APPENDIX B

MARINE FISH LIFE HISTORY, HABITAT CONDITIONS, AND HEARING

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1.0 MARINE FISH LIFE HISTORIES

1.1. ESA-LISTED SALMONIDS

1.1.1. Puget Sound Chinook

1.1.1.1. STATUS

The Puget Sound Chinook salmon evolutionarily significant unit (ESU) was listed as federally threatened under the Endangered Species Act (ESA) in 1999 (64 Federal Register [FR] 14308), with the threatened listing reaffirmed in 2005 (70 FR 37160). Critical habitat was designated for Puget Sound Chinook in 2005 (70 FR 52685). In 2002, average adult Chinook escapement (number of fish surviving to reach spawning grounds or hatcheries) was relatively low, particularly for the mid-Hood Canal stock, for which average escapements were typically below the low escapement threshold of 400 Chinook fish (Washington Department of Fish and Wildlife [WDFW] 2002). In the most recent 5-Year Review, NMFS found that while natural origin recruit escapements have remained fairly constant from 1985–2009, total natural origin recruit abundance and productivity have continued to decline (NMFS 2011).

This Puget Sound Chinook ESU comprises all naturally spawned populations of Chinook salmon from rivers and streams flowing into Hood Canal, and includes 26 artificial propagation programs in Puget Sound, such as the Hamma Hamma and George Adams hatcheries. Within mid-Hood Canal, the Big Beef Creek Chinook salmon hatchery was terminated from this program, with the last of the adults returning to spawn in 2008 (NMFS 2011). Two populations of Chinook, the Mid-Hood Canal population and the Skokomish River population, are included in the ESA-listed Distinct Population Segment (DPS) within Hood Canal drainages, and are considered essential to the recovery of the species.

All Puget Sound Chinook salmon populations are considered well below escapement abundance levels identified as required for recovery to low extinction risk in the recovery plan (NMFS 2011). NMFS (2011) stated that the updated information on abundance, productivity, spatial structure and diversity since the last review does not indicate a change in this ESU's biological risk category. Although a review of 1999–2008 returning spawning abundance data indicated neither of the Hood Canal populations displayed an increasing or decreasing trend in population abundance (NWFSC 2013), these criteria for the ESU overall are in decline (NMFS 2011).

Since the listing of Puget Sound Chinook, reduced viability of these specific stocks was attributed to habitat loss and degradation, hatcheries, and harvest management issues. Additionally, dissolved oxygen (DO) levels in portions of Hood Canal are at a historic low, which is a concern and future threat to recovery of the Hood Canal stocks of this and all other Hood Canal salmonid ESUs (70 FR 76445). DO levels at the waterfront of Naval Base (NAVBASE) Kitsap Bangor are discussed in Section 3.1.1.1.2.

1.1.1.2. LIFE HISTORY

Chinook salmon (*Oncorhynchus tshawytscha*) is the largest of the *Oncorhynchus* species, typically reaching 8 to 10 kg, although Chinook salmon have been documented in excess of 45 kg (Healey 1991; Quinn 2005). Resident Puget Sound Chinook salmon, however, are typically on the smaller end of this scale. Due to their relatively large size, Chinook salmon generally spawn in larger rivers or streams than other salmonids (Healey 1991; Quinn 2005). Chinook salmon can be highly variable between and within given watersheds. They have various in-migration (e.g., spring versus fall) and out-migration (e.g., ocean-type versus stream-type) times that can vary within a given system, stock, or run of fish (WDFW 2002; Healey 1991; Myers et al. 1998; Duffy 2003, 2009; Duffy et al. 2005; Redman et al. 2005; Quinn 2005).

Emergent Chinook fry, like fry of other Pacific salmonids, depend on shaded, nearshore freshwater habitat, with slow-moving currents, where they forage on drift organisms, including insects and zooplankton (Healey 1991). In general, ocean-type parr (the freshwater stage of juvenile salmon, which usually occurs in the first one to two years of life) usually migrate to estuarine areas from April through July with some variability (peak out-migration occurring from May to early July), becoming smolts (juveniles that have transitioned from fresh water to salt water) soon after entering marine waters. Duffy et al. (2005) found that wild ocean-type Chinook out-migrate to Puget Sound waters from March to July, while hatchery Chinook occupy nearshore Puget Sound waters soon after release and in pulses from May to June. Once reaching the marine environment, they then spend a few weeks or longer rearing in the estuary (Duffy 2003, 2009; Duffy et al. 2005).

Table B–1 provides detailed information regarding the in-migration and spawn timing of adult Puget Sound Chinook past NAVBASE Kitsap Bangor, and within the greater Hood Canal region. Adult Chinook salmon enter Hood Canal waters from August to October to begin spawning in their natal streams in September, with peak spawning in October.

Table B–1. Spawn Period Timing and Peak of Adult Hood Canal Stocks of Puget Sound Chinook

Stock	Time period detected in Hood Canal	Spawn time period	Spawn peak
Skokomish stock	Late-August to October	Mid-September to October	Mid-October
Mid-Hood Canal stock	Mid-August to late October	Early September to late October	October

Source: Healey 1991

1.1.1.3. OCCURRENCE

Chinook salmon are one of the least abundant salmonids occurring along the Bangor shoreline (Figure B–1). From 2005 to 2008, a total of 58,667 salmonids were captured in beach seine surveys along the Bangor waterfront (SAIC 2006; Bhuthimethee et al. 2009). During that time period, only 224 of the total number of salmonids captured (approximately 0.4 percent) were juvenile Chinook salmon (Figure B–1).

Offshore tow-netting and beach seine surveys during the 1970s (Schreiner et al. 1977; Prinslow et al. 1980; Bax 1983; Salo 1991), and nearshore beach seine surveys from 2005–2008 (Science Applications International Corporation [SAIC] 2006; Bhuthimethee et al. 2009), determined that Chinook salmon migrating from southern Hood Canal streams and hatcheries occur most frequently along the Bangor waterfront from late May to early July (Table B–2). These studies indicate that peak occurrence in these waters generally occurs from as early as May to as late as July (Table B–2). More recent tagging investigations have shown that juvenile Chinook distribution and movement patterns are not well known (Chamberlin et al. 2011). Juvenile Chinook salmon may have extended intrabasin residence times and utilize these habitats for extended rearing periods, not specifically as a nearshore migratory corridor.

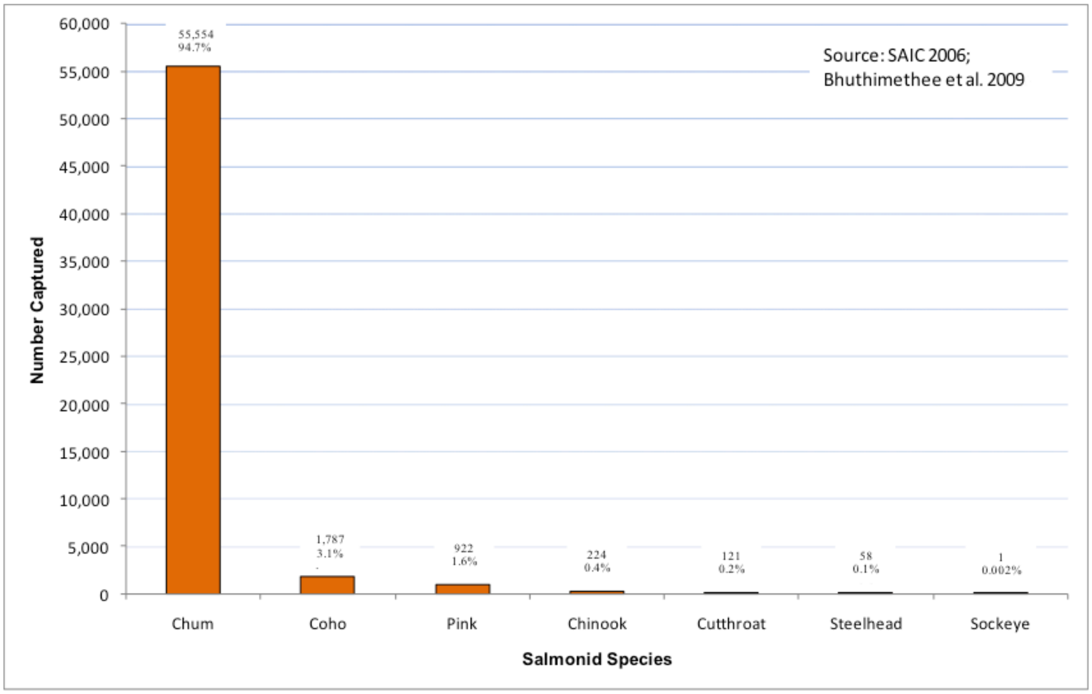

Figure B–1. Salmonids, in Order of Abundance, Captured During 2005–2008 Bangor Beach Seine Surveys

Table B–2. Timing of Puget Sound Chinook Juvenile Presence and Out-migration on NAVBASE Kitsap Bangor

Reference	Time period detected in Hood Canal	Peak out-migration timing
Bax et al. 1978; Bax et al. 1980	February to July	May to early June
Schreiner 1977	May to July	Late June to early July
SAIC 2006	April to September	Mid-June to late June

In an effort to clarify the timing of juvenile salmonid arrival to mid-Hood Canal estuaries, a number of joint investigations by state and federal resource agencies and non-governmental entities were conducted. The findings in Hood Canal tributaries indicated slightly earlier arrivals to the lower portions of these drainages (Weinheimer 2013). Screw traps were deployed from January to July 2012 to capture juvenile salmonids within the lowest 0.5 mile of the Duckabush and Hamma Hamma Rivers. Findings showed that chum arrived as early as January. Within the Duckabush, results indicated the migration reached a median point in April and was 95 percent complete by the first week of June. Within the Hamma Hamma, results indicated the migration reached a median point in March and was 95 percent complete by April 10.

1.1.2. Hood Canal Summer-run Chum Salmon

1.1.2.1. STATUS

The Hood Canal summer-run chum salmon ESU was federally listed as threatened under the ESA in 1999, and the threatened listing was reaffirmed in 2005 (70 FR 37160) (Table B–1). Two populations of Hood Canal summer-run chum salmon within Hood Canal are considered essential to the recovery of the species. In a review of returning spawners data for this ESU through 2007, NWFSC indicated the populations were displaying an increasing trend, with Strait of Juan de Fuca populations increasing at a slightly higher rate than Hood Canal populations (NWFSC 2013). Critical habitat was also designated for Hood Canal summer-run chum ESU in 2005, and the National Marine Fisheries Services (NMFS) recovery plan for this species was adopted on May 24, 2007 (72 FR 29121).

Historically, there were sixteen stocks within the Hood Canal summer-run chum ESU, eight of which are extant (six in Hood Canal and two in the eastern Strait of Juan de Fuca) with the remaining eight extinct (71 FR 47180). Six current summer chum stocks have been identified in Hood Canal: Quilcene, Dosewallips, Duckabush, Hamma Hamma, Lilliwaup, and Union (NMFS 2011). Six additional stocks were identified as recent extinctions: Skokomish, Finch, Tahuya, Dewatto, Anderson, and Big Beef.

The Hood Canal summer-run chum salmon ESU includes all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries, as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington, and eight artificial propagation programs: Quilcene NFH, Hamma Hamma Fish Hatchery, Lilliwaup Creek Fish Hatchery, Union River/Tahuya, Big Beef Creek Fish Hatchery, Salmon Creek Fish Hatchery, Chimacum Creek Fish Hatchery, and the Jimmycomelately Creek Fish Hatchery summer-run chum hatchery programs (NMFS 2011). However, five Hood Canal summer chum hatchery programs were terminated since the last status review, including: Quilcene National Fish Hatchery, Union River/Tahuya River, Big Beef Creek, Salmon Creek, and Chimacum Creek programs. The last adult fish produced through these terminated programs returned in 2008 (NMFS 2011).

Based on the most recent 5-Year Review, NMFS (2011) found that the overall trend in spawning abundance is generally stable for the Hood Canal population (all natural spawners and natural-origin only spawners) and for the Strait of Juan de Fuca population (all natural spawners). Only the Strait of Juan de Fuca population's natural-origin spawners show a significant positive trend. Productivity from 2005 to 2009 was very low, especially compared to the relatively high productivity observed from 1994 to 2004.

Reduced viability, lower survival, and listing of extant stocks of summer-run chum and recent stock extinctions in Hood Canal are attributed to the combined impacts of three primary factors: (1) habitat loss and degradation, (2) climate change, and (3) increased fishery harvest rates (Hood Canal Coordinating Council [HCCC] 2005). An additional factor cited in WDFW and Point No Point Treaty Tribes (PNPTT) (2000) and HCCC (2005) was impacts associated with the releases of hatchery salmonids, which compete with naturally spawning stocks for food and other resources.

1.1.2.2. LIFE HISTORY

Chum salmon (*Oncorhynchus keta*) have the broadest distribution of all salmonid species (Pauley et al. 1988) and range along the Northeast Pacific coast from Monterey Bay, California, to the Arctic Ocean (Pauley et al. 1988; Salo 1991; Johnson et al. 1997). Chum salmon generally live 3 to 5 years and are relatively large compared to other salmonids, second only to Chinook. Similar to pink salmon, adult chum salmon prefer to spawn in the lower reaches of their natal streams (Pauley et al. 1988; Tynan 1997; Quinn 2005). Sumer-run adults typically migrate from marine waters into Hood Canal from early August through the end of September (Tynan 1997). Summer-run adult salmon typically migrate from the marine waters to spawning grounds from early September through mid-October (Tynan 1997).

Female chum salmon lay between 900 and 8,000 eggs (Pauley et al. 1988) that are extremely sensitive to changes in the environment, with a high degree of mortality (up to 90 percent) in the developing eggs (Pauley et al. 1988). Emerging fry spend only a few days to a few weeks rearing in fresh water before migrating toward marine habitats from March to May (Pauley et al. 1988; Salo 1991; Johnson et al. 1997; Quinn 2005). While in this environment, chum fry stay in very shallow, nearshore habitats and consume a number of epibenthic invertebrates, including gammaridean amphipods, harpacticoid copepods, cumaceans, and mysids (Pauley et al. 1988). Chum salmon utilize estuarine habitats for a few more weeks before migrating to coastal, then offshore waters.

During out-migration, fry move within the nearshore corridor and into and out of sub-estuaries with the tides, most likely in search of food resources (Hirschi et al. 2003). At a migration rate of 4.4 miles per day, the majority of chum emigrants from southern Hood Canal exit the canal to the north 14 days after their initial emergence in seawater (WDFW and PNPTT 2000). Table B–3 provides a summary of the presence and out-migration timing of juvenile summer-run chum from Hood Canal. Juvenile summer-run chum are expected to occur near the proposed project areas from late January through early June.

Table B–3. Timing of Hood Canal Summer-run Chum Juvenile Presence and Out-migration in Hood Canal and along the Bangor Shoreline

Reference	Sampling Location(s)	Time Period Detected in Hood Canal	Peak Out-migration Timing on NAVBASE Kitsap Bangor
Prinslow et al. 1980; Salo et al. 1980; Bax 1983	NAVBASE Kitsap Bangor	February to March	March
WDFW and PNPTT 2000	Estimated emergence from Hood Canal	February to late May	Late March
SAIC 2006	NAVBASE Kitsap Bangor	Late January through early June	Late March

1.1.2.3. OCCURRENCE

Beach seine surveys were conducted along the Bangor waterfront from 2005 to 2008 (SAIC 2006; Bhuthimethee et al. 2009). During that time, 55,554 out of 58,667 total salmonids captured (approximately 94.7 percent) were juvenile chum salmon (Figure B–1). Chum salmon peak abundance along the NAVBASE Kitsap Bangor shoreline generally peaks in late April to early May (Bhuthimethee et al. 2009). However, this peak abundance is strongly influenced by hatchery releases. In 2007, Hood Canal hatcheries released approximately 26 million juvenile chum salmon (Bhuthimethee et al. 2009). Release dates varied from February to May, although at least 23 million of these fish were released from April 1 to April 20. However, because they are visually indistinguishable at smaller sizes, no distinction in the field could be made between hatchery-produced fish and naturally produced ("wild") fish. To gain a better understanding of natural production of these stocks, studies need to be conducted in freshwater systems, away from the influences of hatchery releases.

To observe juvenile salmon out-migration away from the influence of hatcheries, Weinheimer (2013) deployed screw traps from January to July 2012 within the lowest 0.5 mile of the Duckabush and Hamma Hamma Rivers. The estuaries for these two systems are located approximately 12 and 17 miles, respectively, south of NAVBASE Kitsap Bangor. Weinheimer (2013) reported that chum salmon were present in both screw traps in January. Similar to comparing hatchery-produced fish to naturally produced fish, they are visually indistinguishable at smaller sizes, so no distinction in the field could be made between fall-run chum and summer-run chum salmon. Within the Duckabush, findings indicated the migration reached a median point in mid-March, and was 95 percent complete by the first week of April. Within the Hamma Hamma, findings indicated the migration reached a median point in mid-March, and was 95 percent complete by April 9. Genetic studies differentiating fall-run and summer-run chum salmon found that summer-run fish comprised over 90 percent of all chum captured in the Duckabush from January through the first week of April. Within the Hamma Hamma trap, summer-run chum comprised over 90 percent of all chum captured from January through mid-March (Weinheimer 2013).

Summer-run chum adults return to Hood Canal from as early as August and September through the first week in October (Washington Department of Fisheries et al. 1993; WDFW and PNPTT 2000). Approximately one month separates peak spawn timing of the early (summer) and later (fall) runs of chum salmon in Hood Canal (Johnson et al. 1997; Table B–4).

Table B–4. Spawning Period, Peak, and 90-Percent Spawn Timing of Adult Stocks of Hood Canal Summer-run Chum

Stock	Time Period Detected in Hood Canal[1]	Spawn Time Period and Peak	Date at which 90 Percent of Spawning is Complete
Big/Little Quilcene	Early September to Mid-October	Mid-September to Mid-October	10/1 to 10/5
Lilliwaup Creek	Early September to Mid-October	Mid-September to Mid-October	10/10
Hamma Hamma	Early September to Mid-October	Mid-September to Mid-October	10/8 to 10/10
Duckabush	Early September to Mid-October	Mid-September to Mid-October	10/11
Dosewalips	Early September to Mid-October	Mid-September to Mid-October	10/9
Union	Mid-August to Early October	Early September to Early October	9/29 to 9/30

Sources: WDFW 2002; WDFW and PNPTT 2000.

1. Range of timing estimates from WDFW and PNPTT, in Appendix Report 1.2 (WDFW and PNPTT 2000).

1.1.3. Puget Sound Steelhead

1.1.3.1. STATUS

The Puget Sound steelhead was listed in May 2007 under the ESA as a threatened distinct population segment (DPS) (72 FR 26722). Critical habitat was designated for Puget Sound steelhead in 2016 (81 FR 9251). Stocks of the Puget Sound steelhead DPS are mainly winter-run, although a few small stocks of summer-run steelhead also occur (71 FR 15666). Eight stocks of winter-run and three stocks of summer-run Puget Sound steelhead occur in Hood Canal (WDFW 2002). Some stocks of Puget Sound steelhead in Hood Canal (i.e., hatchery supplementation or hatchery releases to non-native streams) may not be considered part of the DPS (71 FR 15668).

The origin and production type of all stocks of Puget Sound steelhead occurring in Hood Canal remain unresolved by the state and tribes (WDFW 2002). The 1996 status review (Busby et al. 1996) and more recent NMFS review for Puget Sound steelhead (Hard et al. 2007) included only three stocks of winter-run steelhead that occur in Hood Canal as native populations: (1) Tahuya winter steelhead, (2) Dewatto winter steelhead, and (3) Skokomish winter steelhead. Official determination for the proposed DPS listing has not been designated, and specifics on all stocks to be included in the DPS listing are forthcoming. In general, abundance of winter-run steelhead stocks in Hood Canal has been low, with most stocks averaging less than 200 adult spawners per year (NMFS 2005a). The status of the listed Puget Sound steelhead DPS has not changed substantially since the 2007 listing. Most populations within the DPS are showing continued downward trends in estimated abundance, some steeply.

The DPS includes all naturally spawned anadromous winter-run and summer-run *O. mykiss* (steelhead) populations, in streams in the river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington, bounded to the west by the Elwha River (inclusive) and to the north by the Nooksack River and Dakota Creek (inclusive), as well as the Green River natural and Hamma Hamma winter-run steelhead hatchery stocks (NMFS 2011). The Hamma Hamma River hatchery program and four other hatchery programs are not considered part of the DPS, with a number of hatchery supplementation programs terminated in the last 10 years. As a result, steelhead supplementation in the Hamma Hamma was discontinued, with the last returning adult steelhead arriving in 2010 (NMFS 2011). Five new steelhead programs propagating native-origin fish for the purposes of preserving and recovering the populations also have been initiated. These programs support recovery of native winter-run steelhead in the White, Dewatto, Duckabush, North Fork Skokomish, and Elwha River watersheds. The new programs warrant consideration for inclusion in the DPS (NMFS 2011).

Freshwater habitat degradation and fragmentation, with consequent effects on connectivity, are among the primary limiting factors and threats facing the Puget Sound steelhead DPS (NMFS 2011). Despite ongoing efforts by multiple parties to improve habitat conditions in Puget Sound, habitat in all ESUs and DPS remains far below that needed to sustain viable populations of listed fish (NMFS 2011). The critical habitat proposed to protect this species places an emphasis on freshwater habitats (78 FR 2726).

1.1.3.2. LIFE HISTORY

Steelhead exhibit the most complex life history of any species of Pacific salmon. Steelhead can be freshwater residents (referred to as rainbow trout) or anadromous (referred to as steelhead), and, under some circumstances, they can yield offspring of the alternate life history form (72 FR 26722). Anadromous forms can spend up to seven years in fresh water prior to smoltification and then spend up to three years in salt water prior to migrating back to their natal streams to spawn (Busby et al. 1996). In addition, steelhead can spawn up to four times and have been documented to live as long as 8 or 9 years (Pauley et al. 1986), whereas other Pacific salmon species generally spawn once and die. Because steelhead grow larger in the productive marine environment, fish that stay in these habitats longer are typically larger. Studies investigating this have found that steelhead range in size from 47 cm (18.5 inches) for a 1-year saltwater resident to 88 cm (34.6 inches) for a 4-year saltwater resident (Maher and Larkin 1954, as cited in Pauley et al. 1986). Steelhead are prevalent throughout streams and tributaries of Puget Sound (Pauley et al. 1986). Both winter and summer steelhead types, or races, occur within Washington State streams and rivers.

Typically adult steelhead return to streams and rivers in the winter or summer and spawn in the spring and summer, with fry emerging in just a few weeks. Upon emergence, steelhead typically rear in the freshwater streams and rivers between 1 and 3 years. Following their downstream migration to marine waters, these fish rear and mature in the ocean for 1 to 3 years before returning to freshwater systems as adults to spawn (Pauley et al. 1989; Quinn 2005). Because steelhead can be repeat spawners, the age and size of returning adults varies considerably.

1.1.3.3. OCCURRENCE

Limited information is available regarding the timing of juvenile out-migration for winter-run steelhead in Hood Canal. WDFW suggests that juvenile out-migration of steelhead stocks in Hood Canal occurs from March through June, with peak out-migration during April and May (Johnson 2006, personal communication). Beach seine surveys from 2005 to 2008 did not catch large numbers of steelhead along the Bangor shoreline (Figure B–1). Steelhead captured during these shoreline surveys occurred most frequently in the late spring and early summer months. A total of 58,667 salmonids were captured in these beach seine surveys (SAIC 2006; Bhuthimethee et al. 2009). During that time period, only 58 of the total number of salmonids captured (approximately 0.1 percent) were juvenile steelhead (Figure B–1). The absence of juvenile steelhead from nearshore surveys is largely due to these juveniles occurring as smolts, much larger than the chum and pink salmon fry that occur along the shoreline. As juvenile steelhead enter nearshore marine waters as smolts, they are already at a size and developmental stage to move further offshore to forage on larger prey items. In the 2013 proposed critical habitat notification, studies reviewed by NMFS indicated that "steelhead migratory behavior strongly suggests that juveniles spend little time (a matter of hours in some cases) in estuarine and nearshore areas and do not favor migration along shorelines" (78 FR 2726).

WINTER-RUN

Most stocks of winter-run steelhead in Hood Canal (Skokomish, Hamma Hamma, Duckabush, Quilcene/Dabob Bay, and Dosewallips) spawn from mid-February to mid-June (WDFW 2002; Table B–5). Information published to date indicates adult spawn timing occurs from mid-February to early June.

SUMMER-RUN

Information on the timing of juvenile out-migration for summer-run steelhead in Hood Canal is not currently available. Spawn timing of summer-run steelhead in Hood Canal is not fully understood; however, spawning is believed to occur from February through April (WDFW 2002).

Table B–5. Migration, Spawning Period, and Peak of Winter-run Stocks of Puget Sound Steelhead

Stock	Time Period Detected in Hood Canal[1]	Spawn Time Period[2]	Peak Spawning
Tahuya winter-run	January through June	Early March to early June	May
Skokomish winter-run	January through mid-July	Mid-February to mid-June	May
Dewatto winter-run	January through June	Mid-February to early June	May
Union winter-run	Not identified	Mid-February to early June	Not identified
Hamma Hamma winter-run	Not identified	Mid-February to early June	Not identified
Duckabush winter-run	Not identified	Mid-February to early June	Not identified
Quilcene/Dabob Bay winter-run	Not identified	Mid-February to early June	Not identified
Dosewallips winter-run	Not identified	Mid-February to early June	Not identified

1. Time period detected in Hood Canal, reported in Busby et al. (1996).
2. Spawn timing reported in WDFW (2002).

1.1.4. Bull Trout

1.1.4.1. STATUS

Currently, all populations of bull trout in the lower 48 states are listed as threatened under the ESA. Bull trout are in the char subgroup of salmonids and have both resident and migratory life histories (64 FR 58910). The Coastal-Puget Sound bull trout DPS reportedly contains the only occurrence of anadromous bull trout in the contiguous United States (64 FR 58912); Hood Canal is one of five geographically distinct regions within this DPS. All Hood Canal bull trout originate in the Skokomish River (WDFW 2004). Critical habitat was originally designated for bull trout in 2005 (70 FR 56212) with a final revision to this habitat published in 2010 (75 FR 63898).

1.1.4.2. LIFE HISTORY

The food sources used by bull trout vary by life form, but in general they are considered opportunistic feeders (64 FR 58911). Both the resident and juvenile forms forage on aquatic and terrestrial insects, macro zooplankton, amphipods, mysids, crayfish, and small fish, whereas adult migratory bull trout primarily consume fish, including trout and salmon species, whitefish, yellow perch, and sculpin (64 FR 58911).

Resident bull trout remain in freshwater streams for their entire life cycle, whereas migratory bull trout, which have the potential to occur along the Bangor shoreline, spawn and rear in streams but migrate to marine waters as juveniles (64 FR 58910). Little information is known about the anadromous life history of this species. The spawning and early juvenile habitat requirements of bull trout are more specific than other salmonids, which may explain their patchy distribution (64 FR 58910). Important habitat features relevant to marine waters include cold water temperature (40 to 48°F), cover/shading, and intact migratory corridors (64 FR 58910). Reasons for declines and listing include habitat loss, degradation, and fragmentation; blocked migratory corridors (by dams or construction); introduced fish species (lake trout, brook trout, brown trout, and hatchery rainbow trout); and incidental harvest (64 FR 58910).

Bull trout in the Skokomish River system are thought to spawn from mid-September to December (WDFW 2004). It is not likely that bull trout migrate through the Bangor waterfront and past the Land-Water Interface (LWI) or Service Pier Extension (SPE) project sites (U.S. Fish and Wildlife Service [USFWS] 2010). For the species as a whole, emergence of fry occurs from early April to May (64 FR 58910).

1.1.4.3. OCCURRENCE

Neither historic nor recent juvenile fish surveys (using beach and lampara seines and tow nets) have captured bull trout (Schreiner et al. 1977; Salo et al. 1980; Bax 1983; SAIC 2006; Bhuthimethee et al. 2009). Not enough is known to fully describe the duration of juvenile out-migration for bull trout in Hood Canal (WDFW 2004).

1.2. ESA-Listed Rockfish

1.2.1. Bocaccio

1.2.1.1. STATUS

Puget Sound bocaccio, a species of rockfish, were federally listed as endangered under the ESA in 2010 (75 FR 22276). Critical habitat for yelloweye rockfish, canary rockfish, and bocaccio of the Puget Sound Georgia Basin was designated in November 2014 (79 FR 68042). WDFW published a revised draft environmental impact statement titled *Puget Sound Rockfish Conservation Plan* on April 6, 2010 (Bargmann et al. 2010). Threats to rockfish in Puget Sound include areas of low DO, commercial and sport fisheries (notably mortality associated with fishery bycatch), reduction of kelp habitat necessary for juvenile recruitment (74 FR 18516), habitat disruption (including exotic species), derelict gear (notably lost or abandoned fishing nets), climate changes, species interactions (including predation and competition), diseases, and genetic changes (Palsson et al. 2009; Drake et al. 2010).

Although rockfish are typically long-lived, recruitment is generally poor as larval survival and settlement depend on a variety of factors including marine currents, adult abundance, habitat availability, and predator abundance (Palsson et al. 2009; Drake et al. 2010). The combination of these factors has contributed to declines in the species within Georgia Basin and Puget Sound in the last few decades (74 FR 18516).

1.2.1.2. LIFE HISTORY

Bocaccio range from Punta Blanca, Baja California, to the Gulf of Alaska, Alaska (Love et al. 2002). They are believed to have commonly occurred in steep-walled habitats in most of Puget Sound prior to fishery exploitations, although they are currently very rare in the region (Love et al. 2002). Information on habitat requirements for most rockfishes is limited despite years of research, and even less is known about bocaccio in Puget Sound (Palsson et al. 2009; Drake et al. 2010). In general, most adult rockfish are associated with high relief, rocky habitats, which are limited in Hood Canal, while larval and juvenile stages of some rockfishes utilize open water and nearshore habitats as they grow. Reviews of rockfish habitat utilization in Puget Sound indicate that nearshore vegetated habitats are particularly important for some species and serve as nursery areas for juveniles (Palsson et al. 2009; Bargmann et al. 2010).

Palsson et al. (2009) indicate that in Puget Sound waters recruitment habitats may include nearshore vegetated habitats, or deep-water habitats consisting of soft and low relief rocky substrates. Much of the information presented below on bocaccio life history and habitat use is derived from other areas where bocaccio occur. Palsson et al. (2009) provides the most comprehensive review of Puget Sound rockfish species distributions and the relative number of occurrences. This review relied heavily on Miller and Borton (1980) data, but also included the review of historical literature, fish collections, unpublished log records, and other sources. Palsson et al. (2009) noted bocaccio were only recorded 110 times in their review of historical studies, with most records associated with sport catches from the 1970s in Tacoma Narrows and Appletree Cove (near Kingston). Only two records occurred for Hood Canal, both in the 1960s.

1.2.1.3. OCCURRENCE

Currently both sport and commercial fishing for rockfish in Hood Canal is prohibited, and no recent scientific surveys of these waters have occurred that document the recent prevalence of bocaccio in these waters. Although there have been no confirmed observations of bocaccio in Puget Sound for approximately 7 years (74 FR 18516), Drake et al. (2010) concluded that it is likely that bocaccio occur in low abundances. As a result, bocaccio have the potential to be affected by the proposed projects and are, therefore, included in the analysis.

1.2.2. Canary Rockfish

1.2.2.1. STATUS

Puget Sound canary rockfish were federally listed as threatened under the ESA in 2010 (75 FR 22276). Critical habitat for yelloweye rockfish, canary rockfish, and bocaccio of the Puget Sound Georgia Basin was designated in November 2014 (79 FR 68042). WDFW's April 2010 *Puget Sound Rockfish Conservation Plan* would be applicable to all rockfish in Puget Sound, including canary rockfish. The same stressors contributing to the decline of bocaccio affect canary rockfish (74 FR 18516; Palsson et al. 2009; Drake et al. 2010).

1.2.2.2. LIFE HISTORY

Canary rockfish range from Punta Blanca, Baja California, to the Shelikof Strait of Alaska, and are abundant from British Columbia to central California. Canary rockfish were once considered fairly common in the greater Puget Sound area (Kincaid 1919; Holmberg et al. 1962), although little is known about their habitat requirements in these waters (Palsson et al. 2009; Drake et al. 2010). Recent reviews of Puget Sound rockfish and their habitats (Palsson et al. 2009; Bargmann et al. 2010; Drake et al. 2010) discuss habitat use by listed rockfish in general terms with little or no distinction between the species. Therefore, as discussed above for bocaccio, adult canary rockfish are considered associated with high-relief, rocky habitats, and larval and juvenile stages likely utilize open water and nearshore habitats. Much of the information presented below on canary rockfish life history and habitat use is derived from research from other areas where canary rockfish are more abundant. After review of historical rockfish records in Puget Sound, Palsson et al. (2009) noted 114 records of canary rockfish prior to the mid-1970s, with most records attributed to sport catch from the 1960s to 1970s in Tacoma Narrows, Hood Canal, San Juan Islands, Bellingham, and Appletree Cove. Within Hood Canal, 14 records occurred: 1 in the 1930s and at least 13 in the 1960s (Miller and Borton 1980).

1.2.2.3. OCCURRENCE

As mentioned for bocaccio, there is a moratorium on both sport and commercial fishing for rockfish in Hood Canal. With the absence of associated catch records, and limited scientific surveys of these waters, the prevalence of rockfish in waters adjacent to NAVBASE Kitsap Bangor remains unknown. Drake et al. (2010) concluded that canary rockfish occur in low and decreasing abundances in Puget Sound. Therefore, canary rockfish have the potential to be affected by the proposed projects and are, therefore, included in the analysis.

1.2.3. Yelloweye Rockfish

1.2.3.1. STATUS

Puget Sound yelloweye rockfish were federally listed as threatened under the ESA in 2010 (75 FR 22276). Critical habitat for yelloweye rockfish, canary rockfish, and bocaccio of the Puget Sound Georgia Basin was designated in November 2014 (79 FR 68042). WDFW's April 2010 *Puget Sound Rockfish Conservation Plan* would be applicable for all rockfish in Puget Sound, including yelloweye rockfish. The same stressors contributing to the decline of bocaccio affect yelloweye rockfish (74 FR 18516; Palsson et al. 2009; Drake et al. 2010).

1.2.3.2. LIFE HISTORY

Yelloweye rockfish are found from Ensenada, Baja California, to the Aleutian Islands in Alaska. They are abundant from southeast Alaska to central California, but extremely rare in Puget Sound. Review of historical rockfish in Puget Sound by Palsson et al. (2009) noted 113 documented yelloweye rockfish records associated with sport catch. Of these records, 14 occurred in Hood Canal waters: 1 in the 1930s and 13 in the 1960s (Miller and Borton 1980). Kincaid (1919) reported yelloweye rockfish used to be relatively common in the deep waters of Puget Sound. Due to the moratorium on both sport and commercial fishing for rockfish in Hood Canal, the absence of associated recent catch records, and no recent scientific surveys of these waters, the prevalence of yelloweye rockfish in these waters remains unknown. As discussed above for canary rockfish, recent reviews of Puget Sound rockfish species and their habitats (Palsson et al. 2009; Bargmann et al. 2010; Drake et al. 2010) suggest little distinction between these rockfish species in terms of habitat use in Puget Sound. Therefore, as discussed above for bocaccio, adult yelloweye rockfish are considered associated with deeper, high-relief, rocky habitats, and larval and juvenile stages may utilize open water and nearshore habitats.

1.2.3.3. OCCURRENCE

As mentioned for bocaccio, there is a moratorium on both sport and commercial fishing for rockfish in Hood Canal. With the absence of associated catch records, and limited scientific surveys of these waters, the prevalence of rockfish in waters adjacent to NAVBASE Kitsap Bangor remains unknown. Drake et al. (2010) concluded that yelloweye rockfish occur in low and decreasing abundances in Puget Sound. Therefore, yelloweye rockfish have the potential to be affected by the proposed projects and are, therefore, included in the analysis.

1.3. NON-ESA-LISTED SALMONIDS

1.3.1. Chum Salmon (Fall-run and Hatchery Fish)

1.3.1.1. LIFE HISTORY

The general life history of fall-run chum salmon is similar to that of summer-run fish. The greatest difference is that fall-run adults spawn a few months later than summer-run adults. Adult fall- and late-fall-run stocks of Hood Canal chum salmon return to their natal streams to spawn between November and January. Consequently, fall-run juvenile salmon out-migrate a little later than do summer-run juvenile salmon. The release of hatchery chum salmon is dependent on hatchery management practices. In general, hatchery releases are timed to occur after summer-run juveniles have past their peak out-migration to minimize competition for limited food resources, such as benthic amphipods. Since fall-run and hatchery origin chum are indistinguishable from the ESA-listed summer-run chum, without genetic analysis, their occurrence is presented in this section at a species level rather than as a seasonally distinguished ESU or run. Similar to pink salmon, the small size of the juvenile chum salmon upon arrival to the marine environment in spring limits their out-migration distribution to the intertidal and shallow subtidal environment for both refuge and available food sources.

1.3.1.2. OCCURRENCE

From the 1970s to mid-2000s, recently hatched out-migrating juvenile chum salmon have been captured along the Bangor shoreline from January through June (Schreiner et al. 1977; Salo et al. 1980; Bax 1983; SAIC 2006; Bhuthimethee et al. 2009), with peak catches from 2006 to 2008 occurring from March to April (SAIC 2006; Bhuthimethee et al. 2009). Relatively small numbers of chum were captured in May and June of 2006, and no chum were captured from July through September, suggesting that the out-migration was completed by July (SAIC 2006).

Chum salmon was documented as the most abundant salmonid along the Bangor shoreline during the 2005 to 2008 surveys, accounting for approximately 94.7 percent of the salmonid catch (Figure B–1) (SAIC 2006; Bhuthimethee et al. 2009). Chum salmon are also the most abundant hatchery fish reared in Hood Canal (SAIC 2006; Bhuthimethee et al. 2009). As with pink salmon, chum salmon released from hatcheries are not marked (fin clipped). Thus, hatchery chum captured in Hood Canal surveys are indistinguishable in the field from naturally spawned chum (SAIC 2006; Bhuthimethee et al. 2009).

1.3.2. Coho Salmon

1.3.2.1. LIFE HISTORY

Like many other salmonids in Washington State, coho salmon (*Oncorhynchus kisutch*) occur as both hatchery-reared and naturally spawned fish. For coho populations in this region, returning adult coho salmon are generally 3-year-olds, and spend approximately 18 months in fresh water and 18 months in marine habitats (Sandercock 1991). Compared to Chinook salmon, coho tend to spawn in smaller streams of modest gradient (Quinn 2005). With some variability, coho salmon generally spawn on a 3-year cycle. Adult coho salmon migrate to their natal streams for spawning from mid-September to mid-November. Following a winter incubation period of 4 to 5 months, the free-swimming fry emerge from the gravel in the spring (Weitkamp et al. 1995). During spring of the second year, Hood Canal coho smolts migrate to sea. Due to the extended period of freshwater rearing time, juvenile coho are larger (2.8 to 3.5 inches [7.1 to 8.9 centimeters]) than some of the other co-occurring salmonids (e.g., chum and pink salmon at 1 to 1.6 inches [2.5 to 4.1 centimeters]) when they reach the waters of Hood Canal (SAIC 2006; Bhuthimethee et al. 2009). As a result, coho are not as dependent on shallow waters for foraging and protection from predators and currents, and occur further offshore from the Bangor shoreline than other salmonids. Maturing coho spend an average of 16 to 20 months rearing in the ocean, then return to fresh water to spawn as 3-year-old adults (Sandercock 1991). Recent tagging investigations have shown that juvenile coho distribution and movement patterns are not well known (Rohde 2013), but that they have extended intrabasin residence times and may utilize nearshore marine for extended rearing periods, not just migratory corridors.

1.3.2.2. OCCURRENCE

Coho salmon captured in beach seine surveys between 2005 and 2006 were the second most abundant salmonid occurring along the Bangor shoreline, accounting for approximately 3.1 percent of the salmonid catch (Figure B–1) (SAIC 2006). There is a run-timing overlap between hatchery and naturally spawning coho during out-migration (Bhuthimethee et al. 2009). In 2006, Hood Canal hatcheries released 1.6 million coho smolts from late April through early June (SAIC 2006). Although these hatchery fish were released at a time when naturally spawned coho also occur, approximately 82 percent of these released fish showed no external hatchery markings (data reviewed in SAIC 2006).

1.3.3. Pink Salmon

1.3.3.1. LIFE HISTORY

Pink salmon (*Oncorhynchus gorbuscha*) are the most abundant salmon along the coast of the northeast Pacific Ocean and are also the smallest at maturity (Bonar et al. 1989; Heard 1991; Quinn 2005). Pink salmon only live for 2 years, with very little variability. In general, large runs of adult pink salmon occur in the fall of odd years (with corresponding large juvenile out-migrations in spring of even years), with much smaller runs occurring in the fall of even years. Adult pink salmon migrate from the ocean to their natal streams from August to September, with spawning occurring in freshwater gravel beds from September through October (Heard 1991). Following their winter emergence from the gravel, 4 to 5 months after spawning, pink salmon fry begin their migration to the marine waters of Hood Canal. Due to their small size (approximately 1.0 to 1.5 inches [2.5 to 3.8 centimeters]) when reaching marine waters, including the NAVBASE Kitsap Bangor region (SAIC 2006; Bhuthimethee et al. 2009), these juveniles out-migrate in the nearshore, seeking food and refuge from predators along the shallow intertidal and shallow subtidal shorelines.

1.3.3.2. OCCURRENCE

Pink salmon generally occur every other year (the majority out-migrate in even years), and were the third most abundant salmonid occurring along the Bangor shoreline in 2005 and 2006. This species accounted for approximately 1.6 percent of the total salmonid catch from 2005 to 2008 (Figure B–1) (SAIC 2006). Though none of the NAVBASE Kitsap Bangor streams support spawning populations of pink salmon, juveniles from southern Hood Canal stream systems migrate in a northerly direction and occur in the vicinity of the project sites.

The Hoodsport Hatchery in southern Hood Canal rears pink salmon for release every other year at the end of the naturally spawned out-migration, usually in April. Currently this hatchery does not mark (fin-clip) pink salmon released in Hood Canal. As a result, recent surveys (2005 through 2008) were not able to distinguish between naturally produced and hatchery-reared pink salmon to determine differences in abundance, occurrence, or run-timing by source (SAIC 2006; Bhuthimethee et al. 2009). Newly emerged pink salmon have been captured along the Bangor shoreline as early as January and as late as June, with a peak occurrence in March to April (Schreiner et al. 1977; Salo et al. 1980; SAIC 2006; Bhuthimethee et al. 2009).

1.3.4. Cutthroat Trout

1.3.4.1. LIFE HISTORY

Spawning for cutthroat trout takes place in freshwater streams. By 2 or 3 years of age, juvenile cutthroat begin to migrate to marine waters. Generally, this migration occurs from March to June, with a peak out-migration in mid-May (Johnson et al. 1999). Upon entering marine waters, juvenile cutthroat form small schools and migrate along the nearshore waters. Some of these fish reside in Puget Sound whereas others enter coastal waters. Upon reaching maturity, cutthroat trout return to their natal streams for spawning, generally from July to December (Johnson et al. 1999). The spawned-out adults return to marine waters in late March or early April (Pacific States Marine Fisheries Commission 1996).

1.3.4.2. OCCURRENCE

Cutthroat trout are considered uncommon along the Bangor shoreline (Schreiner et al. 1977; Bax et al. 1978, 1980; Salo et al. 1980; SAIC 2006), representing less than 1 percent of the salmonids caught in beach seine studies conducted from 2005 to 2008 (Figure B–1) (SAIC 2006; Bhuthimethee et al. 2009). Both juvenile and adult cutthroat trout have been captured along the Bangor shoreline throughout the year, but peak abundance was in May and June from 2005 to 2008 (SAIC 2006; Bhuthimethee et al. 2009). At the Bangor waterfront, adult cutthroat were captured more frequently near the southern periphery and along the northern portion of the waterfront, away from the project sites. This may be the result of adult cutthroat attraction to the fresh water exiting Cattail Lake and Devil's Hole.

1.3.5. Sockeye Salmon

No documented runs of sockeye salmon occur within any of the tributaries of Hood Canal, with the nearest stock to Hood Canal occurring in Lake Washington (WDFW 2002). Other nearby populations of these fish include the Baker Lake and Lake Washington sockeye populations. Although a lone 12-inch sockeye was captured along the Bangor waterfront in March of 2006 (SAIC 2006), this fish was likely a stray individual sockeye stock from either Lake Washington, Fraser River, or British Columbia (Ruggerone 2006, personal communication). No other sockeye salmon have been captured conducted in the 1970s or 2000s along the Bangor shoreline (Schreiner et al. 1977; Bax et al. 1978, 1980; Salo et al. 1980; SAIC 2006, Bhuthimethee et al. 2009). Due to the primary absence of this species from the region of the projects, sockeye salmon are not discussed further in this document.

1.4. FORAGE FISH

Nearshore habitat requirements for forage fish are similar to those described in Section 2, below, for salmonids with respect to water and sediment quality, physical and biological habitat use, and underwater noise. One notable difference is that forage fish species use some areas of Puget Sound shorelines for spawning habitat, whereas salmonids use freshwater systems for spawning. Suitable spawning habitat for forage fish is species specific, and is discussed below for each species.

1.4.1. Pacific Herring

1.4.1.1. LIFE HISTORY

Pacific herring (*Clupea pallasii*) are relatively small (9-inch [22.9 centimeter]) schooling fish distributed along the Pacific coast from Baja California, Mexico, to the Bering Sea and northeast to the Beaufort Sea, Alaska. Adult herring feed primarily on planktonic crustaceans, and juveniles prefer a diet of crab and shrimp larvae. Herring are an important food resource for other species in Puget Sound waters. Puget Sound stocks of young herring spend at least their first year in Puget Sound, with some stocks displaying resident behavior, and others migrating in summer months to coastal areas of Washington and southern British Columbia (Bargmann 1998). The majority of herring spawning in Washington State waters occurs annually from late January through early April (Bargmann 1998). Herring deposit their eggs on intertidal and shallow subtidal eelgrass and marine algae. Large spawning areas are found with patchy distribution in northern Hood Canal (Stick and Lindquist 2009). However, the only documented herring spawning grounds potentially affected by the projects occur near Squamish Harbor (Figure 3.3–4).

1.4.1.2. OCCURRENCE

Pacific herring have been detected in small numbers during late winter months and large numbers in early summer months during recent surveys along the Bangor waterfront (SAIC 2006; Bhuthimethee et al. 2009). These very large (occasionally numbering in the thousands), but infrequent summer schools of herring can comprise the majority of all forage fish occurring along the Bangor shoreline, when these larger schools are present. As indication of school variability, in 2005 and 2008 Pacific herring represented less than 1 percent of the beach-seine captured forage fish at NAVBASE Kitsap Bangor, while in 2006 and 2007 they represented

73 percent and 84 percent, respectively, of all forage fish captured (SAIC 2006; Bhuthimethee et al. 2009), though these schools were captured in just a few sampling events.

OCCURRENCE AT LWI PROJECT SITES

In the 2005 to 2008 nearshore fish surveys, Pacific herring were captured at both LWI project sites (SAIC 2006; Bhuthimethee et al. 2009). The sampling effort was most comparable in effort and location in 2006, 2007, and 2008, due to a much lower 2005 sampling effort. Therefore, only the three comparable years are discussed below. A single sample location occurred in the immediate vicinity of the proposed north LWI project site. At the north LWI project site, less than one percent of all Pacific herring captured in 2008 occurred at the nearby sampling location (SAIC 2006; Bhuthimethee et al. 2009). In 2007, only 5 percent of all herring captured along the 15 waterfront sampling sites occurred at this location. However, in 2006, 49 percent of the Pacific herring catch occurred at this location. At the south LWI project site, two sampling locations occurred, immediately north and south of the proposed south LWI project site. At these sampling sites, only one Pacific herring was captured in 2006 and 2008 (SAIC 2006; Bhuthimethee et al. 2009). In 2007, however, of the 15 stations sampled along the waterfront, 10 percent of all herring captured occurred at these two stations (Bhuthimethee et al. 2009). In general, many more Pacific herring were captured at the one sampling location near the north LWI project site than the two sampling stations near the south LWI project site. However, these numbers largely reflect the capture of large schools of fish, and they likely do not indicate a difference in habitat quality or preference between the two locations. The study results indicate that Pacific herring collected along the NAVBASE Kitsap Bangor shoreline in late spring and summer can occur in distinct schools that are not large enough to extend across multiple sampling sites and they do not appear to be attracted to, reside for an extended period at, or show preference for a specific location.

OCCURRENCE AT THE SPE PROJECT SITE

The two fish survey sampling locations that occurred nearest to the SPE project site during the 2006, 2007, and 2008 sampling efforts occurred on either side of Carlson Spit, immediately south of the existing Service Pier structure (SAIC 2006; Bhuthimethee et al. 2009). The inconsistent capture of Pacific herring at this location was similar to that described for the two LWI project sites. Of the 12 stations sampled in 2006, the 2 located at Carlson Spit accounted for 24 percent of the Pacific herring captured. However, of the 15 stations sampled in 2007 and 2008, less than 1 percent of all Pacific herring captured occurred at these two sites. As discussed above, these numbers largely reflect the capture of large schools of fish on a few occasions, and likely do not indicate any preference of this location by Pacific herring.

1.4.2. Surf Smelt

1.4.2.1. LIFE HISTORY

Surf smelt (*Hypomesus pretiosus*) is a common and widespread nearshore forage fish throughout Washington marine waters (Penttila 2007). There is no evidence of widespread migrations to and from Puget Sound to the outer coast. Surf smelt in Puget Sound do not appear to form large schools in open water, instead occurring more exclusively in nearshore waters. This is supported by mid-water research trawl surveys with catches suggesting a distinct preference for more shallow, nearshore habitats and a tendency to remain close to the bottom at all times. In fact, as indicated by Penttila (2007), young-of-the-year surf smelt are virtually ubiquitous along Puget Sound shorelines. Surf smelt are schooling plankton feeders, with an apparent preference for calanoid copepods, along with other small, epibenthic crustaceans and tunicates (Simenstad et al. 1988; Penttila 2007).

These small (9-inch [22.9 centimeters]) schooling fish are distributed along the Pacific coast from Long Beach, California, to Chignik Lagoon, Alaska. During 2005–2006 beach seine surveys, surf smelt were the second most abundant forage fish captured, representing 20 percent of the total forage fish catch (SAIC 2006). As with other forage fish species, surf smelt are an important component in Puget Sound, both as a food resource in the marine food web and as part of the commercial fishing industry.

In southern Hood Canal surf smelt spawn most frequently in the fall and winter. However, in many other regions of Puget Sound, including northern Hood Canal, spawning can occur year round. Potential surf smelt spawning habitat includes beaches composed of mixed sand and gravel in the uppermost one-third of the tidal range, from approximately +7 feet up to extreme high water (Penttila 2007). Although Penttila (1997) found no surf smelt spawning grounds along the Bangor waterfront during surveys conducted from May 1996 through June 1997, they may utilize the northern portion of Squamish Harbor (at the northern boundary of the area affected by the projects) for spawning.

1.4.2.2. OCCURRENCE

In nearshore beach seine surveys conducted from 2005 to 2008, surf smelt were most abundant along the Bangor waterfront in late spring through summer (SAIC 2006; Bhuthimethee et al. 2009).

OCCURRENCE AT LWI PROJECT SITES

Juvenile surf smelt have been found to rear in nearshore waters (Bargmann 1998) and were captured along the shoreline near both LWI project sites from January through the mid-summer months (SAIC 2006; Bhuthimethee et al. 2009). In 2006, of the 12 locations sampled, less than 1 percent of all surf smelt were captured at the one sampling location in the vicinity of the north LWI project site. However, in 2007 and 2008 when 15 locations were sampled, 5 percent and 34 percent, respectively, of the surf smelt captured occurred at the north LWI project site. The survey findings were similar for the south LWI project site. At this site, two sampling locations occurred, immediately north and south of the proposed site. In 2006, of the 12 locations sampled, less than 2 percent of all surf smelt were captured at the two sampling locations in the vicinity of the south LWI project site. However, in 2007 and 2008, when 15 locations were sampled, 10 percent and 34 percent, respectively, of the surf smelt captured occurred at the two sampling locations that occur in the vicinity of the site. Although occurring somewhat more broadly among sampling locations than herring, surf smelt also occur in distinct schools, and do not appear to be attracted to, reside for any extended period at, or show preference toward any specific location along the waterfront. Instead, when these schools occur they appear to be using the nearshore environment as a migratory pathway, similar to salmonids.

OCCURRENCE AT SPE PROJECT SITES

The two fish survey sampling locations that occurred nearest to the SPE project site during the 2006, 2007, and 2008 sampling efforts occurred on either side of Carlson Spit, immediately south of the existing Service Pier structure (SAIC 2006; Bhuthimethee et al. 2009). Juvenile and adult surf smelt were captured in very low abundances along the shoreline near the SPE project site (SAIC 2006; Bhuthimethee et al. 2009). In 2006, of the 12 stations sampled, less than 1 percent of all surf smelt captured occurred at the 2 sampling locations. In 2007 and 2008, 15 stations were sampled, with less than 1 percent and less than 5 percent, respectively, of all surf smelt occurring at these 2 sampling locations.

1.4.3. Pacific Sand Lance

1.4.3.1. LIFE HISTORY

The Pacific sand lance (*Ammodytes hexapterus*), another relatively small (8-inch) schooling fish, occurs throughout the coastal northern Pacific Ocean between the Sea of Japan and southern California, across Arctic Canada, and throughout the Puget Sound region. All life stages of sand lance feed on planktonic organisms, primarily crustaceans, with juveniles showing a preference for calanoid copepods (Penttila 2007). As with other forage fish, the Pacific sand lance is an important part of the trophic link between zooplankton and larger predators in local marine food webs. Bargmann (1998) indicated that 35 percent of all juvenile salmon diets and 60 percent of the juvenile Chinook diet comprised sand lance. Other regionally important species (such as Pacific cod, Pacific hake, and dogfish) feed heavily on juvenile and adult sand lance.

Pacific sand lance are the only forage fish species with spawning habitat documented along the Bangor shoreline. Sand lance deposit eggs on a range of nearshore substrates, from soft, pure, fine sand beaches to beaches armored with gravel up to 1.2 inches (3 centimeters) in diameter; however, most spawning appears to occur on the fine-grained substrates (Bargmann 1998). Spawning occurs at tidal elevations ranging from 5 feet (1.5 meters) above to about the mean higher high water (MHHW) line. Sand lance spawning activity occurs annually from early November through mid-February. Because the sand lance spawns on sand gravel beaches in the upper intertidal zone throughout the increasingly populated Puget Sound basin, it is particularly vulnerable to the cumulative impacts from various types of shoreline development.

Although this species is common and widespread in Puget Sound, very little is known about the life history or biology of sand lance populations in Washington State. Pacific sand lance are highly unusual among local forage fish species in their habit of actively burrowing into nearshore sand-gravel bottom sediments during parts of their diurnal and seasonal cycles of activity (Quinn 1999). Pacific sand lance are known to burrow in soft sediments in intertidal and subtidal areas to escape predation and conserve energy, because they lack a swim bladder to aid in swimming. While slightly older Pacific sand lance have been shown to occupy or be associated with intertidal eelgrass habitats, young-of-the-year sand lance are negatively correlated with these same habitats (Haynes et al. 2008). In addition to age-related habitat preferences, Haynes et al. (2008) postulated that there may be different sediment preferences of sand lance depending on whether the habitat occurs in intertidal or subtidal regions. Although Pacific sand lance are largely associated with these nearshore spawning habitats, an investigation of deeper water sand waves and benthic sediments within the San Juan Islands detected habitat use and occurrence of eggs and non-larval ages of sand lance (Greene et al. 2011).

1.4.3.2. OCCURRENCE

OCCURRENCE AT LWI PROJECT SITES

Pacific sand lance were the third most abundant forage fish collected along the Bangor waterfront during recent surveys and comprised 7 percent of the total forage fish catch (SAIC 2006). At the north LWI project site, Pacific sand lance spawning habitat has been documented along an estimated 1,000-foot (305-meter) length of the shoreline extending from the proposed abutment location southward (Figure 3.3–4) (WDFW 2013). At this location, in 2006 and 2007 less than 1 percent of all sand lance captured along the waterfront occurred in the vicinity of the north LWI project site (SAIC 2006; Bhuthimethee et al. 2009). However, in 2008, 57 percent of all sand lance captured along the NAVBASE Kitsap Bangor shoreline, occurred at this location. At the south LWI project site, spawning habitat has been documented along the shoreline approximately 500 feet (150 meters) north of the proposed abutment location, extending approximately 1,600 feet (488-meters) north (Figure 3.3–4) (WDFW 2013). In 2006 and 2007 at the two sampling locations in the vicinity of the south LWI project site, less than 1 percent of all sand lance captured along the waterfront occurred in this area. However, in 2008, 16 percent of all sand lance captured along the NAVBASE Kitsap Bangor shoreline occurred at the two sampling locations in the vicinity of the south LWI project site.

OCCURRENCE AT SPE PROJECT SITES

The Pacific sand lance spawning habitat that occurs on both sides of Carlson Spit extends northward to include intertidal habitats under the Service Pier causeway (Figure 3.3–4) (WDFW 2013). The two nearest fish survey locations occurred on either side of Carlson Spit (SAIC 2006; Bhuthimethee et al. 2009). In 2006 Pacific sand lance captured at these 2 locations accounted for 22 percent of all Pacific sand lance captured from the 12 NAVBASE Kitsap Bangor shoreline locations sampled that year. In 2007 and 2008, when 15 locations were sampled, the Pacific sand lance captured in the vicinity of the SPE site represented 7 percent and 6 percent, respectively, of all Pacific sand lance captured along the NAVBASE Kitsap Bangor shoreline.

2.0 HABITAT CONDITIONS

Salmonids are most abundant in Hood Canal during the spring juvenile salmonid out-migration (Schreiner et al. 1977; Prinslow et al. 1980; Bax 1983; Salo 1991; SAIC 2006; Bhuthimethee et al. 2009), when these fish are dependent on nearshore habitats for foraging and refuge. NMFS, USFWS, and the Pacific Fisheries Management Council (PFMC) have prepared guidance on the evaluation of properly functioning conditions (PFCs) for salmonids in freshwater systems. Although this Matrix of Pathways Indicators has only been constructed for freshwater and not for marine systems, marine and estuarine habitat requirements for juvenile and adult salmonids have been described by many authors (Fresh et al. 1981; Shepard 1981; Healey 1982; Levy and Northcote 1982; Weitkamp et al. 2000).

Ideally, reliable stock-specific habitat requirements would exist for all populations of listed species that would allow the impacts of an action to be quantified in terms of population impacts (NMFS 1999). However, as stated in the Habitat Approach, an August 1999 supplement to the National Oceanic and Atmospheric Administration (NOAA) Fisheries guidance document *Making Endangered Species Act Determinations of Effects for Individual or Grouped Action at* *the Watershed Scale* (NMFS 1996), in the absence of population-specific information, an assessment must define the biological requirements of a listed fish species. These requirements are defined in terms of PFCs, which are described as the sustained presence of natural habitat-forming processes necessary for the long-term survival of the species through the full range of environmental variation (NMFS 1999). Indicators of PFCs vary in different landscapes based on unique physiological and geologic features (NMFS 1999). Since aquatic habitats are inherently dynamic, PFCs are defined by the persistence of natural processes that maintain habitat productivity at a level sufficient to ensure long-term survival, and are not necessarily defined by absolute thresholds and parameters (NMFS 1999). A more detailed description of the potential impacts of the proposed projects on ESA-listed marine fish using the PFC analysis approach is provided in the Biological Assessment.

2.1. Water and Sediment Quality

As described in greater detail in Section 3.1.1.1.1, turbidity along the Bangor waterfront meets water quality standards and is considered properly functioning. DO levels meet the extraordinary standard for surface waters (3 to 20 feet [1 to 6 meters] in depth) year round and for deep water (66 to 197 feet [20 to 60 meters] in depth) most of the year, although deeper waters can drop to a fair standard in late summer (Hafner and Dolan 2009; Phillips et al. 2009; Hood Canal Dissolved Oxygen Program 2009).

2.1.1. Water and Sediment Quality at the LWI Project Sites

Existing nearshore current patterns along the shoreline at both LWI project sites, primarily driven by tidal exchange, are described in greater detail in Section 3.1.1.1.1. The nearest freshwater source to the north LWI project site is the Hunter's Marsh system, located immediately behind the Explosives Handling Wharf (EHW)-1 structure, south of the north LWI project site. The strong tides and currents, combined with a small outflow from the marsh, result in well-mixed waters at the north LWI project site with no habitat that acts as an estuary. The south LWI project site occurs near the Devil's Hole outlet. The freshwater exiting the lake has contributed to higher temperatures and lower salinities in the nearshore waters at this location (Phillips et al. 2009). Temperature, pH, and other water quality parameters meet water quality standards, and there is no known water contamination within the general LWI project areas (Section 3.1.1.1.2).

Sediment investigation studies have shown that marine sediments in the vicinity of the LWI project sites are composed of gravelly sands with some cobbles in the intertidal zone, transitioning to silty sands in the subtidal zone (Hammermeister and Hafner 2009). In general, sediment characterization studies along the waterfront demonstrated that organic contaminants, metals, polycyclic aromatic hydrocarbons (PAHs), phthalates, phenols, and some chlorinated pesticides occur at concentrations below the sediment quality standards (SQS) (Section 3.1.1.1.3).

2.1.2. Water and Sediment Quality at the SPE Project Site

Temperature, pH, and other water quality parameters near the SPE project site meet water quality standards, and there is no known water contamination within the general SPE project area (Section 3.1.1.1.2).

As discussed above for the LWI project sites, sediment characterization studies along the waterfront, including the SPE project site, demonstrated that organic contaminants, metals, PAHs, phthalates, phenols, and some chlorinated pesticides occur at concentrations below the cleanup thresholds (see Section 3.1.1.1.3). Additionally, results from the SAIC 2007 sediment survey at Bangor (Hammermeister and Hafner 2008) indicate that surficial sediments near Service Pier consist of 73 to 93 percent sand and gravel, with total organic carbon levels ranging from 0.4 to 2 percent (Section 3.1.1.1.3). There was no evidence of elevated metals, PAHs, pesticides, polychlorinated biphenyls, and all sediment contaminant concentrations were below the corresponding SQS guidelines.

2.2. Physical Habitat and Barriers

The eight in-water structures along the waterfront (Carderock Pier, Service Pier, Keyport/Bangor Dock (KB Dock), Delta Pier, Marginal Wharf, EHW-1, EHW-2 [under construction] and the Magnetic Silencing Facility [MSF]) likely act as migrational barriers to shoreline migrating juvenile salmon. Although there are many nearshore structures in the southern portion of Hood Canal, primarily smaller docks, NAVBASE Kitsap Bangor represents the only industrial waterfront within the Hood Canal area of Puget Sound. Within northern Hood Canal, nearshore development is limited. A few docks and a small pier occur at Seabeck, more than 8 miles (13 kilometers) to the south, and the Hood Canal Bridge, approximately 7 miles (11 kilometers) north of the MSF. The remainder of the northern Hood Canal shoreline is generally undeveloped. For the Marginal Wharf, the large number of piles, their close spacing, the low height-over-water design, and the nearshore location of the wharf likely make this the greatest barrier to migrating juvenile salmon. Most of the other structures have been designed to have the majority of their overwater structures farther offshore, have a greater height-over-water, and an increased separation between piles. Recent fish surveys have captured large numbers of salmonids behind and along the shoreline immediate to the north of each structure, including Marginal Wharf (SAIC 2006; Bhuthimethee et al. 2009), suggesting juvenile salmonids are able to migrate around, or through, these structures. Although statistical analyses of those surveys did not indicate a significant barrier effect of these nearshore structures (Bhuthimethee et al. 2009), they were designed to detect the occurrence, distribution, and habitat use of nearshore fish species, and did not include a study design specific for detecting the potential barrier effects of nearshore NAVBASE Kitsap Bangor structures.

2.2.1. Physical Habitat and Barriers at the LWI Project Sites

Structures along the entire waterfront and in the immediate vicinity of the north and south LWI project sites include in-water physical structures, overwater shading and overwater lighting, considered as potential barriers to juvenile salmonid migration in Puget Sound (Simenstad et al. 1999; Nightingale and Simenstad 2001a).

Existing physical barriers at the north LWI project site includes the piles supporting the EHW-1 causeways, less than 1,000 feet (305 meters) south of the north LWI footprint. Although some delay or slight alteration in migratory behavior of nearshore migrating fish may occur due to the presence of the causeways, the large height over water reduces the potential shading effect, and the larger separation between piles, relative to Marginal Wharf, reduces this effect.

Existing physical barriers at the south LWI project site includes the piles supporting Delta Pier, less than 1,000 feet (305 meters) north of the south LWI footprint. As with the north LWI project site, structural designs of these causeways reduce the potential shading effect and minimize the barrier effect of in-water piles; however, some delay or slight alteration in migratory behavior of nearshore migrating fish may occur due to the presence of in-water structures supporting Delta Pier.

2.2.2. Physical Habitat and Barriers at the SPE Project Site

In addition to the Service Pier itself, in-water structures in the vicinity of the SPE project site include KB Dock, approximately 500 feet (152 meters) to the north, and Carderock Pier approximately 500 feet to the south. The existing structures along the entire waterfront, and in the immediate vicinity of the SPE project site, may delay or slightly alter the existing migratory behavior of nearshore migrating fish due to factors such as in-water physical structures, overwater shading, and overwater lighting.

2.3. BIOLOGICAL HABITAT

2.3.1. Prey Availability

The large majority of salmonids that occur along the Bangor waterfront are juveniles, recently emerged from their natal streams, migrating toward the Pacific Ocean (Schreiner et al. 1977; Salo et al. 1980; Bax 1983; SAIC 2006; Bhuthimethee et al. 2009). At these smaller sizes, juvenile salmonids prefer small benthic invertebrate prey, although larger age-0 fish will prey on smaller fish. Other species, notably coho salmon, can occur as larger age-1 fish during their out-migration, and use larval and juvenile forage fish as a food resource during their migration. Subadult and adult salmonids use juvenile and adult forage fish, among other species, as a food resource (Healey 1991; Salo 1991; Sandercock 1991). A detailed description of forage fish life history and occurrence, including prey resources such as benthic invertebrates used extensively by the younger, more abundant, juvenile salmonids, is provided in Section 1.4 in this appendix.

The presence of small invertebrate prey resources such as harpacticoid copepods, gammarid and corophoid amphipods, which are preferred juvenile salmon prey sources (Healey 1991; Salo 1991; Webb 1991a,b; Fujiwara and Highsmith 1997; HCCC 2005), indicate an epibenthic community capable of providing suitable food resources during the juvenile salmon out-migration along the Bangor shoreline.

2.3.1.1. PREY AVAILABILITY AT THE LWI PROJECT SITES

As described in Section 3.2.1.1.3, benthic organisms, including a number of preferred amphipod species, are abundant and diverse at both LWI project sites. Larger eelgrass beds along the Bangor shoreline, such as the one at the south LWI project site (SAIC 2009), were identified by Salo et al. (1980) as superior foraging habitats for juvenile salmonids due to high standing stocks of their preferred prey. However, the eight nearshore docks, piers, or wharves that occur along the Bangor waterfront include piles and overhead shading of benthic habitat reduce productivity of benthic habitat in the immediate vicinity of these structures.

2.3.1.2. PREY AVAILABILITY AT THE SPE PROJECT SITE

As described in Section 3.2.1.1.3, benthic organisms that occur at the SPE project site are expected to be less abundant than occur in dense eelgrass beds, elsewhere along the shoreline. The SPE project site is located in waters deeper than 30 feet (9 meters) below mean lower low water (MLLW), generally the depth at which eelgrass becomes light limited. An adjacent eelgrass bed likely supports an invertebrate community providing foraging opportunities for juvenile salmonids. However, the existing overwater trestles and decking result in direct shading and reduced productivity of benthic habitat in the immediate vicinity of these structures.

2.3.2. Aquatic Vegetation

Juvenile salmonids use nearshore marine aquatic vegetation, notably eelgrass, as forage and refuge habitat during their migration from natal streams (Simenstad and Cordell 2000; Nightingale and Simenstad 2001a,b; Shafer 2002). Marine vegetation communities, including eelgrass beds, in Puget Sound provide a unique habitat, supporting a variety of invertebrates, such as copepods, amphipods, and snails, which might otherwise not be found on soft sediments (Mumford 2007). As indicated by Salo et al. (1980), the copepods and other zooplankton found in these habitats represent the major food base for the food chain in Puget Sound, specifically for small and juvenile fish including forage fish and salmonids.

2.3.2.1. AQUATIC VEGETATION AT THE LWI PROJECT SITES

The existing marine vegetation community is considered to be healthy and diverse at both LWI project sites, as described in Section 3.2.1.1.2. However, the EHW-1 structure occurs immediately to the south of the north LWI project site, shading the marine vegetation community in its footprint. The presence of this structure likely limits the southern extent of the eelgrass bed at the north LWI project site. The south LWI project site, includes an extensive eelgrass bed fed by the freshwater outflow of Devil's Hole on a small intertidal delta. The combination of shallow waters with plentiful nutrients and no shade likely contributes to the health of the marine vegetation community at this site. Similar to benthic and forage fish spawning habitat, more aquatic vegetation habitat likely would have been present prior to the nearshore construction of the existing piers or wharves. Therefore, it can be assumed that, at a minimum, the reduction in light attenuation due to the presence of these overwater structures limits the suitability of benthic habitats in their immediate vicinity to support healthy aquatic vegetation.

2.3.2.2. AQUATIC VEGETATION AT THE SPE PROJECT SITE

Although the SPE project site occurs in deeper waters, where marine vegetated communities become light limited (generally at depths greater than 30 feet [9 meters] MLLW), a narrow band of eelgrass occurs in the intertidal habitat long the shoreline (Section 3.2.1.1.2). In addition to the light limitation of deeper water, as with other habitats located near overwater structures, at a minimum, the reduction in light attenuation due to the presence of the existing Service Pier, and its causeway, likely contributes to reduced benthic habitat productivity, including healthy aquatic vegetation, in the immediate project vicinity.

2.4. UNDERWATER NOISE

Elevated underwater noise from anthropogenic sources has been found to alter the distribution, behavior, and health of fish that are present during these conditions (Hastings 2002; Hastings and Popper 2005; Popper et al. 2006). The existing underwater noise along the Bangor waterfront is attributed to a variety of both natural and human-related sources. Average underwater noise levels measured along the Bangor waterfront are elevated over ambient conditions due to waterfront operations, but are within the minimum and maximum range of measurements taken at similar environments within Puget Sound.

With respect to underwater noise impacts on fish, the presence of an internal air (swim) bladder to maintain buoyancy likely makes these species more susceptible to injury from underwater noise. This bladder is susceptible to expansion/decompression when a pressure wave from underwater noise is encountered. When the pressure is applied rapidly and at a sufficient level, rapid expansion/decompression is fatal for fish. However, underwater noise threshold criteria, established by a multi-agency working group, currently do not differentiate between species with air bladders and those without them (Fisheries Hydroacoustic Working Group 2008). Additional details regarding fish hearing capabilities is provided in Section 3.0, below.

3.0 FISH HEARING AND RESPONSE TO UNDERWATER SOUND

The degree to which an individual fish would be affected by underwater sound depends on a number of variables, including (1) species of fish, (2) fish size, (3) presence of a swim bladder, (4) physical condition of the fish, (5) maximum sustained sound pressure and frequency, (6) shape of the sound wave (rise time), (7) depth of the water, (8) depth of the fish in the water column, (9) amount of air in the water, (10) size and number of waves on the water surface, (11) bottom substrate composition and texture, (12) effectiveness of bubble curtain sound/pressure attenuation technology (if used for mitigation), (13) tidal currents, and (14) presence of predators (NMFS 2005b). Depending on these factors, effects on fish from underwater sound can range from changes in behavior to immediate mortality. There has been no documented injury or mortality resulting from the use of vibratory hammers; however, fish injury has been documented during installation of steel piles.

3.1. PHYSIOLOGICAL RESPONSES

As with underwater noise impacts on behavior, injury threshold levels and corresponding effects on fish at different intensities of underwater sound are unclear (Hastings and Popper 2005). Many of the previous studies cited for the physical effects, including injury and mortality, of underwater sound on fish were based on seismic air gun and underwater explosives studies (Hastings and Popper 2005). Physical effects from these types of impulsive sounds can include swim bladder, otolith, and other organ damage; hearing loss; and mortality (Hastings and Popper 2005).

Fish with swim bladders, including salmonids and larval rockfish, are more susceptible to barotrauma from impulsive sounds (sounds of very short duration with a rapid rise in pressure) because of swim bladder resonance (vibration at a frequency determined by the physical parameters of the vibrating object). A sound pressure wave can be generated from an impulsive sound source, such as an impact hammer striking a steel pile. When this wave strikes a gas-filled space, such as a swim bladder, it causes that space to vibrate (expand and contract) at its resonant frequency. When the amplitude of this vibration is sufficiently high, the pulsing swim bladder can press against and strain adjacent organs, such as the liver and kidney. This pneumatic compression can cause injury in the form of ruptured capillaries, internal bleeding, and maceration of highly vascular organs (CALTRANS 2002). Larval rockfish generally develop a swim bladder from two to three weeks after their birth (Tagal et al. 2002), but may be vulnerable to harm from noise before the bladder develops. However, not all pile driving is the same with respect to generating a sound pressure wave. In general, larger steel piles being driven by an impact hammer generate more biologically harmful pressure waves than smaller steel piles, similar-sized steel piles generate more harmful pressure waves than concrete piles when being driven by an impact hammer, and piles driven using a vibratory hammer generally do not produce a pressure wave sufficient to cause barotrauma effects on fish that can result from impact hammers. More detailed information on underwater sound produced from pile driving is provided in Appendix D.

Hastings and Popper (2005) also noted that sound waves can cause different types of tissue to vibrate at different frequencies, and that this differential vibration can cause tearing of mesenteries and other sensitive connective tissues. Exposure to high noise levels can also lead to injury through "rectified diffusion," the formation and growth of bubbles in tissues. These bubbles can cause inflammation; cellular damage; and blockage or rupture of capillaries, arteries, and veins (Crum and Mao 1996; Vlahakis and Hubmayr 2000; Stroetz et al. 2001). These effects can lead to overt injury or mortality. Death from barotrauma and rectified diffusion injuries can be instantaneous or delayed for minutes, hours, or even days after exposure.

Even in the absence of mortality, elevated noise levels can cause sublethal injuries affecting survival and fitness. Similarly, if injury does not occur, noise may modify fish behavior that may make them more susceptible to predation. Fish suffering damage to hearing organs may suffer equilibrium problems and have a reduced ability to detect predators and prey (Turnpenny et al. 1994; Hastings et al. 1996). Other types of sublethal injuries can place the fish at increased risk of predation and disease. Adverse effects on survival and fitness can occur even in the absence of overt injury. Exposure to elevated noise levels can cause a temporary shift in hearing sensitivity (referred to as a temporary threshold shift, or TTS), decreasing sensory capability for periods lasting from hours to days (Turnpenny et al. 1994; Hastings et al. 1996).

The severity of effects from high noise levels produced by impact-driving of steel piles depends on several factors, including the size and species of fish exposed. Regardless of species, smaller fish appear to be far more sensitive to injury of non-auditory tissues (Yelverton et al. 1975). For example, NMFS biologists observed that approximately 100 surf perch from three different species (*Cymatogaster aggregata*, *Brachyistius frenatus*, and *Embiotoca lateralis*) were killed during impact pile driving of 36-inch (91-centimeter) diameter steel pilings at Bremerton, Washington (Stadler, NMFS, 2002, personal observation). Dissections revealed complete swim bladder destruction across all species in the smallest fish (7.6 centimeters fork length), while swim bladders in the largest fish (16.51 centimeters fork length) were nearly intact. However, swim bladder damage was typically more extensive in *C. aggregata* compared *to B. frenatus* of similar size. Because of their large size, adult salmon can tolerate higher noise levels and are generally less sensitive to injury of non-auditory tissues than juveniles (Hubbs and Rechnitzer 1952). However, no information is available to determine whether or not the risk of auditory tissue damage decreases with increasing size of the fish.

3.2. Behavioral Responses

Data are limited for assessing the effects of anthropogenic-produced underwater sound on fish behavior (Hastings and Popper 2005; Popper and Hastings 2009). Of those studies investigating behavioral responses to underwater sound, not all collected the underwater sound data using a similar method, making comparisons between studies difficult (Hastings and Popper 2005). Part of the difficulty is that there are many different anthropogenic noise sources, with each source producing different types of underwater sound (e.g., impulsive vs. non-impulsive sound). Existing studies of fish behavioral response to underwater noise have investigated a variety of noise sources, including pile driving, seismic air gun, sonar, and vessel noise. Depending on the noise source, the physical environment, and the fish species, behavioral responses can vary. A summary of studies that include an investigation of fish behavior reviewed for this EIS is provided below.

A number of studies have been conducted that indicate fish under natural settings display a behavioral or startle response to anthropogenic-produced underwater noise. Wardle et al. (2001) examined the behaviors of various fish species (e.g., gadoids, saithe, whiting, and small cod) on a reef in response to seismic air guns that were calibrated to have a peak level of 210 dB re 1 μPa at 16 meters from the source and 195 dB re 1 μPa at 109 meters from the source. Although they found that fish displayed a startle response, the noise did not chase the fish away and resulted in no permanent changes in the behavior of fish on the reef over the course of the study.

Slotte et al. (2004) utilized a vessel with two seismic sources, each of 20 air guns and 10 hydrophone streamers, and investigated the change in abundance of pelagic fish (including blue whiting and herring) relative to the seismic noise source. Regardless of species, Slotte et al. (2004) found that fish in the area of the air guns appeared to move to greater depths after ensonification compared to their vertical position prior to air gun usage. However, because the acoustic mapping prior to the shooting along some of the seismic transects gave no indications of short-term reactions, it was not evident whether a startle response occurred and the findings were inconclusive.

In a caged fish study, investigating the effects of a seismic air gun on five species of rockfish (*Sebastes* spp.), Pearson et al. (1992) found that the general threshold for startle response occurred at 180 dB re 1 μPa. Behaviors varied between species, although fish generally formed tighter schools and remained somewhat motionless (Pearson et al. 1992). Skalski et al. (1992) found that, following the noise produced from a seismic air gun at the base of rockfish aggregations (186 dB peak re 1 μ Pa), the average rockfish catch for hook and line surveys decreased by 52 percent. Fathometer observations showed that the rockfish schools did not disperse but remained aggregated in schooling patterns similar to those prior to exposure to this noise. However, these aggregations elevated themselves in the water column, away from the underwater noise source.

Other studies have shown that some fish species may habituate to underwater noise (Feist 1991; Feist et al. 1992; Nedwell et al. 2006; Ruggerone et al. 2008) and would continue to occur within an area where underwater noise was well above background levels. Feist (1991) and Feist et al. (1992) investigated the effects of impact pile driving on the behavior of juvenile pink and chum salmon. Observers were placed at various locations and distances from the noise source. A hydrophone was placed at a specific distance from the noise source in an attempt to correlate fish behavior with levels of underwater sound. Feist et al. (1992) concluded that pile driving has an impact on the distributions and behavior of juvenile chum and pink salmon, although the findings suggest no change in overall fish abundance due to elevated underwater sound. Observations included startle responses and changes in general behavior and school size. However, pile driving did not appear to affect foraging of either species. Unfortunately, correlating behavioral effects of these salmonids relative to a specific underwater sound was not possible due in part to the study design where observers could not see fish in deeper environments, and due to methodological and logistics problems.

Ruggerone et al. (2008) investigated the behavioral response of juvenile coho salmon placed in cages at various distances from piles being driven with an impact hammer. Results indicated that coho salmon did not consistently exhibit a startle response during the first or subsequent hammer strikes of each pile. A brief startle response was observed during 4 of 14 first-strikes (29 percent of piles), and during 1 of 14 second-strikes (7 percent). Gut content analysis indicated that both test and control fish readily consumed food. Similarly, based on an investigation of behavioral responses of brown trout (a surrogate for other salmonids), Nedwell et al. (2006) found that fish placed in cages at distances as close as 98 and 177 feet (30 and 54 meters) from a vibratory pile driver driving 36-inch and 20-inch (0.9-meter and 0.5-meter) piles showed very little to no behavioral response, including a startle response, to the underwater sound generated from the activity. However, the study acknowledged that brown trout lack the hearing sensitivity of other salmonids. Further, some acoustic experts have shown hesitancy to include fish behavioral findings from caged fish studies into the development of criteria.

In a critical review of studies investigating the effects of underwater sound on fish, Popper and Hastings (2009) concluded that "very little is known about effects of pile driving and other anthropogenic sounds on fishes, and that it is not yet possible to extrapolate from one experiment to other signal parameters of the same sound, to other types of sounds, to other effects, or to other species." Since sufficient investigations with similar methodologies regarding the behavioral response of fish to anthropogenic noise sources are limited, threshold criteria for this effect have not been developed. As a result, the current approach for estimating the distances from an underwater noise source at which a fish will display a behavioral response are the guideline criteria of 150 dB RMS described by Hastings (2002).

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