}^{n} IE_{SLAC}$$

As part of the potential effect analysis, 51 species-lifestage combinations and 354 activity sub-groups were examined; thus, the theoretical maximum intensity of effect value for all species-

$$IE_{Maximum} = \frac{ME}{(1-AE)} = \frac{1}{1-0.9} = 10$$

lifestage and activity sub-groups in a given section is 17,340 and the minimum is zero. The analysis of the distribution of the intensity of effects was based on the combined influence of activities authorized by Washington DNR within a given section on all species present. The intensity of effects distribution (IED) was calculated by adding the intensity of effect (IE) values for each species-lifestage-activity combination (SLAC) within a section (Equation 3).

Examination of the intensity of effect distribution values for individual sections is a useful and convenient method to identify specific locations within the state where numerous species-lifestages and activities interact. To illustrate the relative effect intensity distribution on a map, the range of scores observed was divided into three equally sized groups and assigned a symbol corresponding to low, medium, or high. As part of the examination of regional differences, the state of Washington was divided into a grid that consisted of 28 equal-area blocks (blocks) that were each 1 degree by 1 degree in length. Basic statistics were generated to examine the number of sections in which effect intensity scores were observed as well as the range of scores observed within blocks.

4.2.5 Expected outcomes, applying conservation measures

A critical component of habitat conservation planning is the implementation of a conservation program or strategy that ". . . ensures that the effects of the authorized incidental take will be adequately minimized and mitigated to the maximum extent practicable" (U.S. Fish and Wildlife Service & National Marine Fisheries Service, 1996). To accomplish this purpose, Chapter 5 lays out Washington DNR's operating conservation program, through the application of conservation measures, to avoid, minimize, and compensate for impacts to the covered species from authorized activities, and to protect and conserve habitats that support these species on state-owned aquatic land.

Conservation measures vary considerably in terms of their specificity for addressing threats to covered species, their potential for use as mitigation measures, and their potential to benefit species and reduce potential impacts to state-owned aquatic lands. The analysis of the measures and their expected outcomes focused on identifying and evaluating actions that would avoid and minimize potential effects to covered species in a cost-effective manner. Only avoidance-and-minimization conservation measures were included in the analysis, because it is assumed that mitigation would be more effective if based on a species-specific “likelihood of survival and recovery” approach, rather than an approach that involves mitigation by activity.

The conservation measures selected for each activity group/sub-group can generally be described as conditions or best management practices that will likely be required as part of current permitting processes for new facilities. Ranking criteria in the spatial analysis description were employed to ensure that each of the measures was:

- Effective in avoiding or minimizing potential effects on covered species and lifestages (reducing threats).
- Applicable across a wide range of Washington DNR authorized activities.
- Addressed operation and maintenance aspects of Washington DNR authorized activities (scope of the potential effects analyses).

This approach made it possible to characterize the reduction in potential effects to covered species that results from the application of a common environmental protection standard to all the authorizations within an activity group. It also provides a basis for examining how different activities can contribute to “a reasonable possibility of not jeopardizing the continued existence of a species” and assist in the recovery of that species with the application of standard best management practices.

4.2.6 Selection of conservation measures

A three-step filtering process was used to select the conservation measures:

- Identification and ranking of the initial pool of potentially applicable conservation measures for each of the nine activity groups defined in the *Potential Covered Activities Technical Paper* (Washington DNR, 2005b).
- Categorization and screening of the pool of identified conservation measures to determine whether measures could be classified as those that avoid, minimize, or mitigate potential effects. Avoidance and minimization measures were retained for possible inclusion in the expected outcomes analysis. Those measures identified as mitigation were separated out as potential programmatic measures to be negotiated with NOAA Fisheries and the U.S. Fish and Wildlife Service.
- Evaluation of the identified avoidance and minimization measures to determine if they would reduce identified direct or indirect effects to covered species.

Step 1: Identification and ranking

An array of possibly applicable conservation measures were identified by Washington DNR scientists using relevant literature and professional judgment (B.C. Ministry of Agriculture and Lands, 2005; Environmental Protection Agency, 2000; G3 Consulting Ltd., 2003; Hanson *et al.*, 2003; Pacific Coast Shellfish Growers Association, 2001; Pentec Environmental, 2000; Washington Administrative Code Title 220; Washington Department of Fish and Wildlife, 1999; Washington Department of Transportation, 2004, 2005; U.S. Fish and Wildlife Service, 2003; United States Army Corps of Engineers, 1989). Conservation measures were retained for further analysis if they focused on the operations and maintenance of activity groups authorized by

Washington DNR, with measures designed for specific projects modified to remove site-specific constraints and make them more generally applicable to the covered activities (for example, aquaculture and overwater structures).

The biological effectiveness of each conservation measure was ranked by scientists at the Washington Department of Fish and Wildlife. Using their professional judgment, they assigned each measure an ordinal score of high (3), medium (2), or low (1), based upon the measures' ability to avoid, minimize, or mitigate direct or indirect effects to covered species. To reduce the subjectivity of ordinal scores, each conservation measure was reviewed and ranked by multiple biologists. The biological effectiveness rank (BER) for each conservation measure was then calculated by first summing the scores in each category (that is, avoid, minimize) for each activity sub-group, and then dividing by the number of Washington Department of Fish and Wildlife scientists who ranked the effectiveness of the measure. Scientists at Washington DNR chose not to further analyze conservation measures with biological effectiveness ranks of less than 1.5 due to their limited potential to provide biological benefit. Conservation measures that were limited to monitoring practices were also removed from the analysis at this point.

Step 2: Categorization and screening

In Step 2, the consulting team screened the conservation measures to ensure that they:

- Were general enough for standard application across the range of groups or sub-groups developed for the potential effects analysis.
- Could be applied to the operation and maintenance of existing structures and facilities authorized by Washington DNR on state-owned aquatic lands.
- Addressed avoidance and minimization of effects rather than compensatory mitigation.

Standard best management practices were desirable, as they provided a mechanism to examine—across activity groups—the changes in effects that result from the application of a common environmental protection standard. If conservation measures were considered too specific or oriented toward compensatory mitigation rather than avoidance or minimization, they were identified as *applicable to mitigation only*.

So that conservation measures could be used more effectively in the analysis, some were slightly reworded to make them more broadly applicable, or they were changed to include operation or maintenance activities (rather than construction). To assist in organization and consistency, conservation measures that were similar in content were combined to create a single measure. If a measure was applicable only as mitigation, then it was neither carried forward in the pool of possibly applicable conservation measures, nor included in the calculation of potentially affected habitat for the expected outcomes analysis.

Step 3: Evaluation of the potential to reduce threats

In step 3, the remaining conservation measures were evaluated to determine whether the threats and potential direct or indirect effects identified could be reduced for each covered activity and covered species. As with the potential effects analysis, this analysis focused on species threats as indicated by the magnitude of direct and indirect effects (ME) and ultimately the intensity of effects (IE).

These *risk pathway* evaluations were based on literature reviews, the *potential effects* portion of this data analysis, and the professional opinion and experience of the consulting team that completed the analysis. The codes in Table 4.8 were used to simplify the process of linking the conservation measures to the mechanisms for direct and indirect effects identified in the potential effects determination. The conservation measure ranks that were calculated in Step 1 were used as decision points in the final selection of conservation measures.

Table 4.8. Direct and indirect effects analyzed by activity group and sub-group.

Mechanism	Assigned Code
Direct Effects	
Species Level	
Increased activity	DE1
Impaired behavior/timing patterns	DE2
Physical harm or harassment	DE3
Habitat Level	
Air quality impairment (acute)	DE4
Water impairment (acute)	DE5
Sediment quality impairment (acute)	DE6
Habitat destroyed or displaced permanently	DE7
Habitat inaccessible permanently	DE8
Indirect Effects	
Habitat loss	
Habitat destroyed or displaced temporarily	IE1
Habitat inaccessible temporarily	IE2
Habitat degradation	
Energy resource reduction	IE3
Air quality impairment (chronic)	IE4
Water quality impairment (chronic)	IE5
Sediment quality impairment (chronic)	IE6
Reduction of structural habitat quality metrics	IE7

The total affected habitat and the percent of total habitat affected by each activity group for each covered species were reviewed using the potential effects analysis before conservation measures were selected. If there was no indication of a significant overlap between an activity and a covered species lifestage, then the species was eliminated from further consideration in the expected outcomes analysis for that activity.

4.2.7 Characterizing expected outcomes

To characterize the expected outcomes of implementing the applicable conservation measures, the amount of potentially affected habitat for each covered species was recalculated to account for the expected benefits of the conservation measures. The matrices used for determining the magnitude of effect were expanded to include an estimate of the effectiveness of the chosen conservation measures using a net conservation measures index (NCMI) for all the applicable conservation measures that would be applied to each activity sub-group. The net conservation measure index was determined using a weight-of-evidence approach based on relevant literature and the analysts' professional judgment as to whether the measure(s) could legitimately reduce the risks of direct and indirect effects. Like the assigned effects-index values, the NCMI was ranked on a 0-to-1 ordinal scale in 0.25 increments; however, the scale was reversed, with:

- 0 equal to the measure being completely effective at eliminating all threats associated with a particular type of effect (such as habitat loss)
- 0.25 equal to a high level of effectiveness
- 0.50 indicating moderate effectiveness
- 0.75 low effectiveness
- 1 no effectiveness

The adjusted effects index (AEI) was then calculated by multiplying the assigned effects index for each activity group and applicable covered species' life stage by the NCMI for the same activity and species (Equation 4).

Equation 4:

$$AEI = (EffectsIndex)x(NCMI)$$

Lower values for net conservation measures lead to a greater reduction in the magnitude of effects. Using the direct effect value for Sub-group A in Table 4.9 as an example, if, prior to applying conservation measures, the effects index was 0.25 (low effect) and NCM was estimated as 0.75 (low effectiveness in eliminating effects), the adjusted effects index becomes 0.19:

$$AEI = (0.25)x(0.75) = 0.19$$

The resulting adjusted effects index was then used to recalculate the magnitude of effect for each species-lifestage-activity combination; this adjusted magnitude of effect (ME) was used in Equation 2 to recalculate the potentially affected area (PAA) .

Table 4.9. Example effect index and net conservation measures index

Species X	Sub-group A			Sub-group B		
Lifestage Y	Effects Index	Net Conservation Measure Index	Adjusted Effects Index	Effects Index	Net Conservation Measure Index	Adjusted Effects Index
Direct Effect						
Species level						
Increased activity	x			x		
Impair behavior/timing patterns	x			x		
Physical harm or harassment	x			--		
Assigned Effects Index Value	0.25	0.75	0.19	0.25	0.75	0.19
Habitat level						
Air quality impairment (acute levels)	--			--		
Water impairment (acute levels)	--			--		
Sediment quality impairment (acute levels)	--			--		
Permanent habitat destruction/displacement	x			--		
Permanently inaccessible habitat	x			--		
Assigned Effect Index Value	0.25	0.75	0.19	0	0.75	0.00
Indirect Effect						
Habitat loss						
Temporary destruction/displacement	x			x		
Temporarily inaccessible	x			x		
Assigned Effect Index Value	0.25	1	0.25	0.25	1	0.25
Habitat degradation						
Energy resource reduction	x			--		
Air quality impairment (chronic levels)	--			--		
Water quality impairment (chronic levels)	--			--		
Sediment quality impairment (chronic levels)	--			--		
Reduction of structural habitat quality metrics	x			--		
Assigned Effect Index Value	0.25	0.75	0.19	0	0.75	0.00
Average Direct Effects Index	**0.25**		**0.19**	**0.13**		**0.09**
Average Effects Index	**0.25**		**0.20**	**0.13**		**0.11**
Magnitude of Effects	**0.25**		**0.20**	**0.13**		**0.11**
Effects Index Scale		**Conservation Measures Effectiveness Scale**				
Scale: 1= total loss; 0.75 = high effect; 0.5 = moderate effect; 0.25 = low effect; 0 = trace effect		1 = Trace or no Effectiveness				
x = Sources of effect		0.75 = Low Effectiveness				
-- = Absence of effect		0.5 = Medium Effectiveness				
NA = Absence of interaction		0.25 = High Effectiveness				
[1] Use direct effect value if greater		0 = Elimination of Effect				

4.2.8 Database improvements, assumptions, and uncertainties

Improvements

While the potential effects model was created using typical activity descriptions and size estimates (Section 4.2.2, Descriptive data), it was also designed to use explicit spatial data as more became available and to allow the inclusion of additional authorizations.

To improve the precision of the potentially-affected-area estimates used in Washington DNR's Endangered Species Act decision-making process, several refinements were made to the original 2005 spatial data. The following specific improvements were made to the original database:

- All use authorization data were updated and are current as of June 2007.
- Only covered species were included in the analysis.

- Ecosystem and water body names were added for all use authorizations.
- Wherever possible, typical activity size estimates were replaced by explicit size information for all covered activities.

The resulting information for the data analysis and methods described is the basis of the affected habitat estimates and potential decreases presented in Sections 4.3 and 4.4. Additional information regarding how potential effects and expected outcomes were identified, including all database results, are located in the *Aquatic Resources Program Endangered Species Act Compliance Project, Potential Effects and Expected Outcomes Technical Paper* (Washington DNR, 2007b) and the *Aquatic Resources Program Habitat Conservation Plan Covered Species Technical Paper* (Washington Department of Natural Resources, 2007).

Assumptions and uncertainties

The following list describes various assumptions and uncertainties within the data analysis that allow for potential unquantifiable errors.

Lease code limitations: Lease codes used to determine use authorization types can change over time. Historically, lease codes have been limiting, because one code could apply to multiple use authorization types. This can lead to assumptions that certain activities occur on state-owned aquatic lands that are not a representation of what is actually present. The agency is currently working on improving this by expanding the lease codes used for new use authorizations and going through existing leases to reassess the codes applied.

Unauthorized uses: There are unauthorized uses on state-owned aquatic lands that were not included in the database analysis. These unauthorized uses could change the values presented for potential effects and expected outcomes.

Ownership uncertainties: State-owned aquatic lands have been identified in various water bodies throughout the state of Washington. State ownership is still unknown in a number of areas. These ownership issues could change the values presented for potential effects and expected outcomes.

Conservation measures change: Certain conservation measures were selected and used in the database analysis to determine potential effects and expected outcomes. Current conservation measures may be different than those used in the initial analysis. Conservation measures can be adjusted over time as more information becomes available that supports a change, such as biological, ecological, and legal information, or considerations of practicality. Alterations in conservation measures could change the values presented for potential effects and expected outcomes.

4.3 Covered activities: potential effects

Aquaculture, log booming and storage, and overwater structures have been identified as the three covered activities in the Aquatic lands Habitat Conservation Plan (Chapter 3). The following section discusses how the covered activities can impact habitat essential to covered species in one or more of their life stages. To determine the potential effects discussed in this chapter, habitat descriptions from Chapter 1 and definitions of covered activities from Chapter 3 were used. Section 4.2 describes the data analysis used to identify the impacts of an activity. Section 4.4 addresses activity-specific effects to covered. Additional information regarding how potential effects were identified is located in the *Aquatic Resources Program Endangered Species Act Compliance Project, Potential Effect and Expected Outcomes Technical Paper* (Washington Department of Natural Resources, 2007b).

Aquaculture: potential effects

When determining the potential effects that shellfish aquaculture has on the habitats that covered species use on state-owned aquatic land, aquaculture descriptions and definitions from Chapter 3 were used. The potential effects attributed to aquaculture are estimated in Chapter 4 by applying assumptions of the typical structure, operation, temporal dynamics, and maintenance required. An area of alteration for aquaculture was determined by totaling the number of leases and multiplying by average width and length measurements (Table 4.10).

Assumed area of alteration: aquaculture

The area of alteration includes the area under cultivation and adjacent areas where support activities or other direct effects occur.

The total footprint for mussel, clam, and oyster aquaculture activities is estimated to be 85,248 meters^2.

Areas outside of cultured areas experience direct effects only from associated shoreline structures and disturbance of wildlife by human activities. A relatively small area of alteration is assumed due to the highly localized nature of the activity sub-group, with the total area of alteration equal to 102,300 meters^2.

Table 4.10. Assumed area of alteration: Aquaculture

Activity Group	Activity Sub-group	Number of Leases	Max. Width (meters)	Max. Length (meters)	Assumed Width (meters)	Assumed Length (meters)	Estimated Footprint (meters^2)	Area of Alteration (meters^2)
Aquaculture	Shellfish	134	183	915	1,332	64	85,248	102,300

Sources, controlling factors, potential effects

Table 4.11 concisely summarizes the potential effects of aquaculture by identifying the source of the effects from the activity, alterations that can become a controlling factor, and the potential effect the controlling factor may have on the biological and ecological community (species or habitat). The data analysis and methods used to identify activity impacts is described in Section 4.2. A literature review was included in those methods and used to develop the table provided and the subsequent narrative. Activity-specific effects to covered species and habitat are identified later (Section 4.4).

Table 4.11. Potential effects: Aquaculture.

Source	Controlling Factors	Potential Biological Effect
Tilling, raking and digging to harvest shellfish	Disturbance and long-term modification of sediment substrates and submerged aquatic vegetation in nearshore unconsolidated habitats, displacement of natural biota and replacement with cultured species	Long-term habitat disturbance during active culture
Placement of structures for growing shellfish, stakes, tubes, lines, dikes, mussel rafts	Placement of aquaculture structures preventing access to habitats and shading of substrate	Long-term inaccessible habitat and habitat impairment, reduction in photosynthetically active radiation
Harvesting activities, pest control, interaction with aquaculture structures	Human and machinery presence, harvesting operations, physical disturbance of substrate	Temporarily inaccessible habitat, physical trauma to organisms, harassment of organisms due to increased turbidity
Mechanical harvesting using hydraulic methods	Increased turbidity; surface/ subsurface substrate and above substrate disturbance (*e.g.* physical structure or vegetation), disturbance of natural substrate with temporary and localized increases in turbidity	Temporary habitat destruction and inaccessibility, reduction in photosynthetically active radiation, water quality impairment
Pest (burrowing shrimp) control using chemical (carbaryl) methods	Contamination of water and substrates with chemical; food web effects	Short-term impairment of water and sediment quality, loss of biomass, incidental mortalities of salmonids

Source	Controlling Factors	Potential Biological Effect
Mussel culture using rafts	Deposition of shells and feces and release of sediment when harvesting	Long-term alteration of sediments, temporary impairment of water quality

Aquaculture impacts to habitat

Direct effects — habitat

Shellfish culture operations use a variety of methods to grow and maintain their crop. As a result, the type and degree of affects to covered species or their habitat varies with the shellfish species being cultivated, cultivation and harvest methods, and the frequency of the disturbance. Preparation, maintenance, and harvest of mussels, clams, and oysters are both by hand and by mechanical means, while access to the culture sites occurs by boat and from adjacent terrestrial lands. Intertidal shellfish harvest is by hand and therefore depends on tidal stage, with harvest operations occurring during day- or nighttime low tidal cycles. Subtidal harvest does not depend on tidal stage and generally occurs during the day.

Destruction of habitat from shellfish culture is generally temporary and limited to harvest cycles of 1 to 5 years, with the cycle varying with the species being cultured. The magnitude of direct effects to habitat vary with the species being cultured, methods used, and harvest cycles. Effects may include, but are not limited to:

- Changes in substrate size/quality.
- Loss or alteration of vegetative communities during seeding, growth, and harvest operations due to dredging, digging, tilling, or raking of sediments, and change/conversion of substrate.
- Altered substrate composition from the deposition of growing mediums, such as shell fragments (cultch) and coarse gravel.
- Alteration of habitat complexity as a result of bed preparation, the installation of structures such as stakes, protective tubes or nets, and anchors.
- Changes in vegetative and invertebrate communities.

Suspended shellfish culture methods (such as longlines and rafts) can alter substrate composition and quality with the alteration of wave and current energies and the deposition of shells, feces, and solids, such as excess food. This can cause changes in sediment oxygen and nutrient flux (Callier *et al.*, 2006; Giles *et al.*, 2006; Hargrave *et al.*, 2008). The three dimensional structure of shellfish aquaculture can cause hydraulic dynamics that may lead to localized changes in substrate composition. The type of equipment and harvest methods that are used also can cause localized changes in substrate. Local bathymetry and drift cell dynamics, as well as the species cultivated and cultivation method, shape these effects. For example, mechanical harvest reduces the quantity of fine grains at a site through resuspension, with longlines potentially increasing sedimentation through decreases in water circulation (Wisehart *et al.*, 2007). Structures such as bags, racks, and longlines can also interrupt the action of waves and currents, resulting in deposition of fine sediments in the immediate vicinity of the structure.

Culture methods that involve the use of elevated or overwater structures (such as longlines and raft culture) artificially shade benthic habitats and may eliminate or reduce aquatic vegetation within the shade footprint. Because of the reduction in vegetation, organic detritus inputs may be decreased locally, limiting food sources for organisms that feed on these inputs (for example, polychaetes and amphipods) and for the species that prey upon them. One study, however reports that the diversity and productivity of oyster culture and eelgrass habitat in Willapa Bay were equivalent (Ferraro and Cole 2007).

Intertidal and shallow subtidal (+1 to -8 feet mean lower low water) shellfish culture occurs in habitats similar to those favored by eelgrass (*Zostera marina*) and other aquatic vegetation—moderately stable fine- to medium-grained sediments, minimal bioturbation, and moderate surface roughness. Shellfish culture can directly affect the distribution of submerged aquatic vegetation through a decrease in the surface area available for colonization; or through direct physical disturbance during seeding and harvest operations and the removal of plants and rhizomes during mechanical harvest or bed harrowing (Carvalho *et al.*, 2006; Simenstad & Fresh, 1995; Tallis *et al.*, 2009). Sites that have been dredge harvested show higher rates of eelgrass growth and flowering than those harvested by other methods (Wisehart *et al.*, 2007).

Ropes used in longline culture can potentially entwine vegetation, increasing desiccation and decreasing plant densities (Wisehart *et al.*, 2007). While the magnitude of the impacts varies with the location and methods used for culturing and harvesting, effects from mechanical harvesting are generally the greatest, while hand harvesting causes the least impact (Wisehart *et al.*, 2007). Narrowly spaced longlines (1.5–2.5 feet) decreased the eelgrass density and percent cover; widely spaced longlines (5–10 feet), on the other hand, had eelgrass cover and density similar to control sites (Rumrill & Poulton, 2004). There is very little information regarding vegetation and rack and bag culture; however, Ward *et al.* (2003) found no spatial loss of eelgrass associated with oyster rack culture.

Shellfish are filter feeders and remove phytoplankton from the water column. As a result, there may be localized decreases in turbidity and an associated increase in the penetration of photosynthetically active radiation (PAR) (Newell, 2004). Shellfish feces and pseudofeces (pellets of indigestible sediment and plankton) may also provide localized increases in sediment nutrients, thereby stimulating shellfish growth (Peterson & Heck, 2001; Reusch & Williams, 1998). Wisehart *et al.* (2007) found that oyster beds that were mechanically harvested every three years had higher seedling abundance and production of seed compared to either an adjacent control or longline areas, although this is not considered a long-term benefit.

Indirect effects — habitat

Shellfish culture has the potential to alter water quality through increased filtration. It can also alter prey/food resource availability for covered species in the habitat conservation plan; and it can reduce the quality of structural habitat for covered species. Bivalve shellfish are filter feeders, removing plankton and suspended sediments from the water column (Cole, 2002; Heffernan, 1999; Stenton-Dozey *et al.*, 2001). In large quantities, they may both degrade and benefit habitat. Biofiltration by shellfish may locally decrease phytoplankton abundance, thereby reducing turbidity and increasing light penetration for submerged vegetation (Grant *et al.*, 2007; Newell, 2004). In areas where shellfish culture dominates, it may also limit nutrient availability for marine vegetation and non-cultured species (Gibbs, 2004). Dumbauld *et al.* (2009) found that although Totten Inlet, near Olympia, has the highest density of shellfish culture of any embayment in Puget Sound, as well as high anthropogenic nutrient inputs, only localized nutrient depletion occurred.

Changes in benthic infaunal and epifaunal communities associated with shellfish culture may alter the forage base for covered species. Several studies document that while species richness, numbers, and biomass associated with aquaculture gear can be equal to or higher than that of eelgrass, diversity varied significantly (Dealteris *et al.*, 2004; Dumbauld *et al.*, 2000, 2009; Feldman *et al.*, 2000; Meyer & Townsend, 2000; O'Beirn *et al.*, 2004; Pinnix *et al.*, 2005; Powers *et al.*, 2007).

Accumulations of feces, pseudofeces, and shell fragments may affect sediment quality in areas that are not well flushed. The substrate may become finer, enriched with nutrients, and, in some cases, anoxic (Heffernan, 1999). Benthic enrichment of the substrate can also change the composition, diversity, and structure of benthic communities, increasing the abundance of pollution-tolerant species and locally altering food-web dynamics (Bendell-Young, 2006; Carvalho *et al.*, 2006). In some cases, recovery of pre-culture community structure and nutrient balance can occur once cultivation stops; however, the process may take several years and depends on a number of environmental parameters that can be challenging to qualify and quantify (Heffernan, 1999; Stenton-Dozey, 2001).

Log booming and storage: potential effects

Chapter 3 provides the descriptions and definitions of log booming and storage that were applied when determining the potential effects of log booming and storage on the habitats used by covered species on state-owned aquatic land. The potential effects attributed to log booming and storage are estimated in this chapter by applying assumptions about the typical structure, operation, temporal dynamics, and maintenance required. An area of alteration for log booming and storage was determined by totaling the number of leases and multiplying the result by average width and length measurements (Table 4.12).

Area of alteration

The area of alteration is based on the extent of bark and debris deposition that occurs in areas beneath and adjacent to log storage areas. The total footprint of log booming and storage areas is estimated to be 79,994 meters^2. Bark deposition may occur on the substrate as far as 60 meters from the edge of the log boom and encompasses approximately 100,000 meters^2 outside the activity footprint (Pease, 1974). Consequently, the total assumed area of alteration is approximately 180,000 meters^2.

Table 4.12. Assumed area of alteration: Log booming and storage activity group.

Number of Leases	**Max. Width** (meters)	**Max. Length** (meters)	**Assumed Width** (meters)	**Assumed Length** (meters)	**Estimated Footprint** (meters^2)	**Area of Alteration** (meters^2)
61	610	762	622	127	79,994	180,000

Sources, controlling factors, potential effects

The Table 4.13 below concisely summarizes the potential effects of log booming and storage by identifying:

- The source of the effects from the activity.
- Alterations that can become a controlling factor.

- The potential effect the controlling factor may have on the biological and ecological community (species or habitat).

The data analysis and methods used to identify activity impacts is described in Section 4.2. A literature review was included in those methods and was used to develop the table and the subsequent narrative. Activity-specific effects on covered species and habitat are identified later in Section 4.4.

Table 4.13. Log booming and storage potential effects

Source	Controlling Factors	Potential Effect
Waste accumulation on benthos	Altered substrate composition, soil compaction Degraded water quality, increased biological and chemical oxygen demand, increased turbidity Depth and slope alteration	Shifts in biological communities from changes in substrate composition or elevation changes Reduced habitat connectivity Reduced prey abundance Behavioral avoidance of degraded water and sediment quality Decline or loss of aquatic vegetation
Boomed logs	Increased artificial shade Reduced wave energy Source of bark deposition Degraded water quality—temperature dissolved oxygen Altered hydrology—reduced circulation Altered structural characteristics of habitat Physical trauma from log movement	Shifts in biological communities due to reduced water circulation in sheltered area and degraded water quality Reduced wave energy alters processes that maintain nearshore beaches Reduced growth of aquatic plants and macroalgae due to increased shading Potential increases in pinniped staging areas increases predation on fish
Operation	Periodic dredging to maintain boat access to log storage areas Offloading logs (dumping) compacting sediment or altering depth and slope characteristics Wave energy from boat traffic increases shoreline erosion Recurrent episodic and unpredictable human activities	Shifts in biological communities due to changes in elevation ranges from dredging and altered substrate Physical trauma to habitat and species from dumping or vessels Reduction of aquatic macroinvertebrate production Reduced habitat connectivity due to physical barriers (*e.g.*, wood debris) Behavioral avoidance from species' ability to use habitat

Log booming and storage impacts to habitat

Direct effects — habitat

Booming or dumping of logs occurs year-round and can be sporadic or constant. The most widely researched effects from log booming and storage are those that relate to alteration of the sediment structure. Dumping logs may result in the scouring and compacting of substrates beneath the logs and within the storage areas, with severe compaction altering benthic prey communities (Pease 1974; Sedell *et al.*, 1991). Thick accumulations of bark, whole logs, and other miscellaneous trash, such as metal bands and cables, may be common on the substrate beneath both dumping and rafting sites (Jackson, 1986; Kirkpatrick *et al.*, 1998; Pease, 1974). Bark deposits may extend outward from the site for up to 60 meters (197 feet); may be greater than 0.5 meters (1.6 feet) thick;, and have been observed to persist at abandoned sites for at least 30 years (Jackson, 1986; Pease, 1974; Sedell *et al.*, 1991). While debris may persist for decades or centuries in freshwater systems, the persistence of woody debris in saltwater systems is considerably shorter because it is broken down by wood-boring organisms such as teredos (*Teredos* spp.) or shipworms (*Bankia setacea*) (Bilby *et al.*, 1999; Naiman *et al.*, 2002; Pease, 1974).

Effects on submerged vegetation are possible through smothering by woody debris, increases in hydrogen sulfide associated with decomposition of the debris, or shading caused by log rafts (Elliott *et al.*, 2006). While there is little research regarding shading from log booming and storage in either fresh- or saltwater, potential effects are considered to be similar to those from overwater structures, marinas, and shipyards and terminals, with the extent of the shade dependent on the orientation of the boom relative to the position of the sun. Permanent habitat effects are also possible, because of changes in water and sediment quality associated with decomposition of the debris, which results in associated decreases in dissolved oxygen, stratification of water temperatures, and wood leachate from either logs or pilings.

Indirect effects — habitat

The effects of log booming and storage on prey resources and the structural quality of habitat are generally the result of the physical and chemical changes associated with accumulations of debris (such as bark, logs, and cables), loss of submerged aquatic vegetation in shaded areas beneath dumping and rafting sites, and sediment compaction and scour associated with log dumping and propeller wash. While these changes are likely most significant beneath the log rafts, the area of alteration associated with bark deposits may extend outward from the site for up to 60 meters (197 feet) (Pease, 1974). Bark and debris can be displaced down slope from the originating area into adjacent, deeper areas, with the deposits persisting for at least 30 years (Kirkpatrick *et al.*, 1998; Sedell *et al.*, 1991).

Although species richness is generally reduced in habitats dominated by bark deposits, epibenthic organisms such as harpacticoid copepods, amphipods (such as *Anisogammarus confervicolus*), and isopods (such as *Exoshpaeroma oregonensis*) may occur in greater abundance beneath and adjacent to log rafts because of the structural habitat provided by the logs and debris (Kirkpatrick *et al.*, 1998; Sedell *et al.*, 1991). In contrast, benthic infauna were less abundant in areas covered with bark and had lower biomass when compared to reference sites, regardless of depth (Jackson, 1986). Suspension feeders are more affected by bark deposits than organisms that feed on deposited material. Sediment compaction may also prevent substrate use by larger suspension feeders, such as clams, and may shift benthic assemblages such that infaunal detritus feeders become the dominant species (Sedell *et al.*, 1991).

Chronic impacts to water and sediment quality affects prey resources, as the decomposition of woody debris and leachate (tannins and lignins) from the logs depletes the dissolved oxygen concentrations surrounding the rafts (Pease, 1974; Power & Northcote, 1991). The anaerobic decomposition of woody debris and associated release of hydrogen sulfide impacts habitat quality, vegetation, and prey resources (Elliott *et al.*, 2006). Additional water and sediment quality impacts associated with the use of treated wood for raft pilings, stormwater runoff from onshore log handling facilities, and vessel traffic are discussed below (overwater structures).

Overwater structures: potential effects

When determining the potential effects that overwater structures have on the habitats used by covered species on state-owned aquatic lands, descriptions and definitions of all eight types of overwater structure were used (see Chapter 3). The potential effects attributed to overwater structures are estimated in Chapter 4 by applying assumptions of typical structure, operation, temporal dynamics, and maintenance required. An area of alteration for overwater structures was determined by totaling the number of leases and multiplying the result by average width and length measurements (Table 4.14).

Table 4.14. Assumed area of alteration: Overwater structures activity group.

Activity Sub-group	**Number of Leases**	**Max. Width** (meters)	**Max. Length** (meters)	**Assumed Width** (meters)	**Assumed Length** (meters)	**Est. Footprint** (meters^2)	**Area of Alteration** (meters^2)
Boat Ramps, Launches, Hoists	56	16	46	8	31	248	275
Docks, Wharves	309	10	122	2	61	122	750
Floating Homes	68	56	23	45	18	810	900
Mooring Buoys	274	10	10	7	7	49	100
Nearshore Buildings	98	244	246	61	63	3,838	11,500
Rafts, Floats	8	11	16	8	8	64	128
Marinas	394	2,000	400	1,000	200	200,000	650,000
Shipyards & Terminals	59	500	4,000	200	2,000	400,000	1,115,000

Area of alteration: docks and wharves

The area of alteration includes the footprint of the structure, the area of changed hydrodynamics, sediment dynamics, shoreline modification, vessel propeller scour, shading, storm water, and chemicals leaching from treated timber.

The estimated footprint of docks and wharves is approximately 122 $meters^2$.

The area of alteration associated with docks and wharves is relatively large due to shading and estimated area of hydrodynamic alteration. For the purposes of this analysis, it is estimated to encompass 750 $meters^2$.

Area of alteration: boat ramps/launches/hoists

The area of alteration for ramps includes the footprint of the structure, along with the surrounding area altered by propeller scour, shoreline modification, and changes in sediment transport.

The estimated footprint of boat ramps is approximately 248 $meters^2$.

A relatively small area of alteration results from the physical structure and placement of boat ramps. Due to their low profile, which is usually level with or only slightly above existing grade, ramps cause relatively little effect on sediment transport, shading, and benthic biota. For the purposes of this analysis, the area of alteration encompasses approximately 275 $meters^2$.

Area of alteration: nearshore buildings

The area of alteration for nearshore buildings includes the estimated footprint of the structure and adjacent aquatic lands that could be affected by the building through shading, shoreline modification, and associated vessel activity.

The estimated footprint of nearshore buildings is approximately 3,838 $meters^2$.

Nearshore buildings have a relatively large area of alteration due to associated modifications of the shoreline and adjacent aquatic land through shading, structures, and vessel activity. For the purposes of this analysis, the area of alteration encompasses approximately 11,500 $meters^2$.

Area of alteration: mooring buoys

The area of alteration for mooring buoys includes the footprint of the anchoring system and float, the area potentially altered as a result of anchor/chain drag, and shading by the buoy and vessel. The estimated footprint of mooring buoys is approximately 49 $meters^2$.

For the purposes of this analysis, the area of alteration encompasses approximately 100 $meters^2$. This area includes the area directly impacted by the chain or unbuoyed cable and shading from the attached vessel and the anchor.

Area of alteration: floats and rafts

The area of alteration for floats and rafts includes the footprint of the structure and the area potentially altered as a result of impacts associated with anchor and chain/cable drag and shading. The estimated footprint of rafts and floats is approximately 64 $meters^2$.

Due to the similarity of structures and effects (for example, anchoring system, cable or chain drag, and shading), the area of alteration relative to the footprint is assumed to be similar to that for mooring buoys and equals 128 met meters^2.

Area of alteration: floating homes

The area of alteration for floating homes includes the footprint of the floating home plus the area potentially altered by impacts from moorage systems and shading. The estimated footprint of floating homes is approximately 810 meters^2.

A relatively small area of alteration is assumed due to the typically low energy and highly impacted environment in which floating homes are located. For the purposes of this analysis, the area of alteration encompasses approximately 900 meters^2.

Area of alteration: marinas

The area of alteration for marinas includes the area of the overwater structure(s) associated with the marina, shading, propeller scour, stormwater pollution, disturbance of aquatic species as a result of boat traffic, and shoreline erosion caused by waves produced by the boat. The adjacent area includes that affected by the discharge of water carrying pollutants from impermeable surfaces or from facilities and by light or noise pollution. In-water alterations are related to impacts extending beyond the footprint of boat traffic that result in scour from propeller wash, paint releases, waste releases, vessel moorage and loading (for example, shading or spillage and accidental discharges of toxins or waste), fueling, vessel repair and associated pollutants, and transfer of materials. The operation of boats can create changes in the physical environment beyond the facility through changes in currents, light, water, and sediment composition. The net effect is that marinas exert a wider influence on the bottom than that contained within the estimated footprint (Washington Department of Natural Resources, 2005c). However, the area of alteration may be restricted due to enclosure by breakwaters, which limits the impact of many controlling factors, such as storm water pollutants, scour, noise, and wave energy.

The estimated footprint of a typical marina is 200 meters by 1,000 meters, totaling approximately 200,000 meters^2 (Table 4.14).

Based on the length of 150 meters for each of four sides of the estimated footprint of a typical marina, the estimated dimensions of the area of potential disturbance of aquatic species as a result of the operation of boats and personal watercraft is 500 meters by 1,300 meters, totaling approximately 650,000 meters^2.

Area of alteration: shipyards and terminals

The area of alteration includes the area of the overwater structure(s) associated with the terminal or shipyard; shading; propeller scour; storm water pollution; disturbance of aquatic species as a result of vessel, vehicle, and loading equipment traffic; and shoreline erosion caused by waves produced from shipping vessels. Adjacent area includes that affected by the discharge of water carrying pollutants from impermeable surfaces or from facilities and by light or noise pollution. In-water alterations are related to impacts extending beyond the footprint of vessel traffic that result in scour from propeller wash, paint releases, waste releases, vessel moorage and loading (for example, shading or spillage and accidental discharges of toxins or waste), fueling, vessel repair and associated pollutants, and transfer of materials. Terminals are associated with storage and warehousing, which require industrial strength grating and the use of heavy equipment and rail or pipelines that move cargo—all of which can contribute toxic discharges, reduction in photosynthetically active radiation, and noise and light pollution.

The estimated footprint of shipyards and terminals is 200 meters by 2,000 meters, totaling approximately 400,000 $meters^2$.

Based on the length of 150 meters for each of four sides of the estimated footprint of a typical marina, the estimated dimensions of the area of potential disturbance of aquatic species as a result of the operation of boats and personal watercraft is 500 meters by 2,300 meters, totaling approximately 1,115,000 $meters^2$.

Sources, controlling factors, potential effects

Table 4.15 concisely summarizes the potential effects of overwater structures by identifying:

- The source of the effects that result from the activity.
- What can result from that source and become a controlling factor.
- The potential effect that the controlling factor has on the biological and ecological community (species or habitat).

The data analysis and methods used to identify activity impacts are described in Section 4.2. A literature review was included in those methods and was used to develop the table and the subsequent narrative. Activity-specific effects on covered species and habitat are identified later in this chapter (see Section 4.4).

Table 4.15. Overwater structure potential effects

Source	Controlling Factors	Potential Effect
Dredging	Depth and slope alteration	Altered biological communities as a result of depth increases and greater saltwater intrusion into freshwater ecosystems
	Degraded water quality	Loss of spawning habitat for some fish species
	Change in substrate composition	Reduced presence of submerged aquatic vegetation and associated biological communities
	Physical disturbance of substrate	Physical trauma or mortality from dredging (e.g., entrainment, crushing) from fish and benthics.
	Recurrent human activity	Reduced prey abundance
	Loss of natural shade	Behavioral avoidance due to degraded water quality or noise
		Reduced fitness or increased mortality due to suspension of persistent bioaccumulative toxins
Fishing	Recurrent disturbance	Mortality

Source	Controlling Factors	Potential Effect
	Physical trauma to fish	Reduced fitness
Vehicular, boat, and foot traffic	Altered substrate composition, soil compaction, trash accumulation	Altered biological communities due to changes in substrate, depth and slope
	Degraded water quality, increased biological and chemical oxygen demand, increased turbidity	Reduced habitat connectivity
	Change in substrate composition	Reduced prey abundance
	Depth and slope alteration	Behavioral avoidance of degraded water quality
	Noise	Mortality of eggs, juveniles, and adults Flushing Behavioral avoidance
	Collision or entrainment	Mortality of eggs, juveniles, and adults
Operational activity	Altered depth/slope profile	Behavioral avoidance
	Altered hydrology	Physical disturbance and stress-related trauma
	Physical disturbance	Degradation of habitat
	Reflected wave energy	Alteration of substrate composition
	Structural habitat alteration (e.g., depth/slope profile)	Nesting failure of birds
		Increased predation
		Reduced habitat connectivity (increased fragmentation)
		Reduced prey abundance
		Reduction of aquatic macroinvertebrate production
		Physical barriers to migration or movement
	Vessel traffic and accompanying human activity	Noise and other human activity can disturb activities such as feeding, nesting, and resting
		Propeller wash can create turbidity, change sediment regime, disturb communities, and injure species
	Water and sediment quality degradation	Direct mortality

Source	Controlling Factors	Potential Effect
Physical structure	Change in habitat structure (pilings)	Aggregation of predatory finfish species (e.g., bass) and birds in fresh and marine ecosystems
		Increased predation on juvenile salmonids in fresh and marine ecosystems
	Displacement of habitat—pilings, boat ramps, and other structures, such as bank hardening and breakwaters	Replaces habitats used for foraging, reproducing, and migrating with a completely different structure and ecological community.
	Shading—behavioral changes	Modified juvenile salmonid behavior (increased schooling, avoidance) in saltwater, estuarine, and freshwater ecosystems
		Increased use of deep water by juvenile salmonids in saltwater ecosystems
	Shading—community changes	Reduction of emergent or submerged aquatic vegetation in saltwater, estuarine, and freshwater ecosystems
		Reduction of benthic infauna in wetland ecosystems
		Modification of benthic infauna community structure (reduction of diversity, increase in abundance of tolerant species) in saltwater ecosystems
		Increased population density of mobile benthic predators and scavengers (e.g., crabs, sea stars, sculpins)
Placement of nearshore stabilization materials (*e.g.*, breakwalls)	Pollution	Reduced water circulation in sheltered area and water quality degradation results in physiological stress and acute or chronic toxicity for some organisms
	Altered hydrology	Reduced water circulation in sheltered area and water quality degradation results in physiological stress and acute or chronic toxicity for some organisms

Source	Controlling Factors	Potential Effect
Placement of shoreline erosion control structures (*e.g.*, rip-rap)	Reduced sediment supply	Changes in community composition and population numbers due to altered habitat
	Reflected wave energy	Increased depth and slope in nearshore ecosystem reduces area within elevation ranges suitable for some organisms
	Change in substrate composition	Loss of large organic debris as cover element
	Depth and slope alteration	Loss of channel complexity
	Structural habitat simplification	Reduced habitat connectivity
	Water quality degradation	Reduced prey abundance
		Behavioral avoidance
Presence of outfall structure on aquatic lands	Artificial hard substrate in habitats	Artificial reef effect: Benthic habitat modification through accumulation of species and biomass not typical to habitat; may include predators (e.g., rockfish, sculpins) of covered species (e.g., salmonids)
	Physical changes in sedimentary processes (scouring, sediment transport, deposition, sediment composition)	Disturbance and change of existing habitat structure and function from unconsolidated to consolidated
	Physical changes in hydrodynamics	Inaccessible habitat because of presence of structure and effluent plume
Storm water or wastewater discharge	Increased nutrient loads	Decreased reproductive success
		Increased productivity and an accompanying decrease in dissolved oxygen
		Increase in algal blooms
		Localized alteration of benthic communities Decline or loss of aquatic vegetation from increased water turbidity and changes in sediment
	Accumulation of toxins (e.g., metals, pesticides, herbicides, hydrocarbons) and other harmful chemicals (e.g., endocrine disrupters) in sediment	Bioaccumulation of toxins
	Degradation of water and sediment quality	Can have indirect effects on health of species.

Source	Controlling Factors	Potential Effect
		Modification of benthic infauna community structure (reduction of diversity, increase in abundance of tolerant species) in saltwater ecosystems
	Discharge of toxins (e.g., metals, pesticides, herbicides, hydrocarbons) and other harmful chemicals (e.g., endocrine disrupters) into the water column	Altered food web dynamics
	Introduction of human and pet pathogens	Increases in disease or lesions
Treated wood in pilings, other structural components, and debris	Impairment of water quality	Little documented effect.
	Impairment of sediment quality	Modification of benthic infauna (decrease in diversity and abundance) in saltwater, estuarine, and freshwater ecosystems.
Waste and chemical contamination	Degraded water quality, increased biological and chemical oxygen demand, increased turbidity	Decreased oxygen levels resulting in impaired respiration
		Introduction of diseases or pathogens

Overwater structures impacts to habitat

Direct effects — habitat

Disturbance from overwater structures can be sporadic or constant, occurring year-round. Use of recreational structures (single-family docks, mooring buoys, boat ramps/launches, and rafts) tends to be greater in April to October, thereby concentrating effects on the breeding and rearing periods of many of the species addressed in Section 4.4. Most of the activities in this group have structural features in common with docks and wharves, while their configuration, materials, and effects on submerged habitats vary. The structures affect predation, behavior, and habitat function by altering physical processes (such as ambient light and sediment transport), which in turn alters the quality and quantity of habitat available for reproduction, rearing, and refuge (Carrasquero, 2001; Nightingale & Simenstad, 2001).

In-water structures, such as pilings, breakwaters, bulkheads, and fill, alter wave and current energies, modifying the longshore transport of sediments and changing nearshore sediment composition and beach/shore nourishment patterns adjacent to the structures. These effects can also permanently alter bathymetry by replacing shallow unconsolidated habitats with deeper, steeper consolidated substrates (Toft *et al.*, 2004). Fill, bulkheads, and jetties associated with shipyards and terminals influence adjacent habitat in similar ways. Marinas, however, that are nearly enclosed with protective breakwaters designed to buffer wave and current energy have a similar, but more pronounced level of effect on these physical habitat parameters and water quality impacts. Construction of in-water structures may also remove or reduce riparian vegetation, leading to a loss of natural shading and increases in nearshore/littoral water and beach temperatures, and reduction of litterfall and organic debris (Beschta, 1997; Jennings *et al.*, 1999; Rice, 2006). Permanent changes in bathymetry and sediment composition may also occur as a result of vessel scour, dredging, and modification of bottom water currents adjacent to storm water or process water outfalls (Diener *et al.*, 1997; King County, 2003; Washington Department of Natural Resources, 2007b).

The combined effects of several types of overwater structures may alter sediment input and transport processes over large areas, disconnecting aquatic ecosystems from important sediment sources, woody debris recruitment, nutrient loading, and affecting infaunal communities. In saltwater ecosystems, stabilization structures can trap sediment from feeder bluffs or structures may prevent tidal or storm inundation and erosion of sediment stored high on beaches (Macdonald *et al.*, 1994). While bank armoring and breakwaters in lakes have similar effects, armoring in low gradient riverine ecosystems does not substantially affect sediment supply and channel patterns (Bolton & Shellberg, 2001; Montgomery & Buffington, 2001; Reid & Holland, 1997). Bank armoring may also increase the transport of sediment near the structure, as reflected wave energy narrows beaches and coarsens substrate, lowering beach elevation as sediment is transported away and large organic debris is eliminated (Macdonald *et al.*, 1994; Williams & Thom, 2001). Similar impacts may be observed in riverine and lake ecosystems, with fine sediments—entrained by reflected waves—transported and deposited elsewhere. In rivers, channel incision, coarsening of bed substrates, and shifting of bank erosion to unarmored sections of the channel is common (Biedenharn *et al.*, 1997).

In addition to site-specific impacts, an area of alteration surrounds the structures, approximately 2 to 10 times larger than the structure footprint. The area of alteration is a result of shading and changes in ambient light levels, changes in shore zone habitat structure, and the disruption of water flow pattern and energy (Carrasquero, 2001; Simenstad *et al.*, 1999; Washington Department of Natural Resources, 2005d). This is particularly true of large structures, such as marinas, shipyards, and terminals, which modify both physical and chemical habitat characteristics, such as light, temperature, salinity, nutrient levels, and wave action (Simenstad et *al.*, 1999).

Shading from overwater structures in both salt- and freshwater ecosystems can eliminate submerged aquatic vegetation—such as eelgrass (*Zostera marina)*, kelp (Laminariales), hornworts (Ceratophyllaceae), and water-starworts (Callitrichaceae)—from a much larger area than just the surface area of the structure (Nightingale & Simenstad, 2001; Simenstad *et al.*, 1999; Washington Department of Natural Resources, 2005d). A study conducted by Washington DNR (2005d) found that while the area shaded by a structure varies with season, water depth, dimensions of the structure, and the presence of vessels, the shadow-to-deck-area is approximately a 4:1 ratio. Mooring buoys may have additional impacts due to the potential for the anchor line to drag on the bottom and remove vegetation within the scope of the system (Betcher & Williams, 1996).

Over- and in-water structures may also lead to acute water and sediment quality impacts. Reduced water circulation behind breakwaters can lead to significant, potentially lethal decreases in dissolved oxygen as a result of increased water temperatures and increases in nutrient concentrations from gray water, storm water, or process water discharges. Storm water may also contain PAHs, as well as high levels of nitrates and phosphates, pesticides, and sediments, as well as bacteria and pathogens from domesticated animals (Ackerman & Weisberg, 2003; Ahn *et al.*, 2005; Cubbage, 1995; Kerwin, 2001; King County, 2004; Olivieri *et al.*, 1977).

Indirect effects — habitat

Overwater structures degrade habitat by changing physical and chemical habitat characteristics, such as light, temperature, nutrient levels, and wave energy (Simenstad *et al.*, 1999). While the changes are attributable to the presence of the structures, the effects are frequently interrelated and intensified by concentrations of structures, operational activities (such as vessels and noise), and associated structures (such as storm water outfalls, bulkheads, and breakwaters).

The presence of aquatic vegetation is likely one of the most important influences on the type, diversity, and density of prey available (Haas *et al.*, 2002). Prey resources may also be impacted by increases in turbidity caused by vessel traffic, changes in current energy, degradation of the quality of water and sediment as a result of operational activities (for example, fuel spills and increased turbidity), and changes to the substrate and sediment transport processes associated with the presence of the structures. The extent of the change in available prey depends on the size of the structure and the magnitude of the disturbance(s). Reductions in prey associated with large overwater structures, such as marinas, shipyards, and terminals, result from a combination of direct disturbance (such as propeller wash), reduced benthic vegetation from shading, and chemical, biological, and physical habitat alterations. While these facilities may be thought of as single, distinct entities, they are in fact a conglomeration of components (for example, docks, nearshore buildings, breakwaters, storm water outfalls, and shoreline armoring), and each component has its own impact. In addition, because marinas, shipyards, and terminals are frequently located in nearshore/littoral and estuarine environments, their effects on prey resources are concentrated in productive environments. Concentrations of smaller structures (recreational docks, buoys, rafts) may also affect prey resources across a large area due to their locations in shallower, productive, nearshore/littoral waters.

Overwater structures may also result in chronic water and sediment quality impacts. Structures may be a source of heavy metals (found in marine paints), fuels, and other polycyclic aromatic hydrocarbons (PAHs); as well as leachate from treated wood (Carrasquero, 2001). Washington State currently allows three types of treated wood: creosote, ammoniacal copper zinc arsenate (ACZA), and chromated copper arsenate type C (CCA). Species are exposed to wood preservatives through contaminants leaching into the water column and sediments and through direct contact with the wood (for example, eggs deposited directly on a treated piling). Existing research suggests that the measurable extent of influence for treatment chemicals is limited to 10 meters (33 feet) from the structure (Brooks, 2000; Poston, 2001; Vines *et al.*, 2000; Weis *et al.*, 1998). The potential for cumulative impacts associated with large quantities of treated wood in a given water body or embayment is largely unaddressed in the literature.

Both point and non-point storm water discharges contain accumulations of toxics (such as metals, pesticides, herbicides, and hydrocarbons), pathogens from human and pet waste, and nutrients, such as nitrogen and phosphorous. While the discharges may lead to localized impacts on prey availability, they may also lead to chronic effects on both high risk species and species of concern through bioaccumulation, increases in disease or lesions, decreased reproductive success, and decreases in dissolved oxygen because of increased algal decay (King County, 2003).

Sediments, especially those with high organic content, often accumulate contaminants and have much higher pollutant concentrations than the overlying water column (EVS Environmental Consultants, 2003). Resuspension, because of in-water construction and propeller turbulence from vessel traffic, can lead to short-term increases in contaminant concentrations, with metals and other toxins entering the food web through consumption by filter feeders. Contaminants from water and sediment may also bioaccumulate in the fatty tissues of higher-level predators (EVS Environmental Consultants, 2003).

Water quality may also be degraded by breakwaters and maintenance dredging. Decreases in flows behind breakwaters may result in increases in pollutants (such as nutrients), as well as increases in sediment deposition. Navigational dredging may increase the extent of saltwater intrusion in otherwise freshwater ecosystems (U.S. Army Corps of Engineers, 1989).

The net result of these changes is a reduction in habitat complexity, as well as in ecosystem function. For example, reflected wave energy from stabilization structures may result in the complete destruction of spawning habitat for forage fish species such as surf smelt and sand lance, while scouring may also decrease the amount of substrate suitable for submerged plants (Thom *et al.*, 1994; Williams & Thom, 2001). Reduction in habitat complexity may also result in the loss of important cover elements, such as large woody debris.

4.4 Covered species, potential effects, and expected outcomes

Section 4.1 describes covered species life history, habitat use, and distribution. Section 4.3 describes potential effects that covered activities have on habitat used by the covered species. This section links the previous two by delineating activity-specific effects on covered species and describing expected outcomes if conservation measures are applied. Conservation measures for each activity are outlined in Chapter 5. The findings provided in this chapter are a result of a complex review of GIS data, database analysis, and relevant literature. Section 4.2 provides details on how numeric values were determined and threats identified, and it defines key terms used. Additional information regarding how potential effects and expected outcomes were identified can be found in the *Aquatic Resources Program Endangered Species Act Compliance Project, Potential Effects and Expected Outcomes Technical Paper* (Washington Department of Natural Resources, 2007b) and the *Aquatic Resources Program Habitat Conservation Plan Covered Species Technical Paper* (Washington Department of Natural Resources, 2007).

Columbia spotted frog (*Rana luteiventris*)

Threats warranting coverage in the habitat conservation plan

The covered activity identified as having potential effects on the Columbia spotted frog is overwater structures. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the Columbia spotted frog in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the Columbia spotted frog occurs, 34 percent overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Changes in habitat structure (such as channel morphology)
2. Increase in predation
3. Water and sediment quality degradation
4. Physical harm or harassment

Log Booming and Storage

- None

Aquaculture

- None

Potential effects of covered activities

Overwater Structures: For the Columbia spotted frog, the relative average area of potentially affected habitat as a result of overwater structures is 186 acres. The types of overwater structures identified as having potential effects on Columbia spotted frog habitat include boat ramps and launches, docks and wharves, and marinas. Estimates of habitat affected for the three life stages are as follows: 220 acres for the adult life stage, 222 acres for the egg stage, and 117 acres for the tadpole stage.

Log Booming and Storage: Potentially affected habitat from log booming and storage is 0 acres, because there is currently no spatial overlap.

Aquaculture: Potentially affected habitat from aquaculture is 0 acres, because there is currently no spatial overlap

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 12 percent decrease in potentially affected area. For the egg stage, there is an estimated 14 percent decrease in potentially affected area. For the tadpole stage, there is an estimated 25 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 17 percent.

Northern leopard frog (*Rana pipiens*)

Threats warranting coverage in the habitat conservation plan

The covered activities identified as having potential effects on the northern leopard frog are **overwater structures** and log booming and storage (there is potential for spatial overlap through future authorizations). The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the northern leopard frog in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the northern leopard frog occurs, 53 percent overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Changes in habitat structure (such as channel morphology)
2. Increase in predation
3. Water and sediment quality degradation
4. Physical harm or harassment

Log Booming and Storage

- None

Aquaculture

- None

Potential effects of covered activities

Overwater Structures: For the northern leopard frog, the relative average area of potentially affected habitat as a result of overwater structures is 108 acres. The types of overwater structures identified as having potential effects on northern leopard frog habitat include boat ramps and launches, docks and wharves, and marinas. Estimates of habitat affected for the three life stages are as follows: 108 acres for the adult life stage, 0 acres for the egg stage, and 0 acres for the tadpole stage.

Log Booming and Storage: Presently, potentially affected habitat from log booming and storage is 0 acres, because there is currently no spatial overlap.

Aquaculture: Potentially affected habitat from aquaculture is 0 acres, because there is currently no spatial overlap.

Expected outcomes with application of conservation measures: northern leopard frog

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 12 percent decrease in potentially affected area. For the egg stage, there is an estimated 0 percent decrease in potentially affected area. For the tadpole stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 12 percent.

Oregon spotted frog (*Rana pretiosa*)

Threats warranting coverage in the habitat conservation plan

There are no covered activities identified as having potential effects on the Oregon spotted frog. Of the current geographic townships in which where the Oregon spotted frog occurs, 0 percent% of them overlap with an authorized activity. The Oregon spotted frog warrants coverage in the Aquatic Lands Habitat Conservation Plan due to the species' highly aquatic nature (occurring in a variety of freshwater habitats), the difficulty of determining species presence, and the possibility of missed spatial overlap of authorized covered activities and species occurrence. The following list identifies potential threats, either to the species or to the habitat it uses, from current use authorizations on state-owned aquatic lands.

Overwater Structures

- None

Log Booming and Storage

- None

Aquaculture

- None

Potential effects of covered activities

Overwater structures: Potentially affected habitat from overwater structures is 0 acres, because there is currently no spatial overlap.

Log booming and storage: Potentially affected habitat from log booming and storage is 0 acres, because there is currently no spatial overlap.

Aquaculture: Potentially affected habitat from aquaculture is 0 acres, because there is currently no spatial overlap.

Expected Outcomes with Application of Conservation Measures

- None

Western toad (*Bufo boreas*)

Threats warranting coverage in the habitat conservation plan

The covered activities identified as having potential effects on the western toad are overwater structures and log booming and storage. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the western toad in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the western toad occurs, 43 percent overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use authorizations on state owned aquatic lands.

Overwater Structures

1. Changes in habitat structure (such as channel morphology)
2. Increase in predation
3. Water and sediment quality degradation
4. Physical harm or harassment

Log Booming and Storage

1. Mortality from traffic
2. Physical harm or harassment
3. Habitat degradation

Aquaculture

- None

Potential effects of covered activities

Overwater structures: For the western toad, the relative average area of potentially affected habitat as a result of overwater structures is 833 acres. The types of overwater structures identified as having potential effects on western toad habitat include boat ramps and launches, docks and wharves, floating homes, nearshore buildings, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 1,356 acres for the adult life stage, 395 acres for the egg stage, and 747 acres for the tadpole stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 48 acres. Estimates of habitat affected for the three life stages are as follows: 75 acres for the adult life stage, 35 acres for the egg stage, and 35 acres for the tadpole stage.

Aquaculture: Potentially affected habitat from aquaculture is 0 acres, because there is currently no spatial overlap.

Expected outcomes with application of conservation measures

Overwater Structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 15 percent decrease in potentially affected area. For the egg stage, there is an estimated 14 percent decrease in potentially affected area. For the tadpole stage, there is an estimated 27 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 19 percent.

Log Booming and Storage: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for log booming and storage has been evaluated and averaged by life stages. For the adult stage, there is an estimated 0 percent decrease in potentially affected area. For the egg stage, there is an estimated 50 percent decrease in potentially affected area. For the tadpole stage, there is an estimated 50 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 33 percent.

Western pond turtle (*Actinemys marmorata*)

Threats warranting coverage in the habitat conservation plan

The covered activities identified as having potential effects on the western pond turtle are **overwater structures** and **log booming and storage**. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the western pond turtle in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the Western pond turtle occurs, 65 percent of the foraging occurrences and 41percent of the overwintering occurrences overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Permanent destruction and fragmentation of wetland, side channel, and backwater habitats
2. Changes in habitat structure (such as channel morphology)
3. Increase in predation
4. Water and sediment quality degradation
5. Physical harm or harassment

Log Booming and Storage

1. Mortality from traffic
2. Physical harm or harassment
3. Habitat degradation

Aquaculture

- None

Potential effects of covered activities

Overwater structures: For the western pond turtle, the relative average area of potentially affected habitat western pond turtle as a result of overwater structures is 48 acres. The types of overwater structures identified as having potential effects on western pond turtle habitat include docks and wharves, floating homes, nearshore buildings, marinas, and shipyards and terminals. Estimates of habitat affected for the two life stages are as follows: 73 acres for the non-wintering life stage and 24 acres for the overwintering stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 8 acres. Estimates of habitat affected for the two life stages are as follows: 8 acres for the non-wintering life stage and 0 acres for the overwintering stage.

Aquaculture: Potentially affected habitat from aquaculture is 0 acres, because there is currently no spatial overlap.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the non-wintering stage, there is an estimated 17 percent decrease in potentially affected area. For the wintering stage, there is an estimated 17 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 17 percent.

Log booming and storage: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for log booming and storage has been evaluated and averaged by life stages. For the non-wintering stage, there is an estimated 31 percent decrease in potentially affected area. For the wintering stage, there is an estimated 0 percent decrease in potentially affected area.

Black tern *(Chlidonias niger)*

Threats warranting coverage in the habitat conservation plan

The covered activity identified as having potential effects on the black tern is **overwater structures**. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the black tern in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the black tern occurs, 32 percent overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Habitat destruction, conversion. and degradation
2. Impaired behavior
3. Changes in habitat structural matrices
4. Water and sediment quality degradation
5. Human disturbance
6. Related prey abundance and reductions in energy resources

Log Booming and Storage

- None

Aquaculture

- None

Potential effects of covered activities

Overwater Structures: For the black tern, the relative average area of potentially affected habitat as a result of overwater structures is 193 acres. The types of overwater structures that have been identified as having potential effects on black tern habitat include boat ramps and launches, docks and wharves, mooring buoys, marinas, and shipyards and terminals. Estimates of habitat affected for the two life stages are as follows: 168 acres for the migration life stage and 219 acres for the nesting stage.

Log Booming and Storage: Potentially affected habitat from log booming and storage is 0 acres, because there is currently no spatial overlap.

Aquaculture: Potentially affected habitat from aquaculture is 0 acres, because there is currently no spatial overlap.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the migration stage, there is an estimated 19 percent decrease in potentially affected area. For the nesting stage, there is an estimated 16 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 17 percent.

Common loon (*Gavia immer*)

Threats warranting coverage in the habitat conservation plan: common loon

The covered activities identified as having potential effects on the common loon are overwater structures, aquaculture, and log booming and storage. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the common loon in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the common loon occurs, 40 percent of the non-breeding occurrences and 14 percent of the nesting occurrences overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Habitat destruction, conversion, and degradation
2. Impaired behavior
3. Changes in habitat structural matrices
4. Water and sediment quality degradation
5. Human disturbance
6. Related prey abundance and reductions in energy resources

Log Booming and Storage

1. Habitat destruction
2. Human disturbance
3. Changes in structural habitat

Aquaculture

1. Permanent habitat destruction/displacement
2. Energy resource reduction
3. Water and sediment quality degradation
4. Increased human activity, impaired behavior, and physical harassment

Potential effects of covered activities

Overwater structures: For the common loon, the relative average area of potentially affected habitat as a result of overwater structures is 8,127 acres. The types of overwater structures that have been identified as having potential effects on common loon habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the two life stages are as follows: 5,372 acres for the nesting life stage and 10,881 acres for the non-nesting stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 1429 acres. Estimates of habitat affected for the two life stages are as follows: 1,379 acres for the nesting life stage and 1,479 acres for the non-nesting stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 37 acres. Estimates of habitat affected for the two life stages are as follows: 0 acres for the nesting life stage and 37 acres for the non-nesting stage.

Expected outcomes with application of conservation measures: common loon

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 14 percent decrease in potentially affected area. For the non-nesting stage, there is an estimated 14 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 14 percent.

Log booming and storage: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for log booming and storage has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 50 percent decrease in potentially affected area. For the non-nesting stage, there is an estimated 26 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 38 percent.

Aquaculture: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for aquaculture has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 0 percent decrease in potentially affected area. For the non-nesting stage, there is an estimated 20 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 20 percent.

Harlequin duck *(Histrionicus histrionicus)*

Threats warranting coverage in the habitat conservation plan

The covered activity identified as having potential effects on the harlequin duck is overwater structures. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the harlequin duck in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the harlequin duck occurs, 65 percent of the non-breeding occurrences and 36 percent of the nesting occurrences overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Habitat destruction, conversion, and degradation
2. Impaired behavior
3. Changes in habitat structural matrices
4. Water and sediment quality degradation
5. Human disturbance
6. Related prey abundance and reductions in energy resources

Log Booming and Storage

- None

Aquaculture

- None

Potential effects of covered activities

Overwater structures: For the harlequin duck, the relative average area of potentially affected habitat as a result of overwater structures is 2,132 acres. The types of overwater structures that have been identified as having potential effects on harlequin duck habitat include nearshore buildings and marinas. Estimates of habitat affected for the two life stages are as follows: 3,644 acres for the nesting life stage and 640 acres for the non-nesting stage.

Log booming and storage: Potentially affected habitat from log booming and storage is 0 acres, because there is currently no spatial overlap.

Aquaculture: Potentially affected habitat from aquaculture is 0 acres, because there is currently no spatial overlap.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 17 percent decrease in potentially affected area. For the non-nesting stage, there is an estimated 15 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 15 percent.

Marbled murrelet *(Brachyramphus marmoratus)*

Threats warranting in the habitat conservation plan

The covered activities identified as having potential effects on the marbled murrelet are **overwater structures, log booming and storage**, and **aquaculture.** The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the marbled murrelet in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the marbled murrelet occurs, 41 percent overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use authorizations on state-owned aquatic lands.

Overwater Structures

1. Habitat destruction, conversion, and degradation
2. Impaired behavior
3. Changes in habitat structural matrices
4. Water and sediment quality degradation
5. Human disturbance
6. Related prey abundance and reductions in energy resources

Log Booming and Storage

1. Habitat destruction
2. Human disturbance
3. Changes in structural habitat

Aquaculture

1. Permanent habitat destruction/displacement
2. Energy resource reduction
3. Water and sediment quality degradation
4. Increased human activity, impaired behavior, and physical harassment

Potential effects of covered activities

Overwater structures: For the marbled murrelet, the relative average area of potentially affected habitat as a result of overwater structures is 10,099 acres. The types of overwater structures identified as having potential effects on marbled murrelet habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the two life stages are as follows: 9,201 acres for the nesting life stage and 10,996 acres for the non-nesting stage.

Log booming and storage: The relative average area of potentially effected habitat from log booming and storage is 1,906 acres. Estimates of habitat affected for the two life stages are as follows: 1,282 acres for the nesting life stage and 2,531 acres for the non-nesting stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 2,406 acres. Estimates of habitat affected for the two life stages are as follows: 2,406 acres for the nesting life stage and 2,406 acres for the non-nesting stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 16 percent decrease in potentially affected area. For the non-nesting stage, there is an estimated 17 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 16 percent.

Log booming and storage: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for log booming and storage has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 26 percent decrease in potentially affected area. For the non-nesting stage, there is an estimated 49 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 38 percent.

Aquaculture: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for aquaculture has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 20 percent decrease in potentially affected area. For the non-nesting stage, there is an estimated 20 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 20 percent.

Western snowy plover *(Charadrius nivosus nivosus)*

Threats warranting coverage in the habitat conservation plan

The covered activity identified as having potential effects on the snowy plover is aquaculture. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the western snowy plover in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the snowy plover occurs, 92 percent overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

- None

Log Booming and Storage

- None

Aquaculture

1. Permanent habitat destruction/displacement
2. Energy resource reduction
3. Water and sediment quality degradation
4. Increased human activity, impaired behavior, and physical harassment

Potential effects of covered activities

Overwater Structures: Potentially affected habitat from overwater structures is 0 acres.

Log Booming: Potentially affected habitat from log booming and storage is 0 acres.

Aquaculture: For the snowy plover, the relative average area of potentially affected habitat as a result of aquaculture is 3,681 acres. Estimates of habitat affected for the two life stages are as follows: 4,098 acres for the nesting life stage and 3,264 acres for the wintering stage.

Expected outcomes with application of conservation measures

Aquaculture: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for aquaculture has been evaluated and averaged by life stages. For the nesting stage, there is an estimated 25 percent decrease in potentially affected area. For the wintering stage, there is an estimated 18 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 22 percent.

Fish Species: Introduction

For certain fish species there was insufficient data to identify any threats warranting coverage in the habitat conservation plan, the potential effects of covered activities, or the expected outcomes with the application of conservation measures. The following are included in the Aquatic Lands Habitat Conservation Plan because of their listing status and assumed habitat overlap on state-owned aquatic lands. These species were listed under ESA and added to the HCP after the potential effects document was developed. The habitat protections provided in the HCP for these species will provide substantial benefits for the habitat within the areas of assumed habitat overlap with the aquatic lands covered in this HCP.

Lamprey: Pacific lamprey *Lampetra tridentata*)

Rock fish: Bocaccio (*Sebastes paucispinis*), canary rockfish (*Sebastes pinniger*), and yelloweye rockfish (*Sebastes ruberrimus*)

Four forage fish species are covered in the Aquatic Lands Habitat Conservation Plan; however, they were added after the data analysis was completed. There is no quantitative data from the data analysis for the following species.

Forage Fish: Eulachon/Pacific smelt (*Thaleichthys pacificus*), Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*)

Fish complex: introduction

The following eight species of fish were evaluated separately and then grouped and treated as a *fish complex* in the analysis because they exhibit similar habitat uses or life histories:

- Bull trout
- Chinook salmon
- Chum salmon
- Coastal cutthroat trout
- Coho salmon
- Pink salmon
- Sockeye salmon
- Steelhead trout

The covered activities identified as having potential effects on the fish complex species are **overwater structures, log booming and storage**, and **aquaculture**. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the fish complex in the Aquatic Lands Habitat Conservation Plan. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Habitat conversion and degradation
2. Physical trauma, harm, and harassment
3. Reduced structural habitat quality
4. Energy resource reduction

Log Booming and Storage

1. Water and sediment quality degradation
2. Human disturbance
3. Habitat degradation

Aquaculture

1. Permanent habitat destruction/displacement
2. Temporary habitat degradation
3. Energy resource reduction resulting from decreased prey abundance
4. Water and sediment quality degradation
5. Increased human activity, impaired behavior, and physical harassment

Potential effects of covered activities

Species-specific effects are described in the pages following.

Expected outcomes with application of conservation measures: fish complex

Overwater structures: Species-specific effects are described in the pages following.

Log booming and storage: For all species within the fish complex, with the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for log booming and storage has been evaluated and averaged by life stages. For the adult stage, there is an estimated 24 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 25 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 16 percent.

Aquaculture: For all species within the fish complex, with the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for aquaculture has been evaluated and averaged by life stages. For the adult stage, there is an estimated 12 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 12 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 6 percent.

Bull trout *(Salvelinus confluentus)*

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the bull trout in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the bull trout occurs, 54 percent of the adult occurrences, 54 percent of the juvenile occurrences, and 15 percent of the incubation/emergence occurrences overlap with an authorized activity. See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For the bull trout, the relative average area of potentially affected habitat as a result of overwater structures is 8,465 acres. The types of overwater structures identified as having potential effects on bull trout habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 10,151 acres for the adult stage, 15,241 acres for the juvenile stage, and 1 acre for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 1,199 acres. Estimates of habitat affected for the three life stages are as follows: 869 acres for the adult stage, 1,529 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows: 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 17 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 23 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 11percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Chinook salmon *(Oncorhynchus tshawytscha)*

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the Chinook salmon in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the Chinook salmon occurs, 59 percent of the adult occurrences, 59 percent of the juvenile occurrences, and 30 percent of the incubation/emergence occurrences overlap with an authorized activity. See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For Chinook salmon, the relative average area of potentially affected habitat as a result of overwater structures is 10,067 acres. The types of overwater structures identified as having potential effects on Chinook habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 12,084 acres for the adult stage, 18,062 acres for the juvenile stage, and 54 acres for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 1,020 acres. Estimates of habitat affected for the three life stages are as follows: 973 acres for the adult stage, 1,701 acres for the juvenile stage, and 388 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows: 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater Structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 17 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 23 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 11 percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Chum salmon *(Oncorhynchus keta)*

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the chum salmon in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the chum salmon occurs, 65 percent of the adult occurrences, 65 percent of the juvenile occurrences, and 23 percent of the incubation/emergence occurrences overlap with an authorized activity (F-2). See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For chum salmon, the relative average area of potentially affected habitat as a result of overwater structures is 5,902 acres. The types of overwater structures identified as having potential effects on chum habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 7,005 acres for the adult stage, 10,647 acres for the juvenile stage, and 54 acres for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 861 acres. Estimates of habitat affected for the three life stages are as follows: 628 acres for the adult stage, 1,093 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows: 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 16 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 22 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 12 percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Coastal cutthroat trout *(Oncorhynchus clarki clarki)*

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the coastal cutthroat trout in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the coastal cutthroat trout occurs, 62 percent of the adult occurrences, 62 percent of the juvenile occurrences, and 30 percent of the incubation/emergence occurrences overlap with an authorized activity (F-2). See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For the coastal cutthroat trout, the relative average area of potentially affected habitat as a result of overwater structures is 8,977 acres. The types of overwater structures identified as having potential effects on coastal cutthroat trout habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 10,851 acres for the adult stage, 16,038 acres for the juvenile stage, and 43 acres for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 1,020 acres. Estimates of habitat affected for the three life stages are as follows: 973 acres for the adult stage, 1,701 acres for the juvenile stage, and 388 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows; 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 16 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 22 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease of potentially affected area of 12 percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Coho salmon *(Oncorhynchus kisutch)*

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the coho salmon in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the coho salmon occurs, 62 percent of the adult occurrences, 62 percent of the juvenile occurrences, and 20 percent of the incubation/emergence occurrences overlap with an authorized activity. See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For coho salmon, the relative average area of potentially affected habitat as a result of overwater structures is 8,981 acres. The types of overwater structures identified as having potential effects on coho habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 10,862 acres for the adult stage, 16,051 acres for the juvenile stage, and 29 acres for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 1,337 acres. Estimates of habitat affected for the three life stages are as follows: 973 acres for the adult stage, 1,701 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows: 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 16 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 22 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 12 percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Pink salmon *(Oncorhynchus gorbuscha)*

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the pink salmon in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the pink salmon occurs, 52 percent of the adult occurrences and 52 percent of the juvenile occurrences overlap with an authorized activity. See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For pink salmon, the relative average area of potentially affected habitat as a result of overwater structures is 4,830 acres. The types of overwater structures identified as having potential effects on pink salmon habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 5,673 acres for the adult stage, 8,806 acres for the juvenile stage, and 12 acres for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 488 acres. Estimates of habitat affected for the three life stages are as follows: 527 acres for the adult stage, 917 acres for the juvenile stage, and 19 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows: 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 16 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 22 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 12 percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Sockeye salmon (Oncorhynchus nerka)

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the sockeye salmon in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the sockeye salmon occurs, 66 percent of the adult occurrences, 66 percent of the juvenile occurrences, and 16 percent of the incubation/emergence occurrences overlap with an authorized activity. See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For sockeye salmon, the relative average area of potentially affected habitat as a result of overwater structures is 10,186 acres. The types of overwater structures identified as having potential effects on sockeye habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 12,052 acres for the adult stage, 18,027 acres for the juvenile stage, and 480 acres for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 1,301 acres. Estimates of habitat affected for the three life stages are as follows: 940 acres for the adult stage, 1,642 acres for the juvenile stage, and 1,322 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows: 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 16 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 22 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 12 percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Steelhead trout (*Oncorhynchus mykiss*)

Threats warranting coverage in the habitat conservation plan

The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the steelhead trout in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the steelhead trout occurs, 57 percent of the adult occurrences, 57 percent of the juvenile occurrences, and 39 percent of the incubation/emergence occurrences overlap with an authorized activity. See the fish complex list, which identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Potential effects of covered activities

Overwater structures: For the steelhead trout, the relative average area of potentially affected habitat as a result of overwater structures is 10,067 acres. The types of overwater structures identified as having potential effects on steelhead habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 12,084 acres for the adult stage, 18,062 acres for the juvenile stage, and 54 acres for the incubation/emergence stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 1,020 acres. Estimates of habitat affected for the three life stages are as follows: 973 acres for the adult stage, 1,701 acres for the juvenile stage, and 388 acres for the incubation/emergence stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 1,203 acres. Estimates of habitat affected for the three life stages are as follows: 2,406 acres for the adult stage, 2,406 acres for the juvenile stage, and 0 acres for the incubation/emergence stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for overwater structures has been evaluated and averaged by life stages. For the adult stage, there is an estimated 16 percent decrease in potentially affected area. For the juvenile stage, there is an estimated 22 percent decrease in potentially affected area. For the incubation/emergence stage, there is an estimated 0 percent decrease in potentially affected area. For all life stages, there is an average decrease in potentially affected area of 12 percent.

Log booming and storage: See fish complex expected outcomes with application of conservation measures, log booming and storage.

Aquaculture: See fish complex expected outcomes with application of conservation measures, aquaculture.

Green sturgeon *(Acipenser medirostris)*

Threats warranting coverage in the habitat conservation plan

The covered activities identified as having potential effects on the green sturgeon are **overwater structures, log booming and storage**, and **aquaculture.** Of the current geographic townships in which the green sturgeon occurs, the percent overlap with an authorized activity is undetermined. The green sturgeon warrants coverage in the Aquatic Lands Habitat Conservation Plan due to the species' highly aquatic nature, the difficulty of determining species presence, and the possibility of missed spatial overlap of authorized covered activities and species occurrence. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Habitat conversion and degradation.
2. Physical trauma, harm and harassment.
3. Reduced structural habitat quality.
4. Energy resource reduction.

Log Booming and Storage

1. Water and sediment quality degradation
2. Human disturbance.
3. Habitat degradation.

Aquaculture

1. Permanent habitat destruction/displacement.
2. Temporary habitat degradation.
3. Energy resource reduction resulting from decreased prey abundance.
4. Water and sediment quality degradation.
5. Increased human activity, impaired behavior, and physical harassment.

Potential effects of covered activities

Overwater structures: For the adult life stage of the green sturgeon, potentially affected habitat as a result of overwater structures is 3,239 acres. The types of overwater structures identified as having potential effects on green sturgeon habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals.

Log booming and storage: For the adult life stage, potentially affected habitat from log booming and storage is 484 acres.

Aquaculture: For the adult life stage, potentially affected habitat from aquaculture is 3,927acres.

Expected outcomes with application of conservation measures

Overwaters: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area for adult and juvenile habitat was 67 percent for mooring buoys, rafts and floats, 24 percent for marinas, nearshore buildings, shipyards, and terminals, and 12 percent for floating homes.

Log booming and storage: For log booming and storage, there is an estimated 26 percent decrease in potentially affected area.

Aquaculture: For aquaculture, there is an estimated 32 percent decrease in potentially affected area.

White sturgeon *(Acipenser transmontanus)*

Threats warranting coverage in the habitat conservation plan

The covered activities identified as having potential effects on the white sturgeon are **overwater structures, log booming and storage**, and **aquaculture**. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the white sturgeon in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the white sturgeon occurs, 65 percent of the adult/spawning occurrences, 35 percent of the juvenile occurrences, and 10 percent of the egg/larvae occurrences overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Habitat conversion and degradation
2. Physical trauma, harm and harassment
3. Reduced structural habitat quality
4. Energy resource reduction

Log Booming and Storage

1. Water and sediment quality degradation
2. Human disturbance
3. Habitat degradation

Aquaculture

1. Permanent habitat destruction/displacement
2. Temporary habitat degradation
3. Energy resource reduction resulting from decreased prey abundance
4. Water and sediment quality degradation
5. Increased human activity, impaired behavior, and physical harassment

Potential effects of covered activities

Overwater structures: For the white sturgeon, the relative average area of potentially affected habitat as a result of overwater structures is 5,946 acres. The types of overwater structures identified as having potential effects on white sturgeon habitat include boat ramps and launches, docks and wharves, floating homes, mooring buoys, nearshore buildings, rafts and floats, marinas, and shipyards and terminals. Estimates of habitat affected for the three life stages are as follows: 13,941 acres for the juvenile/adult stage, 1,956 acres for the larvae stage, and 1,941 acres for the egg stage.

Log booming and storage: The relative average area of potentially affected habitat from log booming and storage is 543 acres. Estimates of habitat affected for the three life stages are as follows: 954 acres for the juvenile/adult stage, 367 acres for the larvae stage, and 309 acres for the egg stage.

Aquaculture: The relative average area of potentially affected habitat from aquaculture is 518 acres. Estimates of habitat affected for the three life stages are as follows: 4,234 acres for the juvenile/adult stage, 1,037 acres for the larvae stage, and 0 acres for the egg stage.

Expected outcomes with application of conservation measures

Overwater structures: With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area of habitat for adult and juvenile white sturgeon was 67 percent for mooring buoys, rafts and floats, 24 percent for marinas, nearshore buildings, shipyards and terminals, and 12 percent for floating homes.

Log booming and storage: For log booming and storage, there is an estimated 18 percent decrease in potentially affected area.

Aquaculture: For aquaculture, there is an estimated 32 percent decrease in potentially affected area.

Southern resident killer whale (Orca) (*Orcinus orca*)

Threats warranting coverage in the habitat conservation plan

The covered activities identified as having potential effects on the southern resident killer whale are overwater structures, log booming and storage, and aquaculture. The identified threats and spatial overlap of authorized covered activities and species occurrence warrant coverage of the southern resident killer whale in the Aquatic Lands Habitat Conservation Plan. Of the current geographic townships in which the southern resident killer whale occurs, 73 percent overlap with an authorized activity. The following list identifies potential threats, either to the species or to the habitat it uses, from current use-authorizations on state-owned aquatic lands.

Overwater Structures

1. Human disturbance
2. Energy resource reduction
3. Water quality impairment
4. Altered behavior, physical harm

Log Booming and Storage

- None

Aquaculture

1. Permanent habitat destruction/displacement
2. Temporary habitat degradation
3. Energy resource reduction resulting from decreased prey abundance
4. Water and sediment quality degradation
5. Increased human activity, impaired behavior, and physical harassment

Potential effects of covered activities

Overwater structures: For the resident life stage of the killer whale, potentially affected habitat as a result of overwater structures is 5,130 acres. The types of overwater structures identified as having potential effects on killer whale habitat include docks and wharves, floating homes, marinas, and shipyards and terminals.

Log booming and storage: For the resident life stage, potentially affected habitat from log booming and storage is 252 acres.

Aquaculture: For the resident life stage, potentially affected habitat from aquaculture is 0 acres.

Expected outcomes with application of conservation measures

With the application of conservation measures to state-owned aquatic lands, the estimated percent decrease in potentially affected area has been estimated for the resident life stage.

Overwater structures: For overwater structures, there is an estimated 0 percent decrease in potentially affected area.

Log booming and storage: For log booming and storage, there is an estimated 0 percent decrease in potentially affected area.

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