Appendix C

Species Descriptions and Life Histories

TABLE OF CONTENTS

List of Tables

1. Chinook Salmon

Five evolutionarily significant units (ESUs) of Chinook salmon (*Oncorhynchus tshawytscha*) are addressed in this biological assessment (BA): Lower Columbia River (LCR), Upper Columbia River (UCR) spring-run, Snake River (SR) fall-run, SR spring/summer-run, and Upper Willamette River (UWR).

1.1 General Chinook Life History

Chinook are the largest of the Pacific salmon species, and are found in the larger river systems and some smaller coastal river drainages from the Ventura River in California to Point Hope, Alaska (Healey 1991). Chinook alevins emerge from redds in spring and exhibit either “ocean-type” (migrating to the ocean primarily within the first year) or “stream-type” (residing in freshwater for a year or more before migrating to the ocean) life history strategies. Migration distance, stream flows and temperatures, and the productivity of streams and estuaries appear to be the strongest environmental factors affecting specific emigration timing (Myers et al. 1998).

Ocean-type Chinook exhibit varied and complex life histories, migrating to the ocean as fry, subyearling, or yearling juveniles. Their migrations follow distinct, coastally oriented patterns (Good et al. 2005). The timing of each population’s return to freshwater and spawning habitat is in part dictated by the ecological characteristics of spawning habitat. Ocean-type juveniles generally rear in estuaries and enter saltwater during their first year, usually in the late summer and fall. There is a close association between rivers with extensive estuary systems and the abundance of ocean-type Chinook juveniles found in the system (Fraser et al. 1982). Estuaries or near-shore environments are important in systems containing smaller streams, unproductive rearing areas, or barriers resulting from flow and/or thermal effects. Estuaries play an important role during rearing life stages, as brackish water in these estuaries likely moderates physiological stresses experienced by juveniles during the smolting process (Myers et al. 1998).

Stream-type life histories are most commonly associated with early runs of adult fish. It has been generally accepted that stream-type Chinook juveniles were the progeny of spring-run Chinook, while ocean-type juveniles were the progeny of summer/fall-run Chinook. Recent smolt trapping and scale sampling data, however, indicate that stream-type and ocean-type juveniles can come from any of the Chinook races (spring-, summer-, or fall-runs) (Sneva pers. comm. 2010).

Chinook spend between 2 and 6 years in the ocean before returning to their natal streams. Harvest data from mid-ocean fisheries indicate different migratory distributions for ocean- and stream-type Chinook (Healey 1991): ocean-type Chinook tend to migrate along or near the coast, while stream-type Chinook are found far from the coast in the central North Pacific (Myers et al. 1998). Ocean migration patterns represent an important form of resource partitioning and are significant to the evolutionary success of the species.

After emergence, fry generally search for suitable rearing habitat within side sloughs, side channels, spring-fed seep areas, and areas along the outer edges of the stream. These quiet-water side margin and off-channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs, and provide protection from predators during early freshwater residence.

1.1.1 Run Timing and Spawning

Chinook runs are designated on the basis of adult migration timing. Early spring-run Chinook enter freshwater as immature (“bright”) fish, migrate far upstream, and spawn in the late summer and early fall (Myers et al. 1998). Fall-run Chinook enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas, and spawn within a few days or weeks (Meehan 1991). Summer-run fish exhibit intermediate characteristics of fall- and spring-run Chinook.

Fall-run Chinook typically enter freshwater in August through October to spawn in large river mainstems and juveniles emigrate from freshwater as subyearlings (ocean-type). Spring-run Chinook enter freshwater in March through June to spawn in upstream tributaries, and generally emigrate from freshwater as yearlings (stream-type).

Run timing for Chinook spawners varies by race, but spawning usually occurs when water temperatures reach 42°F to 57°F, usually in mainstem rivers and larger streams where suitable substrate is present. Suitable spawning habitat includes clean, cobble-sized substrate (up to 4 inches in diameter), hyporheic flow, and adequate levels of dissolved oxygen. Because of their large body size relative to other salmonids, Chinook tend to use deeper water and larger gravel size than other salmon. The female digs a redd in areas with moderate to high velocities (0.30 to 1.09 meters per second [m/s]) in water approximately one foot deep (Reiser and Bjornn 1979). Average fecundity is about 5,000 eggs (ranges from 2,250 to 7,750) (Myers et al. 1998). Chinook are semelparous and die after spawning.

Incubation depends on water temperature, and ranges between 90 to 150 days. Recommended incubation temperatures range between 41°F and 58°F (Reiser and Bjornn 1979). Fry emerge in March and April. Ocean-type Chinook migrate to sea relatively quickly after emergence from the gravel, while stream-type Chinook rear in freshwater for a year or more. However, both types require certain habitat characteristics while rearing in freshwater, seeking out pools for cover, large substrate, large woody debris, and undercut banks. They prefer to remain in the mainstem of rivers and streams; off-channel ponds are not typically used for (stream-type) overwintering (Everest and Chapman 1972).

1.1.2 Factors for Decline

Because Chinook occur in larger rivers and streams, habitat loss and impacts to the species at all life stages have been particularly pronounced, perhaps affecting Chinook more than any other salmon species. As with other salmonids, hatchery practices have contributed to the decline of wild Chinook by increasing juvenile competition and diluting the genetic composition of native Chinook populations (Meehan 1991).

1.2 Lower Columbia River Chinook

The LCR Chinook ESU was listed as threatened by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA) in 1999 (64 Federal Register [FR] 14308) and reaffirmed on June 28, 2005 (70 FR 37160).

1.2.1 Distribution and Condition

This ESU includes all naturally spawned populations of Chinook from the Columbia River and its tributaries between the river’s mouth at the Pacific Ocean upstream to a transitional point between Washington and Oregon east of the Hood River and the White Salmon River (70 FR 37160). This ESU also includes the Willamette River up to Willamette Falls, Oregon, with the exception of spring-run Chinook in the Clackamas River. There are 17 artificial propagation programs for Chinook in this ESU.

The LCR ESU is composed of six major Chinook population groups, according to the Willamette-Lower Columbia Technical Recovery Team (WLCTRT) (2003), and 32 historical populations. The populations are distributed through three ecological zones. The combination of life history types based on run timing and ecological zones results in six major population groups (referred to as strata by the WLCTRT). There are 23 (tule) fall- and (bright) late fall-run populations, and nine spring-run populations, some of which existed historically but are now extirpated or nearly so. Also included in the ESU are 17 hatchery programs. Excluded from the ESU are Carson spring-run Chinook and introduced bright fall-run Chinook occurring in the Wind and (Big) White Salmon Rivers; as well as spring-run Chinook released at terminal fishery areas in Youngs Bay, Blind Slough, and Deep River; and in the mainstem Columbia. Populations of spring-run Chinook in the Willamette River (and the Clackamas River) are part of the Upper Willamette River (UWR) ESU.

Myers et al. (2002) hypothesized that this ESU historically consisted of 20 fall-run populations (tules), 2 late fall-run populations (brights), and 9 spring-run populations, for a total of 31 populations (Good et al. 2005).

1.2.2 Life History

LCR Chinook are comprised of three races, each with distinct life histories: fall-run (tules), late fall-run (brights), and spring-run (Good et al. 2005). Fall-run Chinook historically were found throughout the range of the ESU, while spring-run Chinook historically were only found in the upper portions of basins with snowmelt-driven flow regimes (western Cascade Crest and Columbia Gorge tributaries). Late fall-run Chinook were identified in only two basins in the western Cascade Crest tributaries. In general, late fall-run Chinook also matured at an older average age than either LCR spring- or fall-run Chinook, and had a more northerly oceanic distribution (NMFS 2008a).

Chinook in the lower Columbia River generally follow an ocean-type life history cycle. Late, fall-run (ocean-maturing) Chinook enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas in the mainstem Columbia and lower reaches of tributaries, and spawn within a few days or weeks of freshwater entry. Fall-run Chinook are the most abundant run in this ESU and are dominated by hatchery production. For the years 2003 to 2008, hatchery returns below Bonneville Dam ranged from 32,000 to 155,000; Bonneville Pool returns (to facilities upstream of Bonneville to the eastern boundary of the ESU) ranged from 14,600 to 180,600. In contrast, natural origin fall-run Chinook returns ranged from 4,200 to 26,000.

Adults enter freshwater between August and December. Peak spawning occurs from late September to November. Depending on water temperatures, egg incubation lasts through the fall and winter months, and emergence occurs in April. Downstream migration begins 1 to 4 months after emergence, and occurs from March to October. Rearing juveniles are likely to be present in the lower Columbia River year-round. Fish in this ESU primarily have an ocean-type life history (Good et al. 2005). The Columbia River estuary is a particularly important area for this ESU, as both juveniles and adults make the critical physiological transition here between life in freshwater and marine habitats (ISAB 2000; Marriott et al. 2002).

1.2.3 Factors for Decline

LCR Chinook abundance began to decline by the early 1900s due to habitat degradation and harvest pressure. Habitat degradation and loss due to extensive hydropower development projects in both mainstem and tributary systems, urbanization, logging, and agriculture have reduced the abundance and quality of Chinook spawning and rearing habitat in the lower Columbia River. In addition, very few naturally self-sustaining populations of native Chinook remain in the LCR ESU. The presence of hatchery Chinook in this ESU presents an important threat to the persistence of the ESU and obscures trends in abundance of native fish (Good et al. 2005). Predation by birds, fish, marine mammals, and humans takes a significant number of juveniles and adults, particularly from spring-run populations. Fishery management, harvest regimes, and climate-related changes in marine survival are also factors contributing to decline (NMFS 2008a).

The fall runs in this ESU are currently dominated by large-scale hatchery production, and experience relatively high harvest and extensive habitat degradation. Large Chinook runs continue to return to many of their natal streams, but there are few sustained native, naturally reproducing populations. The Lewis River late fall run is the healthiest in the ESU and has a reasonable probability of being self-sustaining. The spring-run populations have been significantly impacted by the loss of access to high-elevation spawning habitat associated with dams and are largely extirpated. Trend indicators for most populations are negative, especially if hatchery fish are assumed to have a reproductive success equivalent to that of natural-origin fish (NMFS 2005a).

Abundance of historical spawners is estimated at 284,000 fish; recent estimates of natural spawners and hatchery adults are approximately 16,300 and 49,600 fish, respectively (NMFS 2008a).

1.3 Upper Columbia River Spring-Run Chinook

UCR spring-run Chinook were listed as endangered by NMFS in 1999 (64 FR 14308); endangered status was reaffirmed on June 28, 2005 (70 FR 37160).

1.3.1 Distribution and Condition

The ESU includes all naturally spawned populations of Chinook in all river reaches accessible to Chinook in Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington, excluding the Okanogan River. There are no estimates of historical abundance for this ESU prior to the dam's construction (Good et al. 2005). Chief Joseph Dam, upstream of Rock Island Dam, is a complete passage barrier to anadromous fish and limits further upstream distribution of this ESU.

Three extant, demographically independent populations of naturally spawning spring-run Chinook are identified for this ESU: the Wenatchee, Entiat, and Methow River basin populations (NMFS 2005a). The Interior Columbia Basin Technical Recovery Team (ICBTRT 2003, 2005) placed these populations into a single major population grouping based on life history type and ecological spawning zone.

The Columbia River rearing and migration corridor consists of the Columbia River and its tributaries from Rock Island Dam (near the downstream border of the Entiat River) downstream to the Pacific Ocean (NMFS 2005a).

1.3.2 Life History

Spring-run Chinook in this ESU have a stream-type life history, which means that juveniles enter marine waters during their second year and return to freshwater as subadults, maturing during their upriver spawning run. Three independent populations of spring-run Chinook are identified for the ESU: those that spawn in the Wenatchee, Entiat, and Methow River basins.

Adults returning to the Wenatchee River enter freshwater from late March through early May, while those returning to the Entiat and Methow Rivers enter freshwater from late March through June. Their arrival times tend to be earlier in low flow years and later in high flow years. In general, Chinook populations with early run times (e.g., spring and summer) use high spring flows to access headwater or interior regions (Good et al. 2005). On their way upriver, the fish hold in deeper pools or under cover until the onset of spawning. They may spawn in the areas where they hold, or move further up into smaller tributaries. Peak spawning for all three populations occurs from August to September, although the timing is highly dependent upon water temperature. The egg incubation/alevin stage goes from August into December, and emergence extends from that point into March. The juveniles typically spend 1 year in freshwater before migrating downstream—primarily in May and June. Most adults return after spending 2 years in the ocean, although 20 to 40 percent return after 3 years at sea.

The complex life cycle of Chinook in this ESU is closely associated with complex habitat needs, particularly during the freshwater phase (Spence et al. 1996). Spawning gravels must be a certain size and free of sediment to allow successful incubation of the eggs. Eggs also require cool, clean, and well-oxygenated waters for proper development. Juveniles need abundant food sources, including insects, crustaceans, and other small fish. They need places to hide from predators (mostly birds and bigger fish), such as under logs, root wads, and boulders in the stream, as well as beneath overhanging vegetation. They also need places to seek refuge from periodic high flows (side channels and off-channel areas) and from warm summer water temperatures (coldwater springs and deep pools). Returning adults generally do not feed in freshwater but instead rely on limited energy stores to migrate, mature, and spawn. Like juveniles, they also require cool water and places to rest and hide from predators. During all life stages, salmon require cool water that is free of contaminants. They also need migratory corridors with adequate passage conditions (timing, water quality, and water quantity) to allow access to the various habitats required to complete their life cycle.

1.3.3 Factors for Decline

In general, tributary habitat problems affecting this ESU include increasing urbanization on the lower reaches, irrigation and flow diversions in upriver sections of the major drainage, and impacts of grazing on middle reaches (Good et al. 2005). Chinook in this ESU are also subject to passage mortalities associated with mainstem hydroelectric projects. Production from all upper Columbia River tributary drainages passes through the four lower Columbia River federal dam projects and a varying number of mid-Columbia River Public Utility District dam projects. The Wenatchee River enters the Columbia River above seven mainstem dams, the Entiat above eight dams, and the Methow and Okanogan Rivers above nine dams.

This ESU has exhibited low abundance and a strong downward trend in annual returns; returns in 1994 to 1996 were the lowest in at least 60 years (NMFS 2005a). Myers et al. (1998) reported long-term trends in abundance for UCR spring-run Chinook were generally negative, ranging from -5 to +1 percent. Analyses of the data series, updated to include 1996–2001 returns, indicate that those trends have continued. Since 1958, Wenatchee River spawning escapements have declined at an average rate of 5.6 percent per year, the Entiat River population at an average of 4.8 percent per year, and the Methow River population at an average of 6.3 percent per year (Good et al. 2005).

1.4 Snake River Fall-Run Chinook

SR fall-run Chinook salmon were listed as endangered by NMFS in 1992 (57 FR 57051); threatened status was reaffirmed on June 28, 2005 (70 FR 37160).

1.4.1 Distribution and Condition

The SR fall-run Chinook ESU is composed of one extant population in one major population group that spawns and rears in the mainstem Snake River and its tributaries below Hells Canyon Dam. Two historical populations were extirpated by the construction of Swan Falls Dam in 1901 and the Hells Canyon Complex from 1958 to 1967 (NMFS 2008a).

This ESU includes all naturally spawned populations of fall-run Chinook in the mainstem Snake River below Hells Canyon Dam, and in the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River subbasins. Four artificial propagation programs are considered to be part of the ESU: The Lyons Ferry Hatchery, Fall-Run Chinook Acclimation Ponds Program, Nez Perce Tribal Hatchery, and Oxbow Hatchery Fall-Run Chinook hatchery programs (70 FR 37160).

Coded-wire tag studies using Lyons Ferry Hatchery Chinook of Snake River origin indicate that SR fall-run Chinook have a broad distribution. The timing of the return and upriver spawning migration of SR fall-run Chinook overlaps the Hanford Reach upriver bright Chinook returns, as well as several large hatchery runs returning to lower river release areas or to the major hatcheries adjacent to the lower mainstem Columbia River (Good et al. 2005).

1.4.2 Life History

SR fall-run Chinook enter the Columbia River in July and August. The Snake River component of the Chinook fall run migrates past the lower Snake River mainstem dams from August through November. Spawning occurs from October through early December, and alevins emerge from the gravels in March and April of the following year. Chinook in this ESU generally exhibit an ocean-type life history, with juveniles migrating downstream from their natal spawning and rearing areas from June through early fall (Good et al. 2005). Individuals in this ESU have also demonstrated a yearling life history (Connor et al. 2005). Natural spawning is currently limited to the area from the upper end of Lower Granite Reservoir to Hells Canyon Dam, the lower reaches of the Imnaha, Grande Ronde, Clearwater, and Tucannon Rivers, and small mainstem sections in the tailraces of the lower Snake River hydroelectric dams.

1.4.3 Factors for Decline

Fall-run Chinook returns to the Snake River generally declined through the first half of the 20th century (Irving and Bjornn 1981). The construction of a series of dams on the Snake River significantly reduced spawning and rearing habitat for this ESU. Historically, the primary fall-run Chinook spawning areas were located on the upper mainstem Snake River. This ESU is currently limited in distribution to 10 to 15 percent of its historical range (NMFS 2008a).

This ESU experienced a steady and severe decline in abundance beginning in the early 1970s, due to a combination of loss of primary spawning and rearing areas upstream of the Hells Canyon Dam complex, an increase in nonlocal hatchery contribution to adult escapement over Lower Granite Dam, and relatively high aggregate harvest impacts by ocean and in-river fisheries (Waples et al. 1991; Myers et al. 1998). However, Lower Granite Dam counts increased in the mid-1990s (NMFS 1999) and the upward trend in returns has continued (Good et al. 2005).

1.5 Snake River Spring/Summer-Run Chinook

SR spring/summer-run Chinook were listed as endangered by NMFS on April 22, 1992 (57 FR 57051); threatened status was reaffirmed on June 28, 2005 (70 FR 37160).

1.5.1 Distribution and Condition

The SR spring/summer-run Chinook ESU consists of five major population groups that spawn and rear in the tributaries of the Snake River between the confluence of the Snake and Columbia Rivers and the Hells Canyon Dam. The five major population groups are further composed of 28 extant populations (NMFS 2008a).

The SR spring/summer-run Chinook ESU includes runs in the Tucannon River, the Grande Ronde River system, the Imnaha River, and the Salmon River (Matthews and Waples 1991). The Salmon River system contains a range of habitats used by spring/summer-run Chinook. The South Fork and Middle Fork Salmon Rivers currently support the bulk of natural production in the drainage. Two large tributaries entering above the confluence of the Middle Fork Salmon River—the Lemhi and Pahsimeroi Rivers—drain broad alluvial valleys and are believed to have historically supported substantial, relatively productive anadromous fish runs.

Sunbeam Dam, on the mainstem Salmon River downstream of Stanley, Idaho, was a serious impediment to migration of anadromous fish and may have been a complete block in at least some years before its partial removal in 1934 (Waples et al. 1991, as cited in Good et al. 2005). Returns into the upper Salmon River tributaries were re-established following the opening of passage around the dam.

1.5.2 Life History

This ESU includes spring- and summer-timed returns, and combinations from the two adult timing patterns. Runs classified as spring-run Chinook are counted at Bonneville Dam beginning in early March and ending the first week of June; runs classified as summer-run Chinook return to the Columbia River from June through August (Good et al. 2005).

Spring/summer-run Chinook from the Snake River basin exhibit stream-type life history characteristics (Healey 1983). Eggs are deposited in late summer and early fall, incubate over the following winter, and hatch in late winter and early spring of the following year. Juveniles rear through the summer, overwinter, and migrate to sea in the spring of their second year of life. Depending on the tributary and the specific habitat conditions, juveniles may migrate extensively from natal reaches into alternative summer-rearing or overwintering areas (Good et al. 2005). SR spring/summer-run Chinook return from the ocean to spawn primarily as 4-and 5-year-old fish, after 2 to 3 years in the ocean. A small fraction of the fish return as 3-year-old “jacks,” heavily predominated by males.

Returning fish hold in deep mainstem and tributary pools until late summer, when they migrate into tributary areas to spawn. In general, spring-run type Chinook tend to spawn in higher-elevation reaches of major Snake River tributaries from mid- through late August; summer-run fish spawn approximately 1 month later than spring-run fish. Summer-run Chinook tend to spawn lower in the Snake River drainages, although their spawning areas often overlap with spring-run spawners (Good et al. 2005).

Habitat utilized by Chinook in this ESU is characterized by two major features: extensive meanders through high-elevation meadowlands, and relatively steep lower sections joining the drainages to the mainstem Salmon River (Matthews and Waples 1991, as cited in Good et al. 2005). Productivity of juveniles in this ESU is influenced by the combination of relatively high summer temperatures and the upland meadow habitat. Historically, the Salmon River system may have supported more than 40 percent of the total return of spring/summer-run Chinook to the Columbia River system (e.g., Fulton 1968, as cited in Good et al. 2005).

1.5.3 Factors for Decline

Limiting factors for the SR spring/summer-run Chinook include federal and private hydropower projects (e.g., their influences on altered flow regimes), predation, harvest, and declines in the quality of estuarine and tributary habitats. Ocean conditions have also affected the status of this ESU. In general, hatchery management has not been identified as a limiting factor for the overall ESU; however, risks to long-term viability associated with the use of outside hatchery stocks have been identified for certain areas, particularly for major sections of the Grande Ronde River basin (Good et al. 2005). Both short- and long-term abundance trends for this ESU have been downward (Myers et al. 1998).

Tributary habitat conditions vary widely among the various drainages of the Snake River basin. Habitat is degraded in many areas of the basin, reflecting the impacts of forestry, grazing, and mining practices. Impacts relative to anadromous fish include lack of pools, higher water temperatures, low water flows, poor overwintering conditions, and high sediment loads. However, habitat in some portions of this ESU’s distribution, for example, the Middle Fork Salmon River drainage, is protected in wilderness areas (Good et al. 2005).

1.6 Upper Willamette River Chinook

UWR Chinook salmon were listed under the ESA as threatened on March 24, 1999 (64 FR 14308). The listing was reaffirmed on June 28, 2005 (70 FR 37160).

1.6.1 Distribution and Condition

The UWR Chinook ESU includes all naturally spawned populations of spring-run Chinook residing in the Clackamas River and in the upper Willamette River above Willamette Falls, but below impassable natural barriers, as well as seven artificial propagation programs. There is only one major population group in this ESU, comprised of seven historical demographically independent populations. Fall-run Chinook above Willamette Falls were introduced and are not considered part of this ESU (Myers et al. 1998). Significant natural production occurs only in the Clackamas and McKenzie Rivers (NMFS 2008a).

1.6.2 Life History

Adult spring-run Chinook enter the Columbia River in March and April, but do not ascend the Willamette Falls until May or June (Myers et al. 1998). Timing of adult migration is limited by the Willamette Falls (RKm 44/RM 27). High flows in the winter and spring allow access over the falls, while low flows during the summer and autumn months prevent later-migrating fish from ascending the falls (NOAA Fisheries 2003).

Juveniles exhibit a diverse migratory life history in the lower Willamette River, with separate spring and fall emigration periods. Spring juvenile emigrants move through the action area from February through April (ODFW 2007; Teel et al. 2009). Fall juvenile emigrants move into the lower Willamette mainstem in summer, rear through summer in the lower Willamette River, Columbia Slough, or lower reaches of other Willamette tributaries; and then emigrate in the fall, winter, or spring (ODFW 2007).

The Upper Willamette River basin historically supported large numbers of spring-run Chinook (perhaps exceeding 275,000 fish). Current abundance of natural-origin fish is estimated to be less than 10,000, with significant natural production occurring only in two populations: the Clackamas and McKenzie Rivers.

1.6.3 Factors for Decline

Habitat degradation has been pervasive in the Willamette River and in the lower reaches of its tributaries. Declines in spring-run Chinook in this ESU have been attributed to the extensive habitat blockages (particularly to spawning habitat) caused by dam construction in the upper Willamette River and its tributaries (Good et al. 2005). Habitat loss due to blockages has been especially severe in the North Santiam, Calapooia, and Middle Fork Willamette subbasins (NMFS 2008a).

Hatchery influence is also a significant factor for this ESU. While counts of hatchery- and natural-origin adult spring-run Chinook over Willamette Falls since 1946 have increased, approximately 90 percent of the return is now composed of hatchery fish. The majority of the natural-origin populations in this ESU have very low current abundances (less than a few hundred fish).

Most natural-origin spring-run Chinook populations in this ESU are probably extirpated or nearly so. The only population considered potentially self-sustaining is the McKenzie River population. However, its abundance has been relatively low, with a substantial number of these fish being of hatchery origin (Good et al. 2005).

2. Steelhead

Five distinct population segments (DPSs) of steelhead (*Oncorhynchus mykiss*) are addressed in this BA: LCR, Middle Columbia River (MCR), UCR, SR, and UWR.

2.1 General Steelhead Life History

The present distribution of steelhead extends from the Kamchatka Peninsula in Asia, east to Alaska, and south to southern California (NMFS 1999, as cited in Good et al. 2005), although their historical range extended at least to the Mexico border (Busby et al. 1996). Steelhead exhibit highly complex life history strategies—more so than other species of Pacific salmonid. Steelhead exhibit both anadromous and freshwater resident life histories, and may produce offspring that take on the opposite life history strategy than their parents. The anadromous form may spend up to 7 years in freshwater before entering the smolt life stage, and then may spend up to 3 years in saltwater prior to first spawning (Good et al. 2005). Steelhead can spawn more than once (iteroparous), whereas almost all other salmonids spawn only once before dying (semelparous).

Non-anadromous (i.e., resident) forms are typically referred to as rainbow trout, or in inland portions of the Columbia River basin, as Columbia River redband trout. Although the anadromous and resident forms are considered to be the same species, the exact relationship between the two forms is not well understood, and little data are available on the interactions between the two forms (Kostow 2003, as cited in Good et al. 2005). In coastal populations, it is unusual for the two forms to co-occur, in part because they are usually separated by a natural or man-made migration barrier (e.g., dam, waterfall). Co-occurrence of anadromous and resident steelhead seems to be more common in inland populations (Good et al. 2005).

Steelhead are divided into two basic reproductive ecotypes, based on the state of sexual maturity at the time of river entry and duration of spawning migration (Burgner et al. 1992, as cited in Good et al. 2005): stream-type and ocean-type. The stream-maturing type (summer-run) enters freshwater in a sexually immature condition between May and October and requires several months to mature and spawn. The ocean-maturing type (winter-run) steelhead enters freshwater between November and April and spawns shortly thereafter.

Some rivers have both summer and winter steelhead, while others have only one race. In basins with summer and winter steelhead runs (including the Columbia River), the summer run appears to occur where habitat is not fully used by the winter run or where a seasonal hydrologic barrier, such as a waterfall, separates them. Summer-run steelhead usually spawn farther upstream than winter-run steelhead (Withler 1966, Roelofs 1983, and Behnke 1992, as cited in Good et al. 2005). Coastal streams contain primarily winter-run steelhead, whereas inland habitat in the Columbia River basin contains almost entirely summer-run steelhead.

Steelhead inhabiting upper portions of the Columbia River basin, particularly the Snake River subbasin, are referred to as either A-run or B-run fish. A and B runs are based on a bimodal migration of adult steelhead at Bonneville Dam (RKm 234), as well as on differences in age (1 or 2 years of age) and adult size of Snake River steelhead. A-run steelhead are believed to occur throughout the Snake River basin and the inland Columbia River, while B-run steelhead are thought to occur only in the Clearwater, Middle Fork Salmon, and South Fork Salmon Rivers. Despite these designations, however, the relationship between patterns observed at the dams and the distribution of adults in spawning areas throughout the Snake River basin is not well understood, and it is unclear whether life history and body-size differences observed as far upstream as the Snake River are well correlated with the groups of steelhead forming the bimodal migration observed at Bonneville Dam (Good et al. 2005).

2.1.1 Run Timing and Spawning

Spawning migrations of steelhead on the west coast occur throughout the year, with seasonal peaks of activity. In a given river basin there may be one or more peaks in migration activity, with fish designated as winter-, spring-, summer-, or fall-run steelhead. Large rivers, such as the Columbia River, contain migrating adult steelhead at all times of the year (Good et al. 2005). Steelhead exhibit a great deal of variability in smolt age and ocean age (NMFS 2005a).

Steelhead spawn in clear, cool, well-oxygenated streams with suitable gravel substrate and water velocity. Adult fish waiting to spawn or in the process of spawning are vulnerable to disturbance and predation in areas without suitable cover. Cover types include overhanging vegetation, undercut banks, submerged vegetation, submerged objects such as logs and rocks, deep water, and turbulence. Spawning occurs earlier in areas of lower elevation and areas of warmer water temperature than in areas of higher elevation and cooler water temperature. Summer steelhead enter freshwater between May and October. During summer and fall before spawning, they hold in cool, deep pools. They migrate inland toward spawning areas, overwinter in the larger rivers, resume migration to natal streams in early spring, and then spawn. Winter steelhead enter freshwater between November and April in the Pacific Northwest, migrate to spawning areas, and then spawn in late winter or spring. Precise spawn timing is related to stream temperature. Repeat spawning is not common among inland steelhead—i.e., those migrating several hundred miles or more upstream from the ocean (NMFS 2005a).

Steelhead eggs hatch in 35–50 days, depending on water temperature. Following hatching, young remain in the gravel for 2 to 3 weeks until the yolk-sac is absorbed. Steelhead spawn when temperatures are typically cold, but increasing. Their spawning time must optimize avoidance of competing risks from gravel-bed scour during high flow and increasing water temperatures that can become lethal to eggs as the warm season arrives (NMFS 2005a).

Fry emergence is typically determined by the time of egg deposition and the water temperature during the incubation period. In the lower Columbia River, emergence timing differs slightly between steelhead races and among subbasins. The different emergence times between races may be a function of spawning location within the watershed (and hence water temperature) or a result of genetic differences. Generally, emergence occurs from March into July, with peak emergence generally in April and May.

Summer rearing takes place primarily in the faster parts of pools, although young-of-the-year are abundant in glides and riffles. Winter rearing occurs more uniformly at lower densities across a wide range of fast and slow habitat types. Some older juveniles move downstream to rear in larger tributaries and mainstem rivers. As they grow, they inhabit areas with deeper water, a wider range of velocities, and larger substrate (NMFS 2005a). Productive steelhead habitat is characterized by complexity—primarily in the form of large and small wood.

2.1.2 Factors for Decline

All five DPSs discussed below have been listed as threatened or endangered. Factors affecting the decline of these populations include habitat degradation (including tributary hydropower development), hatchery effects, fishery management and harvest decisions, and ecological factors, including predation. Tributary habitat has been degraded by extensive development and other effects of changing land use.

2.2 Lower Columbia River Steelhead

2.2.1 Distribution and Condition

The LCR steelhead DPS includes all naturally spawned populations of steelhead in streams and tributaries to the Columbia River between the Cowlitz and Wind Rivers, Washington (inclusive), and the Willamette and Hood Rivers, Oregon (inclusive). Excluded are steelhead in the upper Willamette River Basin above Willamette Falls and steelhead from the Little and Big White Salmon Rivers in Washington. This DPS was listed as threatened on March 19, 1998 (63 FR 13347); threatened status was reaffirmed on January 5, 2006 (71 FR 834).

2.2.2 Life History

This DPS includes both summer- and winter-run steelhead, as well as two ecological spawning zones (Cascade and Columbia Gorge), resulting in a total of four strata for this DPS: Cascade summer- and winter-run populations, and Columbia Gorge summer- and winter-run populations (McElhany et al. 2002). Migrating adult steelhead can occur in the Columbia River year-round.

Summer steelhead return to freshwater from May to October in a sexually immature condition, and require several months in freshwater to reach sexual maturity and spawn. Winter-run steelhead enter freshwater from November to April as sexually mature individuals that spawn shortly thereafter (NMFS 2005a).

The dominant age class of outmigrating steelhead smolts in the lower Columbia River is age 2. In the lower Columbia River, outmigration of steelhead smolts generally occurs from March to June, with peak migration usually in April or May (NMFS 2005a).

2.2.3 Factors for Decline

Factors affecting the decline of this DPS include habitat degradation (including mainstem and tributary hydropower development), hatchery effects, fishery management and harvest decisions, and ecological factors such as predation. Tributary habitat has been degraded by extensive development and other effects of changing land use. This has adversely affected stream temperatures and reduced the habitat diversity needed for steelhead spawning, incubation, and rearing. Steelhead access to tributary headwaters has been restricted or blocked by dams built without passage facilities or facilities that were inadequate and have caused injury and delay.

2.3 Middle Columbia River Steelhead

The MCR steelhead DPS was listed as threatened species on March 25, 1999 (64 FR 14517); threatened status was reaffirmed on January 5, 2006 (71 FR 834).

2.3.1 Distribution and Condition

The DPS includes all naturally spawned populations of steelhead in streams from above the Wind River, Washington, and the Hood River, Oregon (exclusive); upstream to and including the Yakima River, Washington; excluding steelhead from the Snake River basin.

2.3.2 Life History

Steelhead in this DPS are predominantly summer-run steelhead, but winter-run fish are found in the Klickitat River, Washington, and Fifteenmile Creek, Oregon. Most fish in this DPS smolt at 2 years and spend 1 to 2 years in saltwater before re-entering freshwater, where they may remain for up to a year before spawning. Juvenile life stages (i.e., eggs, alevins, fry, and parr) inhabit freshwater/riverine areas throughout the range of the DPS. Parr usually undergo a smolt transformation as 2-year-olds, at which time they migrate to the ocean. Subadults and adults forage in coastal and offshore waters of the North Pacific Ocean before returning to spawn in their natal streams. Redband trout (as discussed above, resident *O. mykiss*) co-occur with the anadromous form in this ESU, and juvenile life stages of the two forms can be very difficult to differentiate. In addition, hatchery steelhead are also distributed within the range of this DPS (NMFS 2005a).

2.3.3 Factors for Decline

Factors in the decline of this DPS include mainstem hydropower projects, tributary habitat and hydropower, water storage projects, predation, hatchery effects, harvest, and degraded estuarine habitat. Passage barriers have prevented access to sizable historical production areas in the Deschutes (by Pelton Dam) and White Salmon Rivers (by Conduit Dam) (NMFS 2005a, NMFS 2008a). Substantial populations of resident trout exist in both areas.

2.4 Upper Columbia River Steelhead

2.4.1 Distribution and Condition

The UCR steelhead DPS includes all naturally spawned populations of steelhead in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the U.S.-Canada border. This DPS was listed as endangered on August 18, 1997 (62 FR 43937); status was upgraded to threatened on January 5, 2006 (71 FR 834); status was reinstated to endangered per a U.S. District Court decision in June 2007, and was then upgraded to threatened per U.S. District Court order in June 2009 (74 FR 42605).

2.4.2 Life History

The UCR steelhead DPS consists entirely of summer-run steelhead. Adults enter freshwater between May and October. During summer and fall before spawning, they hold in cool, deep pools. They migrate inland toward spawning areas, overwinter in the larger rivers, resume migration to natal streams in early spring, and then spawn. Spawning occurs in the late spring of the calendar year following entry into the river (Good et al. 2005). In general, adults in this DPS spawn later than in most downstream populations, often remaining in freshwater for a year before spawning (NMFS 2005a).

The dry habitat conditions in the upper Columbia River are less conducive to steelhead survival than in many other parts of the Columbia River basin. Although the life history of this DPS is similar to that of other inland steelhead, smolt ages are some of the oldest on the West Coast (up to 7 years old), probably due to the area's cold water temperatures (Good et al. 2005; NMFS 2005a). The cold stream temperatures may also mean that many fish in this DPS are thermally fated to a resident (rainbow trout) life history, whether they are the progeny of resident or anadromous parents. Most current natural production occurs in the Wenatchee and Methow River systems, with a smaller run returning to the Entiat River. Very limited spawning also occurs in the Okanagan River basin. Most of the fish spawning in natural production areas are of hatchery origin. The limited data available indicate that smolt age in this DPS is dominated by 2-year-olds (NMFS 2005a).

2.4.3 Factors for Decline

Factors in the decline of this DPS include hydropower projects, physical passage barriers (e.g., mortality at hydroelectric projects in the mainstem Columbia River, water withdrawals, and unscreened diversions), excess sediment in spawning gravels, loss of off-channel habitat and deep pools due to sedimentation, predation, harvest, hatchery effects, degraded tributary habitat, and degraded estuary habitat (NMFS 2008a).

2.5 Snake River Steelhead

2.5.1 Distribution and Condition

The SR steelhead DPS includes all naturally spawned populations of steelhead in streams in the Snake River basin of southeast Washington, northeast Oregon, and Idaho. This DPS includes all anadromous populations that spawn and rear in the mainstem Snake River and its tributaries between Ice Harbor and the Hells Canyon hydro complex. There are five major population groups, with 24 populations. Inland steelhead in the Columbia River basin are commonly referred to as either A-run or B-run, based on migration timing and differences in age and size at return. A-run steelhead are believed to occur throughout the steelhead streams in the Snake River basin, while B-run are thought to reproduce only in the Clearwater and Salmon Rivers (NMFS 2008a).

The SR steelhead DPS was listed as threatened on August 18, 1997 (62 FR 43937); threatened status was reaffirmed on January 5, 2006 (71 FR 834).

2.5.2 Life History

Snake River steelhead migrate a substantial distance from the ocean (up to 930 miles) and use high elevation tributaries (typically 3,300-6,600 feet above sea level) for spawning and juvenile rearing. Steelhead in this DPS occupy habitat that is considerably warmer and drier (on an annual basis) than other steelhead DPSs. Snake River basin steelhead are generally classified as summer-run, based on their adult run timing patterns. Summer steelhead enter the Columbia River from late June to October, hold over the winter, then spawn during the following spring (March to May) (NMFS 2005a).

Emergence occurs by early June in low elevation streams and as late as mid-July at higher elevations. Snake River steelhead usually rear in the natal tributaries for 2 to 3 years before outmigrating (NMFS 2008a).

2.5.3 Factors for Decline

Factors affecting the decline of this DPS include degraded tributary channel morphology, physical and temperature passage barriers, excess sediment in gravel, degraded riparian condition, water withdrawals resulting in reduced tributary stream flow, and degraded tributary water quality including elevated summer temperatures. Additional limiting factors include hydropower projects, predation, harvest, and hatchery effects.

2.6 Upper Willamette River Steelhead

2.6.1 Distribution and Condition

UWR steelhead were listed as threatened in 1999 (64 FR 14517).This DPS includes all naturally spawned anadromous steelhead populations below natural and man-made impassable barriers in the Willamette River and its tributaries upstream from Willamette Falls to the Calapooia River (inclusive). There is only one major population group in this DPS, comprised of four historical populations. All four remain extant and produce moderate numbers of natural-origin steelhead each year. The hatchery summer-run steelhead that occur in the Willamette River basin are an out-of-basin stock that is not part of the DPS (NMFS 2008a).

2.6.2 Life History

Steelhead of this DPS are late-migrating winter steelhead, entering freshwater primarily in March and April (Howell et al. 1985, as cited in 63 FR 11797) and entering the mouth of the Willamette River from March through May (Busby et al. 1996). Winter-run steelhead historically occurred above Willamette Falls, while summer-run steelhead did not. Juvenile outmigration past Willamette Falls occurs between early April and early June (Howell et al. 1985), with migration peaking in early to mid-May. Steelhead smolts generally migrate away from the shoreline and enter the Columbia River via the Multnomah Channel rather than the mouth of the Willamette River. Most spend 2 years in the ocean before re-entering freshwater to spawn (Busby et al. 1996). Steelhead in this DPS generally spawn once or twice. Repeat spawners are predominantly female and generally account for less than 10 percent of the total run size (Busby et al. 1996).

2.6.3 Factors for Decline

Factors affecting the decline of this DPS include habitat loss and degradation (including tributary hydropower development), hatchery effects, fishery management and harvest decisions, and predation. Habitat loss due to passage barriers associated with dams has been especially severe in the North Santiam (Big Cliff and Detroit Dams) and Calapooia subbasins (NMFS 2008a). Major habitat blockages also resulted from the construction of Green Peter Dam on the South Santiam River. In addition to blocking winter steelhead access to historical upstream habitat in the South and North Santiam Rivers, these dams also affect flows, water quality, sediment transport, and downstream habitat in the North and South Santiam Rivers and in the mainstem Willamette River. Flow storage and release operations and, to a lesser extent, irrigation withdrawals have also altered temperatures and channel-forming processes.

3. Sockeye

One ESU of sockeye salmon (*Oncorhynchus nerka*) is addressed in this BA: SR sockeye.

3.1 General Sockeye Life History

Sockeye spawn in North America from the Columbia River in Oregon north to the Noatak River in Alaska (Atkinson et al. 1967; Burgner 1991, as cited in Good et al. 2005). Most sockeye spawn in lakes or in the inlets or outlets of lakes. The juveniles of lake-type sockeye rear in lakes for 1 to 3 years, migrate to sea, and return to their natal lake systems to spawn after 1 to 4 years in the ocean. However, some sockeye populations spawn in rivers without juvenile lake-rearing habitat. Juveniles of these populations rear in slow-velocity sections of rivers for 1 or 2 years (river-type), or migrate to sea as subyearlings, rearing primarily in saltwater (sea-type) (Wood 1995). Similar to lake-type sockeye, river- and sea-type sockeye return to their natal spawning habitat after 1 to 4 years in the ocean.

Resident (non-anadromous) populations of sockeye that remain in lake environments are referred to as kokanee in North America. Genetic differentiation among sockeye and kokanee populations indicates that kokanee are polyphyletic, having arisen from sockeye on multiple independent occasions, and that kokanee may occur sympatrically or allopatrically with sockeye. Numerous studies (reviewed in Gustafson et al. 1997, as cited in Good et al. 2005) indicate that sockeye and kokanee exhibit a suite of heritable differences in morphology, early development rate, seawater adaptability, growth, and maturation. These differences appear to be divergent adaptations, having arisen from different selective regimes associated with anadromous versus non-anadromous life histories. These studies also provide evidence that sympatric populations of sockeye and kokanee can be both genetically distinct and reproductively isolated (see citations in Gustafson et al. 1997). Occasionally, a proportion of juveniles in an anadromous sockeye population remain in the rearing lake environment throughout their life cycle and are observed on spawning grounds together with anadromous sockeye (Good et al. 2005).

The CR sockeye run consists of the Okanagan, Wenatchee, and Snake River stocks. The Okanagan and Wenatchee stock abundance is cyclic, with occasional strong return years followed by years of low returns. The UCR sockeye run consist of four age groups. Fish returning to Osoyoos Lake in the Okanagan Basin are typically 3- and 4-year-old fish. Those returning to Lake Wenatchee in the Wenatchee Basin are typically 4- and 5-year-old fish. The SR sockeye run, largely returning to the Stanley Basin in Idaho, is extremely depleted. A small remnant population of the Snake River sockeye returns to Redfish Lake. Production is maintained through a captive brood program, and most returning adults are progeny of this program (NMFS 2005a).

3.1.1 Run Timing and Spawning

Sockeye migrate through the lower Columbia River during June and July, with normal peak passage at Bonneville Dam around July 1. The Wenatchee stock generally migrates earlier than the Okanogan stock, although the run timing of these stocks overlap. Sockeye counts at Ice Harbor Dam (on the Snake River) and Priest Rapids Dam (on the upper Columbia River) both extend from early June through mid-July, which suggests that the SR component has similar run timing to the UCR sockeye (Good et al. 2005).

3.1.2 Factors for Decline

Factors affecting the decline of sockeye in the Columbia basin include initial high harvest levels from the late 1800s through the 1900s; the eradication of sockeye from Sawtooth Valley lakes in the 1950s and

1960s; the development of mainstem hydropower projects on the lower Snake and Columbia Rivers in the 1970s and 1980s, and consequent loss of access to historic migration and spawning areas; and poor ocean conditions from 1977 through the late 1990s (NMFS 2008a).

3.2 Snake River Sockeye

3.2.1 Distribution and Condition

SR sockeye were listed as endangered on November 20, 1991; endangered status was reaffirmed on June 28, 2005 (70 FR 37160). This ESU includes all anadromous and residual sockeye from the Snake River basin, Idaho, as well as artificially propagated sockeye from the Redfish Lake Captive Broodstock Program.

3.2.2 Life History

SR sockeye are distinctive in that they spawn at a higher elevation (approximately 6,000 feet) and have a longer freshwater migration (900 miles) than any other sockeye population in the world (Waples et al. 1991).

Historically, SR sockeye adults entered the Columbia River in June and July, migrated upstream through the Snake and Salmon Rivers, and arrived at Redfish Lake in the Stanley Basin in August and September (Bjornn et al. 1968, as cited in NMFS 2008a). Spawning in lakeshore gravels peaked in October. Fry emerged in late April and May and moved immediately to the open waters of the lake where they fed on plankton for 1 to 3 years before outmigrating in April and May. SR sockeye spend 2 to 3 years in the ocean before returning to their natal lake to spawn (Good et al. 2005).

3.2.3 Factors for Decline

Sockeye were historically numerous in many areas of the Snake River basin. Development of mainstem hydropower projects on the lower Snake and Columbia Rivers in the 1970s and 1980s had a significant impact on this ESU. Most of the historic production of sockeye occurred in nursery lakes located in the uppermost reaches of the Columbia and Snake River basins. Upstream passage was blocked by the construction of several key dams, including Grand Coulee (completed 1941) in the upper Columbia system and by Swan Falls (1901), Sunbeam (1913; removed in 1934), Black Canyon (1914), and Brownlee (1958) Dams in the Snake River system (NMFS 2008a).

Additional factors affecting the decline of this ESU include intense commercial harvest of sockeye beginning in the mid-1880s, the eradication of sockeye from Sawtooth Valley lakes in the 1950s and 1960s, the development of the Columbia and Snake River hydroelectric systems, and poor ocean conditions in 1977 through the late 1990s (NMFS 2008a). Snake River sockeye are now predominantly from a captive broodstock program associated with Redfish Lake and other Sawtooth Valley lakes. Although access to spawning and rearing lakes is now considered functional, large portions of the migration corridor in the Salmon River are water quality-limited for temperature, which is likely to reduce the survival of adult sockeye returning to the Stanley Basin in late July and August (NMFS 2008a).

4. Coho

One ESU of coho (*Oncorhynchus kisutch*) is addressed in this BA: LCR coho.

4.1 General Coho Life History

Coho have a widespread distribution, occurring in most major river basins around the Pacific Rim from Monterey Bay in California north to Point Hope, Alaska; through the Aleutians; and in Russia, Korea, and Japan (Laufle et al. 1986, as cited in Good et al. 2005). In general, coho adults occurring south of central British Columbia are 3-year-olds, having spent approximately 18 months in freshwater and 18 months in saltwater (Gilbert 1912, Pritchard 1940, and Sandercock 1991, as cited in Good et al. 2005). Exceptions to this pattern are jacks—sexually mature males that return to freshwater to spawn after only 5 to 7 months in the ocean (Good et al. 2005).

Summer and winter freshwater habitats preferred by coho consist of quiet areas with low flow, such as backwater pools, beaver ponds, dam pools, and side channels; preferred spawning habitat consists of small streams with stable gravels (Reeves et al. 1989, as cited in Good et al. 2005). Habitats used during winter generally have greater water depth than those used in summer, with greater amounts of large woody debris (Good et al. 2005).

4.1.1 Run Timing and Spawning

West Coast coho smolts typically leave freshwater in the spring (April to June), returning to freshwater as sexually mature adults from September to November. Spawning occurs from November to December, and occasionally into January (Sandercock 1991, as cited in Good et al. 2005). Stocks from British Columbia, Washington, and the Columbia River often have very early runs (entering rivers in July or August) or late runs (spawning into March), in addition to normally timed runs (Good et al. 2005).

4.1.2 Factors for Decline

Factors affecting the decline of coho include habitat degradation (e.g., tributary hydropower development), hatchery effects, fishery management and harvest, and predation (by piscivorous birds and fish).

4.2 Lower Columbia River Coho

4.2.1 Distribution and Condition

The LCR coho ESU was listed as threatened in 2005 (70 FR 37160). This ESU includes all naturally spawned coho populations in streams and tributaries to the Columbia River in Washington and Oregon, from the mouth of the Columbia up to and including the White Salmon and Hood Rivers. This ESU also includes the Willamette River up to Willamette Falls, Oregon, as well as 25 artificial propagation programs. There are 24 historical populations in three major population groups in this ESU (NMFS 2008a).

4.2.2 Life History

In general, coho do not have the major life-history variation seen in some of the other listed salmonid species occurring in the lower Columbia River (e.g., steelhead or Chinook) (Good et al. 2005). This ESU includes two distinct runs: early returning (Type S) and late returning (Type N). Type S coho salmon generally migrate south of the Columbia once they reach the ocean, returning to freshwater in mid-August and to the spawning tributaries in early September. Spawning peaks from mid-October to early November. Type N coho have a northern distribution in the ocean, return to the Columbia River from late September through December, and enter the tributaries from October through January. Most Type N spawning occurs from November through January, but some spawning occurs in February and as late as March (LCFRB 2004, as cited in Good et al. 2005).

4.2.3 Factors for Decline

LCR coho populations have been in decline for the last 70 years. Factors affecting this decline include habitat degradation (e.g., tributary hydropower development), hatchery effects, fishery management and harvest, and predation. For populations originating in tributaries below Bonneville, migration and habitat conditions in the mainstem and estuary have been affected by hydrosystem flow operations. Tributary habitat degradation is pervasive due to development and other land uses, and hydroelectric projects have blocked some spawning areas (Good et al. 2005).

Coho populations in the lower Columbia River have also been heavily influenced by extensive hatchery releases. While those releases represent a threat to the genetic, ecological, and behavioral diversity of the ESU, some of the hatchery stocks at present also protect a significant portion of the ESU's remaining genetic resources. Most populations in Oregon, except for the Clackamas and Sandy River populations, are believed to have very little, if any, natural production. No populations on the Washington side of this ESU are known to be self-sustaining (Good et al. 2005).

5. Chum

One ESU of chum (*Oncorhynchus keta*) is addressed in this BA: LCR chum.

5.1 General Chum Life History

Chum have the largest natural geographic and spawning distribution of any Pacific salmonid, primarily because their range extends farther along the shores of the Arctic Ocean than other salmonids. Chum salmon have been documented to spawn from Korea and Japan, around the rim of the North Pacific Ocean to Monterey Bay in California. Presently, major spawning populations are found only as far south as Tillamook Bay on the northern Oregon coast (Good et al. 2005). Chum may historically have been the most abundant of all salmonids: it is estimated that prior to the 1940s, chum contributed almost 50 percent of the total biomass of all salmonids in the Pacific Ocean (Neave 1961, as cited in Good et al. 2005).

Chum also grow to be among the largest of Pacific salmon (Chinook being the largest). The species is known for its large canine-like fangs and the striking body color (a pattern made up of bold, jagged, reddish and black lines) of spawning males. Females have less color than males and lack the large fangs (Good et al. 2005).

Chum spend more of their life history in marine waters than other Pacific salmonids. They usually spawn in coastal areas, and juveniles outmigrate to the ocean almost immediately after emergence (Salo 1991, as cited in Good et al. 2005). Such ocean-type migratory behavior indicates that survival and growth of juvenile chum depends less on freshwater conditions than on favorable estuarine conditions (Good et al. 2005). Unusual among salmonids, chum are known to form schools, presumably to reduce predation (Pitcher 1986, as cited in Good et al. 2005), especially if their movements are synchronized to swamp predators (Miller and Brannon 1982, as cited in Good et al. 2005).

5.1.1 Run Timing and Spawning

Chum are semelparous and spawn primarily in freshwater. There are no recorded landlocked or naturalized freshwater populations of chum (Randall et al. 1987, as cited in Good et al. 2005).

5.1.2 Factors for Decline

The development of the federal Columbia River hydropower system, overexploitation, habitat degradation, and loss of key spawning locations have all contributed to dramatic declines in chum populations during the last century (Nehlsen et al. 1991; Johnson et al. 1997; Hillson 2003, as cited in Tomaro et al. 2007).

5.2 Lower Columbia River Chum

5.2.1 Distribution and Condition

The LCR chum ESU was listed as threatened on March 25, 1999 (64 FR 14507); threatened status was reaffirmed on June 28, 2005 (70 FR 37160). This ESU includes all naturally spawned populations of chum in the Columbia River and its tributaries, as well as three artificial propagation programs. Historically, there were 16 historical populations in three major population groups (Coastal, Cascade, and Columbia Gorge) in Oregon and Washington between the mouth of the Columbia River and the Cascade crest (Myers et al. 2002, as cited in Good et al. 2005); significant spawning now occurs in only two of the 16 historical populations: Grays River and Lower Columbia Gorge (Good et al. 2005).

5.2.2 Life History

Adult chum return to the Columbia River in late fall (mid-October to December). They primarily spawn in the lower reaches of the Columbia River, digging redds along the edges of the mainstem and in tributaries or side channels. Some spawning sites are located in areas where geothermally warmed groundwater or mainstem flow upwells through the gravel (NMFS 2008a).

Chum migration is related to water temperature; peak migration generally occurs at river temperatures between 7°C and 11°C (Salo 1991). Chum spawning around Ives and Pierce Islands seem to follow this pattern of temperature-dependent migration and spawning. Ives/Pierce Islands chum begin spawning when river temperatures are between 10°C and 13°C, and spawning peaks at river temperatures between 7°C and 12°C (Tomaro et al. 2007).

Chum fry outmigrate from March through May, shortly after emergence. Juvenile chum feed in estuaries before entering the ocean. The period of estuarine residence appears to be a critical life history phase and may play a major role in determining the size of the subsequent adult run returning to freshwater (NMFS 2008a).

Juvenile chum rearing around Ives and Pierce Islands is likely a mixture of natural production from Hamilton and Hardy Creeks and the mainstem Columbia. Chum spawn in both tributaries as well as in portions of the mainstem near tributary mouths (Tomaro et al. 2007).

5.2.3 Factors for Decline

Chum in the Columbia River once numbered in the hundreds of thousands of adults, and at times approached 1 million per year (Good et al. 2005). Major factors affecting the decline of chum include mainstem and tributary hydropower development, and loss or impairment of tributary and estuarine habitat (NMFS 2008a). Alterations in attributes of flow and diking have resulted in the loss of emergent marsh, tidal swamp and forested wetland habitats. These habitats are used extensively by chum juveniles, which migrate from their natal areas soon after emergence (Fresh et al. 2005, as cited in NMFS 2008a). Because chum spend only a short time in natal streams before emigration, the loss or impairment of rearing habitat in the Columbia River estuary has been an important factor in their decline.

Direct mainstem hydro impacts on the CR chum ESU are most significant for the Upper and Lower Gorge populations. Impacts to populations originating in subbasins further downstream (i.e., below the Portland/Vancouver area) are limited to migration and habitat conditions in the lower Columbia River (below Bonneville Dam), including the estuary (NMFS 2008a).

Harvest has also been identified as a factor in decline; prior to the 1950s, harvest rates were as high as 70 percent (NMFS 2008a).

In addition, widespread development and land use activities have severely degraded stream habitats, water quality, and watershed processes affecting anadromous salmonids in most lower Columbia River subbasins, particularly in the low to moderate elevation habitats most often used by chum (NMFS 2008a).

6. North American Green Sturgeon

6.1 General Green Sturgeon Life History

The green sturgeon (*Acipenser medirostris*) is an anadromous sturgeon found in nearshore marine waters from Baja Mexico to Canada. Green sturgeon are long-lived, slow-growing fish and the most marine-oriented of the sturgeon species. Mature males range from 4.5–6.5 feet (1.4–2 m) in "fork length" and do not mature until they are at least 15 years old (Van Eenennaam 2002, pers. comm.), while mature females range from 5–7 feet (1.6–2.2 m) fork length and do not mature until they are at least 17 years old. Maximum ages of adult green sturgeon are likely to range from 60–70 years (Moyle 2002). Diet includes benthic invertebrates such as shrimp, mollusks, amphipods, and even small fish (Moyle et al. 1992).

Northern DPS and Southern DPS green sturgeon occupy coastal estuaries and coastal marine waters from southern California to Alaska, including Humboldt Bay, the lower Columbia river estuary, Willapa Bay, Grays Harbor, and coastal waters between Vancouver Island, BC, and southeast Alaska (Israel et al. 2004; Moser and Lindley 2007; Lindley et al. 2008). Thus, green sturgeon observed in coastal bays, estuaries, and coastal marine waters outside of natal rivers may belong to either DPS. The Southern DPS at present contains only a single spawning population, in the Sacramento River (73 FR 52084).

6.1.1 Distribution and Condition

Green sturgeon range from the Bering Sea, Alaska, to Ensenada, Mexico. A few green sturgeon have been observed off the southern California coast, including fish less than 100 cm total length (Fitch and Lavenberg 1971, and Fitch and Schultz 1978, both cited in Moyle et al., 1995). Green sturgeon abundance increases north of Point Conception, California (Moyle et al. 1995). Green sturgeon occupy freshwater rivers from the Sacramento River up through British Columbia (Moyle 2002), but spawning has been confirmed in only three rivers, the Rogue River in Oregon and the Klamath and Sacramento rivers in California. Green sturgeon have many life history characteristics that make them vulnerable to habitat degradation and over-exploitation, including large size, late maturity, low productivity, long life span, and an anadromous life history (73 FR 52084).

Green sturgeon were petitioned for listing in June 2001 by the Environmental Protection Information Center, the Center for Biological Diversity, and Waterkeepers Northern California. The NMFS Biological Review Team (BRT) identified two DPSs of North American green sturgeon in the eastern Pacific population. The Southern DPS (those sturgeon spawning in the Sacramento River of California) was subsequently listed as threatened on April 7, 2006 (71 FR 17757), while the Northern DPS (those sturgeon spawning north of and including the Eel River, California) were designated a Species of Concern. Sturgeon from both DPSs occur in the Columbia River estuary during summer months, but typically occur offshore from late fall through early spring. Few green sturgeon have been recorded in commercial landings or in winter and spring test fisheries over the last several decades (JCRMS 2006).

6.1.2 Run Timing and Spawning

Spring spawning occurs in deep pools in large, turbulent river mainstreams including the Sacramento, Klamath, and Rogue Rivers. Spawning habitat preferences are unclear, but likely include large cobbles, sand, and/or bedrock. Adults spawn every few years beginning about age 17. Adults migrate to the north (generally north of Vancouver Island, Canada) in spring and return to southern spawning areas in the spring.

Adults typically migrate into freshwater beginning in late February; spawning occurs from March to July, with peak activity from April to June (Moyle et al. 1995). Females produce 60,000–140,000 eggs (Moyle et al. 1992). Juvenile green sturgeon spend 1–4 years in fresh and estuarine waters before dispersal to saltwater (Beamsesderfer and Webb 2002). They disperse widely in the ocean after their outmigration from freshwater (Moyle et al. 1992).

6.1.3 Factors for Decline

The extent of green sturgeon decline is unclear. However, water development and sedimentation-forming land-use practices in the Klamath, Rogue, and Eel Rivers have affected the green sturgeon's freshwater habitat by blocking access to historical spawning areas, raising water temperatures, and by entraining juvenile green sturgeon. Exotic species also appear to be a factor in decline for the Southern DPS, most notably in the Sacramento-San Joaquin River and Delta systems, where nonnative bivalves have replaced native forage species to some extent; striped bass may also prey on juvenile green sturgeon (NMFS 2005b).

7. Bull Trout – Columbia River Population

7.1 General Bull Trout Life History

Bull trout (*Salvelinus confluentus*) were historically distributed in major river drainages of the Pacific Northwest from the McCloud River in northern California north to the headwaters of the Yukon River of Canada. They also occur in the Jarbidge River of Nevada, Puget Sound, coastal rivers of British Columbia and southeast Alaska, the Klamath River basin of Oregon, and throughout many of the tributaries of the Columbia River basin. Despite the fairly wide range of bull trout in the Northwest, current distribution in the Columbia River basin represents approximately only 45 percent of their historical distribution in this basin (63 FR 31647).

Bull trout exhibit resident and migratory life history strategies, depending on population and local habitat accessibility and structure. Resident bull trout spend their life cycle in the stream or tributary in which they spawn and rear. Migratory bull trout spawn in streams where rearing takes place for up to 4 years before migrating to lakes (adfluvial populations), rivers (fluvial populations), or in some cases, the ocean (anadromous populations). Resident and migratory populations may occur together (63 FR 31647).

Compared to other salmonids, bull trout have a more narrow tolerance for habitat quality parameters, and require particularly cold, clean water. Water temperatures above 15ºC (59ºF) may limit bull trout distribution (Fraley and Shepard 1989; Rieman and McIntyre 1995). Other habitat parameters influencing abundance and distribution include complex in-stream cover (e.g., woody debris, undercut banks, pools), channel dynamics, quality and availability of spawning and rearing substrates, and access to migratory corridors.

7.1.1 Run Timing and Spawning

Suitable spawning habitat consists of low-gradient streams with loose, clean gravels in water of 5-–9ºC (41–48ºF) from late summer to early fall (Fraley and Shepard 1989; Goetz 1989). Redds are often located in streams fed by springs or other sources of cold groundwater. As with other salmonids, excessive levels of fine sediments reduce egg survival and emergence. Habitat components of sufficient quantity and quality are not equally distributed throughout the bull trout range, contributing to patchy distribution of this species.

Bull trout reach breeding age between 4 and 7 years of age, and may live up to 12 years. Spawning timing is correlated with low water temperature and generally takes place between August and November; migratory bull trout may begin spawning in April. The time between egg deposition and emergence may be up to 200 days. Fry emerge in early April to May, depending on water temperature. Feeding strategies vary somewhat according to life history type and size—resident and juvenile migratory bull trout feed on invertebrates, zooplankton, and small fish, whereas adult migratory bull trout are typically piscivorous (63 FR 31647).

7.1.2 Distribution and Condition

Bull trout in the Columbia River were listed as threatened on June 10, 1998 (63 FR 31647). The Columbia River population includes bull trout in the Columbia River basin and its tributaries within the United States with the exception of those bull trout constituting a separate DPS in the Jarbidge River in Nevada.

The CR DPS includes bull trout residing in portions of Oregon, Washington, Idaho, and Montana. Bull trout are estimated to have occupied about 60 percent of the Columbia River basin, and presently occur in 45 percent of their estimated historical range (Quigley and Arbelbide 1997). The Columbia River population segment is composed of 141 subpopulations. For discussion and analysis, NMFS considered four geographic areas of the Columbia River basin: (1) lower Columbia River (downstream of the Snake River confluence), (2) middle Columbia River (Snake River confluence to Chief Joseph Dam), (3) upper Columbia River (upstream from Chief Joseph Dam), and (4) Snake River and its tributaries including the Lost River drainage (63 FR 31647).

The Lower Columbia Recovery Unit Team identified the Lewis and Klickitat Rivers as two “core” areas (that is, habitat considered important for full recovery to occur) within the recovery unit. Based on survey data and professional judgment, the Lower Columbia Recovery Unit Team has also identified local populations of bull trout within the core areas. Local populations within the Lower Columbia Recovery Unit are currently contained in Cougar, Pine, and Rush Creeks (Lewis River), and in the West Fork of the Klickitat River. While no local populations within the White Salmon River have been identified, this system contains core habitat and could support bull trout if passage barriers (i.e., Condit Dam) are addressed and habitat connectivity is re-established with the mainstem Columbia River.

7.1.3 Factors for Decline

Threats to bull trout include habitat degradation and fragmentation, passage barriers restricting access to historical habitat, poor water quality (e.g., elevated temperatures), impacts associated with road construction and maintenance, incidental recreational harvest, entrainment, and competition with non-native fish (64 FR 58910).

Within the Lower Columbia Recovery Unit, historic and current land use activities have impacted bull trout local populations. Dams have fragmented bull trout habitat, isolated local populations, and prevented access to historical foraging and overwintering habitat. Forest management activities have altered habitat conditions in portions of the recovery unit. Impacts to bull trout result from impassable culverts, excessive erosion and sedimentation, reduced recruitment of large woody debris, channel changes, and altered patterns of water temperature, instream flow, and runoff. Grazing has resulted in eroded stream banks, increased sedimentation, and incised stream channels. Water withdrawals for agriculture reduce in-stream flows and result in increased water temperatures. Non-native species pose a threat to bull trout through potential hybridization, competition for resources, and predation.

8. Steller (Northern) Sea Lion

8.1 General Steller Sea Lion Life History

Steller (northern) sea lions (*Eumetopias jubatus*) occur in near-shore and pelagic habitats from Japan through the Bering Sea and Gulf of Alaska, south to central California. The areas of highest abundance are the Gulf of Alaska and the Aleutian Islands. Breeding colonies, or rookeries, occur through this distribution but are concentrated in Alaska. Rookeries tend to be remote islands and other beaches of sand, gravels, cobbles, or bedrock protected from humans and other predators (e.g., sharks, orcas). Haul-outs include beaches, jetties, rocks, floating docks, and sea ice. Females produce a single pup annually, giving birth in late May to early July. Steller sea lions disperse widely in coastal waters through their range after the breeding season. They feed on fish and sometimes invertebrates, and are known to ascend rivers in pursuit of prey.

The Steller sea lion is the largest member of the Otariid (eared seal) family. Males may be up to 325 cm (10-11 feet) in length and can weigh up to 1,100 kg (2,400 pounds). Females are smaller than males, generally 240-290 cm (7.5-9.5 feet) in length and up to 350 kg (770 pounds) in weight (NMFS 2009).

Steller sea lions are opportunistic predators, feeding primarily on a wide variety of fishes and cephalopods. Prey varies geographically and seasonally. Some of the more important prey species in Alaska include walleye pollock (*Theragra chalcogramma*), Atka mackerel (*Pleurogrammus monopterygius*), Pacific herring (*Clupea harengus*), Capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), Pacific cod (*Gadus macrocephalus*), and salmon (*Oncorhynchus* spp.). Steller sea lions have been known to prey on harbor seal, fur seal, ringed seal, and possibly sea otter pups, but this would represent only a supplemental component to the diet (NMFS 2009).

Bulls become mature between 3 and 8 years of age, but typically are not massive enough to hold territory successfully until they are 9 or 10 years old. Females reproduce for the first time at 4 to 6 years of age, bearing at most a single pup each year. Pups are born from late May through early July, with peak numbers of births during the second or third week of June. Females stay with their pups for about 9 days before beginning a regular routine of foraging trips to sea. Females mate 11 to 14 days after giving birth. Implantation takes place in late September or early October, after a 3-4 month delay. Weaning is not sharply defined as it is for most other pinniped species, but probably takes place gradually during the winter and spring prior to the following breeding season. It is not uncommon to observe 1- or 2-year-old sea lions suckling from an adult female (NMFS 2009).

8.1.1 Distribution and Condition

Steller sea lions were listed as threatened on November 26, 1990 (55 FR 49204). The species was reclassified into two distinct population segments in 1997: a western DPS located west of 144 degrees W longitude (approximately west of Cape Suckling, Alaska) was reclassified as endangered, while the eastern DPS remained listed as threatened.

The overall trend for the western DPS (the Alaska portion of the Gulf of Alaska/Aleutian Islands/Bering Sea) since 1990 is either stable or declining slightly. By contrast, the eastern DPS has exhibited a gradual increasing trend in abundance. Based on counts of adult and juvenile Steller sea lions observed at rookery and haul-out trend sites by year and geographical area, populations in Oregon have shown a stable or gradually increasing trend since the early 1980s, although populations in California remain low (Angliss and Allen 2007).

8.1.2 Factors for Decline

Specific causes of the decline of Steller sea lions are not well understood, but likely include reduced availability of prey resulting (in part from competition with commercial fisheries), disease, pollution, and harassment at rookeries and haul-out sites. Low juvenile survival and low fecundity rates have been implicated in population declines (Holmes and York 2003).

NMFS (2009) reports that many factors could have contributed to the decline of the western Steller sea lion stock in the 1980s and 1990s. These include factors that cause mortality directly, such as incidental take in fisheries, illegal and legal shooting, predation or certain diseases, as well as other factors that indirectly would lead to population declines by reducing productivity. Such indirect factors include the effects of climate change or fisheries which would alter prey abundance, distribution or species composition leading to nutritional stress, and the effects of certain diseases or contaminants.

9. Eulachon – Southern DPS

9.1 General Eulachon Life History

Eulachon (*Thaleichthys pacificus*) (also called Columbia River smelt, candlefish, or hooligan) are members of the osmerid family (smelts) and are endemic to the northeastern Pacific Ocean. Historic distribution ranged from the southern California and Baja California coasts to southwest Alaska to the southwest Bering Sea. Current southern distribution is limited to Monterey Bay and Klamath River, California. Within this range, major production areas or "core populations" for this species include the Columbia and Fraser Rivers. The discussion below is specific to eulachon in the Columbia River system.

The Columbia River and its tributaries support the largest known eulachon run in the world (NMFS 2008c). Within the Columbia River basin, the major and most consistent spawning runs return to the mainstem of the Columbia River (from just upstream of the estuary, RM 25, to immediately downstream of Bonneville Dam, RM 146), and the Cowlitz, Grays, Kalama, and Lewis Rivers. Table C-1 contains a list and classification of all known eulachon spawning areas in Washington, based on the 2008 Eulachon Status Review (NMFS 2008c).

Table C-1. Eulachon Spawning and Estuarine Areas in Washington

Eulachon Spawning Areas	Spawning Regularity[a]	Estuary
Columbia River Mainstem	Regular	Columbia River
Grays River	Regular	Columbia River
Skamokawa Creek	Rare	Columbia River
Elochoman River	Irregular	Columbia River
Cowlitz River	Regular	Columbia River
Toutle River	Rare	Columbia River
Kalama River	Regular	Columbia River
Lewis River	Regular	Columbia River
Washougal River	Rare	Columbia River
Klickitat River	Anecdotal	Columbia River
Bear River	Occasional	Willapa Bay
Naselle River	Occasional	Willapa Bay
Nemah River	Rare	Willapa Bay
Wynoochie River	Rare	Grays Harbor
Quinault River	Occasional	Coast
Queets River	Occasional	Coast
Quillayute River	Rare	Coast
Elwha River	Occasional	Juan de Fuca
Puyallup River	Rare	Puget Sound

Source: NMFS 2008c.

a Regular – occurring yearly or in most years; Rare, Irregular, Anecdotal, Occasional – sporadic, infrequent occurrence, does not occur every year and may not occur in most years, especially those rivers with a spawning regularity of "rare." Eulachon are described as "common" in Grays Harbor and Willapa Bay on the Washington coast, and "abundant" in the Columbia River (NMFS 2008c) (73 FR 13187).

Eulachon feed on zooplankton, primarily crustaceans such as copepods and euphausiids, including *Thysanoessa* spp. (Barraclough 1964; Hay and McCarter 2000); unidentified malacostraceans (Sturdevant et al. 1999); and cumaceans (Smith and Saalfeld 1955). Eulachon larvae and post-larvae eat phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, worm larvae, and eulachon larvae (WDFW and ODFW 2001). Adults and juveniles commonly forage at moderate depths (15 to 182 m) in inshore waters (Hay and McCarter 2000). Eulachon only feed while at sea. They do not feed in freshwater and remain there only a few weeks (Rogers et al. 1990; WDFW and ODFW 2001).

Eulachon are very important to the Pacific coastal food web due to their availability during spawning runs and their high lipid content. Avian predators include harlequin ducks, pigeon guillemots, common murres, mergansers, cormorants, gulls, and eagles. Marine mammal predators include baleen whales, orcas, dolphins, pinnipeds, and beluga whales. Fish that feed on eulachon include white sturgeon, spiny dogfish, sablefish, salmon sharks, arrowtooth flounder, salmon, Dolly Varden, Pacific halibut, and Pacific cod. Eulachon and their eggs provide a significant food source for white sturgeon in the Columbia River.

9.1.1 Distribution and Condition

The Southern DPS of eulachon consists of populations spawning in rivers south of the Nass River in British Columbia, Canada, to, and including, the Mad River in California. Eulachon in the Southern DPS are differentiated from eulachon in the northern portions of the species' distribution by preferred spawning temperatures, length- and weight-at-maturity, ecological features of both the oceanic and freshwater environments occupied by eulachon, and genetic analysis (74 FR 10857).

The BRT determined that the Southern DPS is significant to the species as a whole because it constitutes over half of the geographic range of the entire species' distribution and includes at least two of the major production areas (Columbia and Fraser Rivers) for the entire species. Therefore, the loss of this DPS would result in a significant reduction in the species' overall distribution (74 FR 10857).

Eulachon abundance exhibits considerable year-to-year variability. However, nearly all spawning runs from California to southeastern Alaska have declined in the past 20 years, especially since the mid 1990s. From 1938 to 1992, the median commercial catch of eulachon in the Columbia River was approximately 2 million pounds (900,000 kg), but from 1993 to 2006, the median catch had declined to approximately 43,000 pounds (19,500 kg), representing a nearly 98 percent reduction in catch from the prior period. Eulachon returns in the Fraser River and other British Columbia rivers similarly suffered severe declines in the mid-1990s and, despite increased returns during 2001 to 2003, presently remain at very low levels. The populations in the Klamath River, Mad River, Redwood Creek, and Sacramento River are likely extirpated or nearly so.

Monitoring of juvenile emigration was begun in the early 1990s to identify timing of peak outmigration and relative spawning success, and to develop more direct measures of brood-year strength. A program to measure eulachon smelt larval densities and depths across several index sites began producing data for the mainstem Columbia River in 1996. In 1997, monitoring was initiated to focus specifically on the lower Columbia River commercial fishery and track daily landings; catch per unit effort (CPUE); length, weight, and sex; and trends in catch by time, area, run timing, and age and sex distribution. These data on spawning success, combined with commercial and residential catch numbers, more accurately represent relative annual run strength than do commercial landing data alone (JCRMS 2006).

9.1.2 Run Timing and Spawning

Eulachon typically spend 3 to 5 years in saltwater before returning to freshwater to spawn from late winter through early summer. River entry and spawning begin as early as December and January in the Columbia River basin and last through May, with peak entry and spawning during February and March (Table C-2) (WDFW and ODFW 2001; NMFS 2008c).

Table C-2. Range and Peak Timing of Documented Washington River Entry and/or Spawn Timing for Eulachon

Basin/River	Source	December	January	February	March	April	May
Columbia Basin							
Columbia River	1						
Cowlitz River, WA	1						
Juan de Fuca Basin							
Elwha River, WA	2						

Notes: Gray = Range; Black = Peak.
1. WDFW and ODFW 2001.
2. Shaffer et al. 2007.

Spawning grounds are typically in the lower reaches of larger rivers fed by snowmelt (Hay and McCarter 2000). Eulachon have been observed ascending well beyond tidally influenced areas (Wilson et al. 2006; Lewis et al. 2002). The maximum extent of adult migration in the Columbia River marks the maximum extent of spawning in the Columbia River. Eulachon have been observed as far upstream as Bonneville Dam; however, the mouth of the Sandy River (RM 120) is probably a more conservative upper end to spawning distribution (Langness 2009 pers. comm.).

Entry into the spawning rivers appears to be related to water temperature and the occurrence of high tides (Ricker et al. 1954; Smith and Saalfeld 1955; Spangler 2002). Eulachon require freshwater for spawning and are unlikely to spawn in the brackish waters of the lower Columbia River estuary. Exposure of eggs to saltwater, especially of salinity greater than 16 parts per trillion (ppt), can be lethal (Farara 1996). Brackish conditions are generally present below RM 25; considerable tidal influence up to this point can also disrupt spawning activities (Langness 2009 pers. comm.).

Major temperature changes can affect survival (Lewis et al. 2002). Spawning occurs at temperatures from 4 to 10ºC in the Columbia River and tributaries (WDFW and ODFW 2001). In the Cowlitz River, spawning generally occurs at temperatures from 4ºC degrees to 7ºC (Smith and Saalfeld 1955). Eulachon broadcast spawn over sand, coarse gravel, or detrital substrates; preferred spawning habitat appears to be primarily coarse, sandy substrates (WDFW and ODFW 2001). Spawning depth generally ranges from 8 to 20 feet, with a preference for calm water near a shoreline (Langness 2009 pers. comm.; LCFRB 2004). Fecundity ranges from 17,300 to 25,000 eggs per female, depending on age of the returning female adult (Hart 1973). Spawning typically occurs at night.

Eggs are fertilized in the water column, sink, and adhere to the river bottom. Eggs are spherical and 1 mm in diameter (WDFW and ODFW 2001). Eulachon eggs hatch in 20 to 40 days, with incubation time dependent on water temperature. Within days of hatching, the larvae, ranging from 4 to 8 mm in length, are rapidly carried downstream and dispersed by estuarine and ocean currents. Eulachon larvae are found in the scattering layer of near-shore marine areas when they reach the sea (Morrow 1980). Juveniles rear in near-shore marine areas at moderate or shallow depths, and grow to lengths of 46 to 51 mm within 8 months (Barraclough 1964). As eulachon grow, they migrate out to deeper depths and have been found as deep as 625 m (Allen and Smith 1988). Adult eulachon range in size from 14 to 30 cm. They return to freshwater to spawn at 3 to 5 years of age, with the majority of adults returning as 3-year-olds (WDFW and ODFW 2001). Although adults can repeatedly spawn, most die shortly after spawning (WDFW and ODFW 2001).

Similar to salmon, juvenile eulachon are thought to imprint on the chemical signature of their natal river basins. However, juvenile eulachon spend less time in freshwater environments than do juvenile salmon. Researchers believe that this short freshwater residence time may cause returning eulachon to stray more from their natal spawning sites than salmon (Hay and McCarter 2000). This short freshwater residence time may be because spawning grounds occur in snowmelt-fed rivers that have a pronounced peak freshet in the spring, which rapidly flushes eggs and larvae out of the spawning river reach. As such, eulachon may tend to imprint and hone in on the larger local estuary rather than on individual spawning rivers (Hay and McCarter 2000).

9.1.3 Factors for Decline

Threats to this species include commercial and recreational overharvest, bycatch in commercial groundfish and shrimp fisheries, poor ocean conditions associated with climate change, industrial pollution of freshwater and marine habitat, and impacts to spawning habitat from logging, dredging, and water diversions.

Changes in ocean conditions due to climate change have been identified as the most significant threat to eulachon and their habitats (NMFS 2008c), and the highest proportion of mortality appears to occur during the ocean-life stage (Langness 2009 pers. comm.). Marine, estuarine, and freshwater habitat in the Pacific Northwest has been influenced by climate change over the past 50 to 100 years, and this change is expected to continue into the future. Average annual northwest air temperatures have increased by approximately 1ºC since 1900, or about 50 percent more than the global average warming over the same period (see ISAB 2007 for a recent review). Change in surface temperature has already modified, and is likely to continue to modify freshwater, estuarine, and marine habitats of eulachon.

In the Columbia River, climate change is likely to result in decreased snowpack, increased peak flows, decreased base flow, and increased water temperatures (ISAB 2007). As in the Fraser River, peak flows in the Columbia and its tributaries are likely to shift, possibly decoupling eulachon spawning and spring freshets.

Changes in the marine environment due to climate change are also likely to affect eulachon. Increases in ocean temperatures off the coast of the Pacific Northwest could alter the abundance and composition of copepod communities, thus reducing the amount of food available for eulachon, particularly larvae. Warming ocean temperatures could also facilitate the northward expansion of warm-water eulachon predators and competitors for food resources, such as Pacific hake (Rexstad and Pikitch 1986; McFarlane et al. 2000; Phillips et al. 2007).

Dams and water diversions have been identified as moderate threats to eulachon in the Columbia River where hydropower generation and flood control are major activities (74 FR 10857). Dams can slow or block eulachon migration. Dams and water divisions alter the natural hydrograph of river systems, in many cases reducing the magnitude of spring freshets with which eulachon have evolved. Dams can also impede or alter bedload movement, changing the composition of river substrates important to spawning eulachon.

Water quality degradation is common in some areas occupied by this DPS. In the Columbia River, large-scale impoundment of water has increased water temperatures, potentially altering the water temperature during eulachon spawning periods (NMFS 2008c). Numerous chemical contaminants are also present in freshwater systems where eulachon spawn, but the exact affect these compounds may have on spawning and egg development is unknown (NMFS 2008c).

The BRT identified dredging as a low to moderate threat to eulachon in the Columbia River (74 FR 10857). Dredging during eulachon spawning would be particularly detrimental, as eggs associated with benthic substrates would likely be destroyed.

The main predators of eulachon, at least during spawning migrations into the Columbia River, are piscivorous birds (e.g., gulls, terns), sea lions, and sturgeon (Langness 2009 pers. comm.).

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