Appendix B

Species Life Histories

Preface

The *Endangered Species Act (ESA)* was established: (1) to provide a means whereby the ecosystems upon which threatened and endangered species depend upon may be conserved, and (2) to provide a program for the conservation of such threatened and endangered species. The salmonid species characterized below are listed as threatened or endangered under the ESA. These species are regulated by two Federal agencies: the *National Marine Fisheries Service (NMFS)* and *U.S. Fish and Wildlife Service (USFWS)*.

The NMFS provides that a population of Pacific salmonid will be considered distinct, and, therefore, a species under the ESA if it represents an *Ecologically Significant Unit (ESU)* of the biological species. A population of salmonid must satisfy two criteria to be considered an ESU: (1) it must be reproductively isolated from other conspecific population units, and (2) it must represent an important component in the evolutionary legacy of the biological species. Currently, there are 15 Pacific salmonid ESUs as threatened or endangered within the boundaries of Washington State. The Lower Columbia River/SW Washington coho and Puget Sound/Strait of Georgia coho are candidate species under consideration for future listing by the NMFS.

The USFWS has identified five *Distinct Population Segments (DPSs)* of bull trout in the coterminous United States: (1) Klamath River, (2) Columbia River, (3) Coastal-Puget Sound, (4) Jarbidge River, and (5) St. Mary-Belly River. A DPS is an ESA term that applies to vertebrate animals under certain conditions: (1) individuals interbreed within each segment, (2) segments are physically discrete from one another, and (3) segments are biologically significant to the species as a whole. Only species, subspecies, or distinct population segments of vertebrate can be listed. Of the current DPSs listed as threatened or endangered, only Coastal-Puget Sound and Columbia River bull trout occur within the State of Washington. The SW Washington/Columbia River Coastal cutthroat trout DPS is proposed for listing as threatened by the USFWS.

Critical Habitat is a designation given by the NMFS and USFWS, and is defined as "the specific areas within the geographical area occupied by the species…on which are found those physical or biological features essential to the conservation of the species and which may require special management consideration or protection; and specific areas outside the geographical area occupied by the species upon a determination by the Secretary [of Commerce (Secretary)] that such areas are essential for the conservation of the species."

To date, critical habitat has been designated for all 19 salmonid species ESUs protected by the NMFS, including the 15 ESUs in Washington. Critical habitat includes all river reaches accessible to listed salmon or steelhead within the range of the ESUs listed, except for reaches on Indian lands. No critical habitat has been designated or proposed for salmonids protected by the USFWS.

Life Histories

1. Chinook Salmon

General Life History

Chinook salmon (*Oncorhynchus tshawytscha*) is the largest of the pacific salmon. Also known as "king" salmon, adult Chinook salmon migrate from a marine environment into fresh water streams and rivers of their birth where they spawn and die. Among chinook salmon, two distinct races have evolved. 1) A "stream-type" chinook is found most commonly in headwater streams. Stream-type chinook salmon have a longer freshwater residency and perform extensive offshore migrations before returning to their natal streams in the spring or summer months. 2) An "ocean-type" chinook is commonly found in coastal streams in North America. Ocean-type chinook typically migrate to sea within the first three months of emergence, but they may spend up to a year in freshwater prior to emigration. They also spend their ocean life in coastal waters. Ocean-type chinook salmon return to their natal streams or rivers as spring, winter, fall, summer, and late-fall runs, but summer and fall runs predominate (Healey, 1991). The difference between these life history types is physical, with both genetic and morphological foundations.

Adult female chinook will prepare a spawning bed, called a redd, in a stream area with suitable gravel composition, water depth and velocity. Depending on the ESU, redds may be created in the spring or through the fall months. Redds will vary widely in size and in location within the stream or river. The adult female chinook may deposit eggs in 4 to 5 "nesting pockets" within a single redd. After laying eggs in a redd, adult chinook will guard the redd from 4 to 25 days before dying. Chinook salmon eggs will hatch, depending upon water temperatures, between 90 to 150 days after deposition. Stream flow, gravel quality, and silt load all significantly influence the survival of developing chinook salmon eggs. Juvenile chinook may spend from 3 months to 2 years in freshwater after emergence and before migrating to estuarine areas as smolts, and then into the ocean to feed and mature. Juvenile ocean-type chinook tend to utilize estuaries and coastal areas more extensively for juvenile rearing. Juvenile chinook salmon feed primarily on aquatic insect larvae and terrestrial insects, typically in the near shore areas.

Below is a description of the six Evolutionary Significant Units (ESUs) for chinook identified by the NMFS within Washington State.

Snake River Spring/Summer Chinook ESU

(Threatened - Critical Habitat “Designated”)

The range for the Snake River Spring/Summer chinook salmon ESU include the accessible portion of the Snake River Basin, the lower Columbia River and the Pacific Ocean. Adult Snake River spring chinook migrate upstream through the lower Columbia River in March through May. The peak of the spring chinook run passes Bonneville Dam in the third week of April. The travel time between Longview and Bonneville Dam is 8 to 10 days. Summer chinook adults begin upstream passage during late May through July at Bonneville Dam, with peak passage during the last week of June to the first week of July. The two stocks often overlap at Bonneville Dam (Schmitten et al. 1995). Spawning of Snake River spring chinook salmon occurs primarily in the upper reaches of tributaries to the Snake River, with the Salmon River basin providing the bulk of the spawning habitat. Spawning begins in August and extends into late September. Fry of both spring- and summer-run fish emerge from the spawning gravel the following spring (mid-March to mid-May). Juveniles of both groups rear for nearly one year before out-migrating to the ocean as yearling fish. During their downstream migration, yearling smolts of both spring- and summer-run Snake River chinook salmon tend to move more rapidly than the fall-run fish. Index counts at Bonneville Dam indicate that yearling chinook salmon generally pass over Bonneville Dam from early April through late June, with a peak typically occurring in late April or early May (FPC 1993, 1995, 1997). However, in some years (e.g., 1992) the peak has occurred in late May.

Snake River Fall Chinook ESU

(Threatened - Critical Habitat “Designated”)

The present range for the Snake River Fall Chinook Salmon ESU includes the Snake River below Hells Canyon Dam, the lower Clearwater River, the lower Tucannon River, the lower Columbia River and the Pacific Ocean.

Adult Snake River fall chinook salmon are present in the lower Columbia River in August through early October. The peak of the run passes Bonneville Dam between September 7-15. Spawning generally takes place from October to November in the Snake River and lower reaches of several Snake River tributaries. Fall chinook salmon fry emergence occurs from late March through June in the Snake River. Some juveniles begin migrating downstream soon after emerging from the gravel. Others rear near the spawning areas for several weeks before beginning the downstream migration. Some of the subyearling outmigrants rearing the shallow water areas of the Columbia River estuary until they reach smolt size. Juvenile fall chinook salmon have been shown to be present in estuarine areas throughout most of the year with peak abundance occurring in June.

Lower Columbia River Chinook ESU

(Threatened - Critical Habitat "Designated")

The present range for Lower Columbia River chinook includes all river reaches accessible to listed chinook salmon in Columbia River tributaries between the Grays and White Salmon Rivers in Washington and the Willamette and Hood Rivers in Oregon, inclusive. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to the Dalles Dam. Excluded are areas above Condit Dam (OR-WA), The Dalles Dam (OR-WA), Bull Run Dam 2 (OR-WA) and Merwin Dam (WA) or above longstanding, naturally impassible barriers (i.e., natural waterfalls in existence for at least several hundred years).

Lower Columbia River Chinook ESU is considered ocean-type. Not included in this ESU is "stream-type" spring chinook salmon found in the Klickitat River or the introduced Carson spring-chinook salmon. Also not included are introduced "upriver bright" fall chinook salmon populations in the Wind, White Salmon and Klickitat Rivers (63 FR 11481). Both fall-run and spring-run stocks of chinook salmon are included in this ESU. The fall run is predominant. The fall run consists of an early component that return to the river in mid-August and spawn within a few weeks (Kostow 1995) and later components that enter over an extended period of time and spawn from late October through November. The majority of the fall run chinook salmon are called "tules" and are distinguished by their dark skin coloration and advanced state of maturation at the time of freshwater entry. A later returning component of the fall chinook salmon run exists in the Lewis and Sandy Rivers (WDF et al. 1993, Kostow 1995). Because of the longer time interval between freshwater entry an spawning, Lewis and Sandy River fall chinook are less mature at freshwater entry than the tule fall chinook salmon and are commonly termed lower river "brights" (Marshall et al. 1995).

Spring-run chinook salmon on the lower Columbia River enter freshwater in March and April well in advance of spawning in August and September. Most of the spring-run populations have probably been influenced by introductions of hatchery fish.

The majority of fall-run chinook salmon juveniles emigrate to the marine environment as sub-yearlings (Reimers and Loeffel 1967). Scales of a portion of the returning adults indicate a yearling smolt migration. However, this may be the result of extended hatchery-rearing programs rather than of natural volitional yearling migration (Meyers et al. 1998). The downstream migration of fall-run chinook salmon undoubtedly extends over a considerable period of time due to the range of water temperature conditions present in lower Columbia River tributaries. Downstream movements of chinook fry have been observed at Willamette Falls as early as December, but the majority of the downstream movement occurs during the summer and fall months after the fish have reached lengths of 90 to 100 mm (Olsen et al. 1992). Spring-run juvenile downstream migration is variable from stream to stream. In some streams it occurs in the spring (e.g. Klickitat River) and in others (e.g. Clackamas River) it occurs in the summer and fall months (Howell et al. 1985, Olsen et al 1992).

Upper Columbia River Spring Chinook ESU

(Endangered - Critical Habitat "Designated")

The range of the Upper Columbia River Spring Chinook Salmon ESU includes all river reaches accessible to listed chinook salmon in Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington, excluding the Okanogan River. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to Chief Joseph Dam in Washington. Excluded are areas above Chief Joseph Dam (WA) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). The chinook salmon in the Okanogan River are not included in this ESU because they exhibit an "ocean-type" life history rather than a "stream-type" life history.

Adult Upper Columbia River spring chinook salmon migrate upstream through the lower Columbia River in March through May. The peak of the spring chinook run passes Bonneville Dam in the third week of April. The travel time between Longview and Bonneville Dam is about 10 days; therefore, the peak of the run in the project area would be about mid-April. Spawning of Upper Columbia River spring chinook salmon occurs primarily in the upper reaches of the Wenatchee, Entiat, and Methow Rivers. Spawning begins in August and extends into mid-September. Juvenile spring chinook in the Upper Columbia River ESU exhibit typical stream-type life history patterns — spending about a year in fresh water before migrating to the ocean. Review of recent passage index data for yearling chinook salmon at Rock Island Dam (FPC 1993, 1995, and 1997) indicate that migration starts in early April, reaches a peak in mid-May, and is essentially complete by late June.

Upper Willamette River Chinook ESU

(Threatened - Critical Habitat "Designated")

The range for the Upper Willamette River Chinook Salmon ESU includes all river reaches accessible to listed chinook salmon in the Clackamas River and the Willamette River and its tributaries above Willamette Falls. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to, and including, the Willamette River in Oregon. Excluded are areas above Cottage Grove Dam (OR), Dorena Dam (OR), Fern Ridge Dam (OR), Blue River Dam (OR), Big Cliff Dam (OR), and Green Peter Dam (OR) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Historic naturally spawned populations in this ESU have an unusual life history that shares features of both the stream and ocean types. Scale analysis of returning adults indicate a predominately yearling smolt life-history and maturity at 4 years of age, but these data are primarily from hatchery fish and may not accurately reflect patterns for the natural fish. Young-of-year smolts have been found to contribute to the returning 3-year-old year class. The ocean distribution is consistent with an ocean-type life history (63 FR 11481). Based on ladder counts at Willamette Falls, adult spring chinook salmon migrated through the lower Willamette River from March through May with a peak in late April.

Relatively little information is available regarding the timing of downstream movements of juvenile chinook salmon in the lower Willamette River. However, Knutsen and Ward (1992) conducted a 4-year fish-sampling program in the Portland Harbor between 1987 and 1990. They found that yearling chinook salmon smolts were present from early March through early May with peak abundance occurring in mid to late March. They also found yearling chinook salmon in the harbor during November. These fish were attributed to November hatchery releases. Sub-yearling chinook salmon began to appear in the catch by late April peaked by mid-May and remained in decreasing numbers through June. Since both ocean- and stream-type life histories occur within this Upper Willamette River Spring chinook salmon ESU, it appears that juveniles of this ESU could occur in the vicinity of the project from March through June.

Puget Sound Chinook ESU

(Threatened – Critical Habitat "Designated")

The range for the Puget Sound chinook salmon ESU includes the all marine, estuarine and river reaches accessible to listed chinook salmon in Puget Sound. Puget Sound marine areas include South Sound, Hood Canal, and North Sound to the international boundary at the outer extent of the Strait of Georgia, Haro Strait, and the Strait of Juan De Fuca to a straight line extending north from the west end of Freshwater Bay, inclusive. Excluded are areas above Tolt Dam (WA), Lansburg Diversion (WA), Alder Dam (WA), and Elwha Dam (WA) or above longstanding, natural impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Adult Chinook salmon migrate from a marine environment into fresh water streams and rivers of their birth where they spawn and die. Among chinook salmon, two distinct races have evolved. 1) A "stream-type" chinook is found most commonly in headwater streams. Stream-type chinook salmon have a longer freshwater residency and perform extensive offshore migrations before returning to their natal streams in the spring or summer months. 2) A "ocean-type" chinook, which is commonly found in coastal streams in North America. Ocean-type chinook typically migrate to sea within the first three months of emergence, but they may spend up to a year in freshwater prior to emigration. They also spend their ocean life in coastal waters. Ocean-type chinook salmon return to their natal streams or rivers as spring, winter, fall, summer, and late-fall runs, but summer and fall runs predominate (Healey, 1991). The difference between these life history types is physical, with both genetic and morphological foundations.

Adult female chinook will prepare a spawning bed, called a redd, in a stream area with suitable gravel composition, water depth and velocity. Redds will vary widely in size and in location within the stream or river. The adult female chinook may deposit eggs in 4 to 5 "nesting pockets" within a single redd. After laying eggs in a redd, adult chinook will guard the redd from 4 to 25 days before dying. Chinook salmon eggs will hatch, depending upon water temperatures, between 90 to 150 days after deposition. Stream flow, gravel quality, and silt load all significantly influence the survival of developing chinook salmon eggs. Juvenile chinook may spend from 3 months to 2 years in freshwater after emergence and before migrating to estuarine areas as smolts, and then into the ocean to feed and mature. Juvenile ocean-type chinook tend to utilize estuaries and coastal areas more extensively for juvenile rearing. Juvenile chinook salmon feed primarily on aquatic insect larvae and terrestrial insects, typically in the near shore areas. Puget Sound chinook salmon hatch and rear in streams and rivers flowing into Puget Sound, and the Dungeness River and its tributaries.

2. Sockeye Salmon

General Life History

Sockeye salmon (*Oncorhynchus nerka*) are anadromous, meaning they migrate from the ocean to spawn in fresh water. They are the third most abundant of the seven species of Pacific salmon. Unique in their appearance, the adult spawners typically turn bright red, with a green head, and are therefore, called "red" salmon in Alaska. During the ocean and adult migratory phase, sockeye often have a bluish back and silver sides, giving rise to another common name, "bluebacks." The name "sockeye" is thought to have been a corruption of the various Indian tribes' word "sukkai." Sockeye salmon exhibit a wide variety of life history patterns that reflect varying dependency on the fresh water environment. With the exception of certain river-type and sea-type populations, the vast majority of sockeye salmon spawn in or near lakes, where the juveniles rear for 1 to 3 years prior to migrating to sea. For this reason the major distribution and abundance of large sockeye salmon stocks are closely related to the location of rivers that have accessible lakes in their watersheds for juvenile rearing (Burgner, 1991). On the Pacific coast, sockeye salmon inhabit riverine, marine, and lacustrine environments from the Columbia River and its tributaries north and west to the Kuskokwin River in western Alaska. There are also *O. nerka* life forms that are non-anadromous, meaning that most members of the form spend their entire lives in freshwater. Non-anadromous *O. nerka* in the Pacific Northwest are known as kokanee. Among the Pacific salmon, sockeye salmon exhibit the greatest diversity in selection of spawning habitat and great variation in timing of river entry and the duration of holding in lakes prior to spawning. The vast majority of sockeye salmon typically spawn in inlet or outlet tributaries of lakes or along the shoreline of lakes where upwelling of oxygenated water through gravel or sand occurs. However, they may also spawn in (1) suitable stream habitat between lakes, (2) along the nursery lakeshore on outwash fans of tributaries or where upwelling occurs along submerged beaches, and (3) along beaches where the gravel or rocky substrate is free of fine sediment and the eggs can be oxygenated by wind-driven water circulation.

Below is a description of the two ESUs for sockeye identified by NMFS within Washington State.

Snake River Sockeye Salmon ESU

(Endangered – Critical Habitat "Designated")

The sockeye salmon is found along the Pacific coast from the Columbia River northward to the Yukon River in Alaska and westward to Japan. In the Columbia River Basin, sockeye salmon migrate to Osoyoos Lake in the Okanogan River Basin, Wenatchee Lake in the Wenatchee River Basin and Redfish Lake in Idaho. Today, Redfish Lake remains the only sockeye lake that is still accessible in the Snake River Basin.

Adult sockeye salmon enter the Columbia River From late May to the middle of August. The peak occurs at Bonneville Dam from late June to the first week of July (Schmitten et al. 1995). Sockeye smolts migrate out of Redfish Lake from late April through may (Bjornn et al. 1968) after spending one or sometimes two years in Redfish Lake. Juveniles are typically found in the estuarine areas of the lower Columbia River during May and June. Juveniles are believed to be actively migrating through the estuary and have relatively short residence time.

Ozette Lake Sockeye ESU

(Threatened – Critical Habitat “Designated”)

The range for Ozette Lake Sockeye includes all lake areas and river reaches accessible to listed sockeye salmon in Ozette Lake, located in Clallam County, Washington. Excluded are areas above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Sockeye is one of the most complex of any Pacific salmon species because of its variable freshwater residency (one to three years in fresh water), and because the species has several different forms: fish that go to the ocean and back, fish that remain in fresh water, and fish that do both. Sockeye is the only Pacific salmon that depends on lakes as spawning and nursery areas. Scientific evidence indicates that only Ozette lake sockeye warrant protection as a threatened species at this time. About 700 fish have returned annually to spawn over the last five years, compared to annual runs of between 2,000 to 20,000 fish between 1926 and 1949. Ozette Lake sockeye have been declining at an average rate of three percent a year since 1977 and 10 percent a year since 1986.

3. Steelhead Trout

General Life History

The life history of *Oncorhynchus mykiss* is one of the most complex of any of the salmonid species. The species exhibits both anadromous forms (steelhead) and resident forms (usually referred to as rainbow or redband trout). They reside in the marine environment for two to three years prior to returning to their natal stream to spawn as 4- or 5-year-old fish. Unlike Pacific salmon, steelhead trout are iteroparous or capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and those that do are usually females.

Biologically, steelhead can be divided into two reproductive ecotypes, based on their state of sexual maturity at the time of river entry. These two ecotypes are termed “stream-maturing” and “ocean-maturing”. Stream-maturing steelhead enter fresh water in a sexually immature condition and require from several months to a year to mature and spawn. These fish are often referred to as “summer run” steelhead. Ocean-maturing steelhead enter fresh water with well-developed gonads and spawn shortly after river entry. These fish are commonly referred to as “winter-run” steelhead. In the Columbia River basin essentially all steelhead that return to streams east of the Cascade mountains are stream maturing. Ocean-maturing fish are the predominate ecotype in coastal streams and lower Columbia River tributaries.

Native steelhead in California generally spawn earlier than those to the north with spawning beginning in December. Washington populations begin spawning in February or March. Native steelhead spawning in Oregon and Idaho is not well documented. In the Clackamas River in Oregon, winter-run steelhead spawning begins in April and continues into June. In the Washougal River, Washington, summer-run steelhead spawn from March into June whereas summer run fish in the Kalama River, Washington spawn from January through April. Among inland steelhead, Columbia River populations from tributaries upstream of the Yakima River spawn later than most downstream populations.

Depending on water temperature, fertilized steelhead eggs may incubate in redds for 1.5 to 4 months before hatching as “alevins”. Following yolk sac absorption, young juveniles or “fry” emerge from the gravel and begin active feeding. Juveniles rear in fresh water for 1 to 4 years, then migrate to the ocean as smolts. Downstream migration of wild steelhead smolts in the lower Columbia River begins in April, peaks in mid-May and is essentially complete by the end of June (FPC 1993, 1995, 1997). Previous studies of the timing and duration of steelhead downstream migration indicate that they typically move quickly through the lower Columbia River estuary with an average daily movement of about 21 kilometers (Dawley et al. 1979 and 1980).

Below is a description of the five ESUs for steelhead identified by the NMFS within Washington State.

Snake River Basin Steelhead Trout ESU

(Threatened – Critical Habitat "Designated")

This steelhead ESU includes all river reaches accessible to listed steelhead in the Snake River and its tributaries in Idaho, Oregon, and Washington. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to the confluence with the Snake River. Excluded are areas above Hells Canyon Dam (ID-OR) and Dworshak Dam (ID) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Snake River steelhead are summer steelhead and comprise two groups, A- and B-run, based on migration timing, ocean age and adult size. Snake River Basin steelhead enter fresh water from June to October and spawn during the following spring from March to May. "A-run" steelhead are thought to be predominately age-1-ocean, while "B-run" steelhead are though to be age-2-ocean (Busby et al. 1996). Snake River Basin steelhead usually smolt as 2- or 3-year olds (BPA 1992). Downstream migration of wild steelhead smolts begins at Lower Granite Dam by mid-June (FPC 1993, 1995 and 1997). These fish probably pass Bonneville Dam during the latter half of the steelhead smolt migration (i.e., between mid-May and mid- to late June).

Lower Columbia River Steelhead ESU

(Threatened – Critical Habitat "Designated")

The Lower Columbia River Steelhead ESU includes all river reaches accessible to listed steelhead in the Columbia River tributaries between the Cowlitz and Wind Rivers in Washington and the Willamette and Hood Rivers in Oregon, inclusive. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to Hood River in Oregon. Excluded are areas above Bull Run Dam 2 (OR-WA) and Merwin Dam (WA) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Adult steelhead from this ESU move upstream through the lower Columbia River throughout all months of the year. Wild summer-run steelhead enter fresh water from March through October. Wild winter-run steelhead enter fresh water from mid-November through May. Spawning for summer-run steelhead generally begins in March and continues through early June. Spawning for winter-run steelhead begins as early as January in some streams. The period of peak spawning varies from stream to stream but generally occurs in April and May.

Juvenile steelhead in the ESU generally smolt at two years of age. Downstream migration of both summer-run and winter-run steelhead through the lower Columbia River begins in March peaks in late April/early May and declines through July (Cramer and Bullock 1995, Dawley et al 1986).

Middle Columbia River Steelhead ESU

(Threatened – Critical Habitat "Designated")

The Middle Columbia River Steelhead ESU includes all river reaches accessible to listed steelhead in Columbia River tributaries (except the Snake River) between Mosier Creek in Oregon and the Yakima River in Washington, inclusive. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to the Yakima River in Washington (inclusive). Excluded are areas above Condit Dam (OR-WA) and Pelton Dam (OR) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Steelhead of the Snake River Basin are excluded.

The life history of steelhead in this ESU is generally typical of the inland steelhead life-history pattern. All of the populations are summer-run fish with the exception of a small winter run in Fifteen Mile Creek near the Dalles, Oregon, and winter fish runs in the Klickitat and White Salmon Rivers in Washington. Both of the latter streams also support summer-run steelhead. Genetic information for the Fifteen Mile Creek population indicates that it is allied with the inland *O. mykiss.* Most Middle Columbia River steelhead smolt at two years and spend 1 to 2 years in salt water. After re-entering freshwater they may remain there for up to a year before spawning. Most streams in this ESU produce about equal numbers of 1-ocean and 2-ocean steelhead. Adults from this ESU occur over an extended period of time in the lower Columbia River. Most of the adults migrate upstream through the lower Columbia River from mid-April through October with a peak in abundance from mid-July through early September. In addition, there are several populations that have later runs that enter fresh water in August and continue in the lower River through October or November. The winter run to Fifteen Mile Creek enters fresh water in January.

Downstream migration of juveniles occurs late March through June, with peak abundance occurring from late April through mid-May.

Upper Columbia River Steelhead ESU

(Endangered – Critical Habitat "Designated")

The Upper Columbia River Steelhead ESU includes all river reaches accessible to listed steelhead in Columbia River tributaries upstream of the Yakima River, Washington and downstream of Chief Joseph Dam. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to Chief Joseph Dam River in Washington (inclusive). Excluded are areas above Chief Joseph Dam (WA) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Life-history characteristics for Upper Columbia River Basin steelhead are similar to those of other inland steelhead ESUs. However, some of the oldest smolt ages, up to seven years, are reported from this ESU. This age may be associated or correlate with cold stream temperatures (Mullan et al., 1992). Based on limited information, it appears that the majority of juveniles smolt at age 2. Passage index counts of wild steelhead smolts at Rock Island dam indicate that the downstream migration begins in April, peaks between late April and late May, and declines through mid-June (FPC 1993, 1995, 1997). These fish probably pass Bonneville Dam during the second half of the steelhead smolt migration (between mid May and late June). Upper Columbia River Basin steelhead typically spend from 1 to 2 years in the ocean before returning to spawn. The upstream migration in the lower Columbia River begins in mid-June and continues into November.

Upper Willamette River Steelhead ESU

(Threatened – Critical Habitat "Designated")

The Upper Willamette River Steelhead ESU includes all river reaches accessible to listed steelhead in the Willamette River and its tributaries above Willamette Falls upstream to, and including, the Calapooia River. Also included are river reaches and estuarine areas in the Columbia River from a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) upstream to, and including, the Willamette River in Oregon. Excluded are areas above Big Cliff Dam (OR) and Green Peter Dam (OR) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Only late-run (native) winter steelhead are included in this ESU. Adults of the late-run Willamette River winter steelhead enter the lower Columbia River in mid-February and

March. Spawning usually commences in the tributaries in April and continues through mid-May (Busby et al. 1996). Information specific to timing of downstream migration of native juvenile late-run winter steelhead is generally lacking. Electrofishing and purse seining conducted in the Portland Harbor in the lower Willamette River during 1987 and 1988 indicate that juvenile steelhead (all stocks) passed through the harbor from late April through June (Knutsen and Ward 1992). As on review of available data, Cramer and Bullock (1995) concluded that downstream migration of juvenile winter steelhead (all stocks) begins in March, peaks in May, and continues at low levels through July.

4. Chum Salmon

General Life History

Chum salmon (*Oncorhynchus keta*) are one of the largest Pacific salmon (only chinook salmon are larger). The are semlparous (spawn only once then die), spawn primarily in fresh water, and apparently exhibit obligatory anadromy, as there is no recorded landlocked or naturalized freshwater populations. Also known as “dog” salmon, the species is best known for the enormous canine-like fangs and striking body color of spawning males (i.e., a calico pattern, with the anterior two-thirds of the flank marked by a bold, jagged, reddish line and the posterior third of the flank marked by a jagged black line). Females are less flamboyantly colored and lack the extreme dentition of the males. Chum have the widest natural spawning distribution of any Pacific salmon. The range of the chum salmon extends from Korea and the Japanese Island of Hoshu, east around the rim of the North Pacific Ocean, to Monterey Bay in southern California.

The life history of chum salmon is similar to other North America species of salmon, but the time spent in freshwater is brief and primarily for reproduction (Bakkala, 1970; Hale, 1981). Chum salmon migrate to the estuaries during their first spring or summer of life, spending minimal time rearing in fresh water. Adult chum salmon live in the offshore marine or estuarine environments. Adult chum salmon enter the Columbia River beginning in late September. The run typically peaks in mid-November.   Adults may enter freshwater to spawn as 3-, 4-, or 5-year-old fish.   Adult Chum salmon usually enter their natal river systems from June to March, depending on characteristics of the population and geographic location. Redds are usually dug in the mainstream or in side channels of the rivers, and the nest site is chosen based on the gravel substrate. Juveniles outmigrate to seawater almost immediately after emerging from the gravel that covers their redds (Salo, 1991). Survival and growth of juvenile chum salmon depend less on freshwater conditions and more on favorable estuarine and marine conditions.

Below is a description of the two ESUs identified by the NMFS within the State of Washington.

Columbia River Chum ESU

(Threatened - Critical Habitat "Designated")

The Columbia River Chum ESU includes all river reaches accessible to listed chum salmon (including estuarine areas and tributaries) in the Columbia River downstream from Bonneville Dam, excluding Oregon tributaries upstream of Milton Creek at river km 144 near the town of St. Helens. Excluded areas are above Bonnevile Dam (OR-WA) and Merwin Dam (WA) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Three streams on the Washington side of the river (Hamilton and Hardy Creeks near Bonneville Dam and the Grays River) support native spawning populations (WDF et al., 1993), while about 23 small native populations have been identified from streams on the Oregon side of the river (Kostow 1995).

Hood Canal Summer Chum ESU

(Threatened - Critical Habitat "Designated")

This ESU includes all river reaches accessible to listed chum salmon (including estuarine areas and tributaries) draining into Hood Canal and Dungeness Bay, Washington. Also included are estuarine/marine areas of Hood Canal, Admiralty Inlet, and the Straits of Juan De Fuca to the international boundary and as far west as a straight line extending north from Dungeness Bay. Excluded are areas above Cushman Dam (WA) or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years).

Hood Canal summer-run chum spawn from mid-September to mid-October. In general, summer-run chum salmon are most abundant in the northern part of the species range, where they spawn in the mainstems of rivers. Farther south, water temperatures and stream flows during late summer and early fall become unfavorable for salmonids. These conditions do not improve until the arrival of fall rains in late October/November. Summer-run chum salmon populations from Washington must return to fresh water and spawn during periods of peak high water temperature, suggesting an adaptation to specialized environmental conditions that allow this life-history strategy to persist in an otherwise inhospitable environment. Therefore, these populations contribute substantially to the ecological/genetic diversity of the species as a whole.

Chum salmon may depend less on freshwater habitats than some other Pacific salmonids; but their spawning areas still extend up to 80 km upstream in many rivers and their requirements for successful spawning and rearing, such as cold, clean water and relatively sediment free spawning gravel, are similar to other Pacific salmon. Alterations and loss of freshwater habitat for salmonids have been extensively documented in many regions. Large woody debris (LWD) plays a significant role in creating and maintaining Pacific salmon spawning and rearing habitat. Many rivers have been cleared for navigation, and extensive stream work was accomplished to facilitate log drives. It is reported that some of the more adverse impacts on the estuarine and freshwater habitats used by chum resulted from stream work in the 1800s and early 1900s when logs were transported down streams and stored in mainstems of rivers, lakes, and estuaries. The factors listed as most significant to chum are as follows: 1) water withdrawal, conveyance, storage, and flood control (resulting in insufficient flows, stranding, juvenile entrainment, and instream temperature increases); 2) logging and agriculture (loss of LWD, sedimentation, loss of riparian vegetation, habitat simplification); 3) mining (particularly gravel removal, dredging, pollution); and 4) urbanization (stream channelization, increased runoff, pollution, habitat simplification).

5. **Lower Columbia River/Southwest Washington &**

Puget Sound/Strait of Georgia Coho ESU

(Candidate Species – Critical Habitat not applicable)

General Life History

Coho salmon (*Oncorhynchus kisutch*) are anadromous, meaning they migrate from the ocean to spawn in fresh water. Also known as “silver” salmon, the species was historically distributed throughout the North Pacific Ocean from central California to Point Hope, AK, west through the Aleutian Islands, and from the Anadyr River, Russia, south to Hokkaido, Japan. Historically, this species probably inhabited most coastal streams in Washington, Oregon, and central and northern California. Some populations, now considered extinct, are believed to have migrated hundreds of miles inland to spawn in tributaries of the upper Columbia River in Washington, and the Snake River in Idaho.

In contrast to the life history pattern of other anadromous salmonids, coho salmon in the region under status review general exhibit a relatively simple, 3-year life cycle. Adults typically begin their freshwater spawning migration in the late summer and fall, spawn by mid-winter, then die. Run and spawn timing of adult coho salmon varies between and within coastal and Columbia River Basin populations. Depending on temperature, eggs incubate in “redds” (gravel nests excavated by spawning females) for 1.5 to 4 months before hatching as “alevins” (a larval life stage dependent on food stored in a yolk sac). Following yolk sac absorption, alevins emerge from the gravel as young juveniles or “fry” and begin actively feeding. Juveniles rear in fresh water for up to 15 months, then migrate to the ocean as “smolts” in the spring. Coho salmon typically spend two growing seasons in the ocean before returning to their natal stream to spawn as 3 year olds. Some precocious males, called “jacks”, return to spawn after only 6 months at sea.

During this century, indigenous, naturally reproducing populations of coho salmon are believed to have been extirpated in nearly all Columbia River tributaries and to be in decline in numerous coastal streams in Washington, Oregon, and California. At least 33 populations have been identified by agencies and conservation groups as being at moderate or high risk of extinction. In general, there is a geographic trend in the status of West coast coho salmon stocks, with the southernmost and easternmost stocks in the worst condition.

The factors threatening naturally reproducing coho salmon populations are numerous and varied. Logging, agricultural activities, urbanization, stream channelization, dams, wetland loss, water withdrawals, and unscreened diversions for irrigation, and mining have contributed to the decline of numerous West Coast populations of coho salmon.

6. Bull trout

General Life History

Bull trout (*Salvelinus confluentus*) are native to western North America, are widespread throughout tributaries of the Columbia River basin, including the headwaters in Montana and Canada. Bull trout are generally non-anadromous and live in a variety of habitats including small streams, large rivers, and lakes or reservoirs. However, Coastal/Puget Sound bull trout are anadromous, migrating and maturing in Puget Sound or the Pacific Ocean. They may spend the first 2 to 4 years in small natal streams and then migrate through the larger rivers, lakes, and reservoirs to Puget Sound and the Pacific Ocean. Bull trout exhibit resident and migratory life history strategies through much of the current range (Rieman and McIntyre 1993). Resident bull trout complete their entire life cycle in the tributary (or nearby) streams in which they spawn and rear. Migratory bull trout spawn in tributary streams where juvenile fish rear from one to four years before migrating to either a lake (adfluvial), river (fluvial), or in certain coastal areas, to saltwater (anadromous), where maturity is reached in one of the three habitats (Fraley and Shepard 1989; Goetz 1989). Resident and migratory forms may be found together and it is suspected that bull trout give rise to offspring exhibiting either resident or migratory behavior (Rieman and McIntyre 1993).

In some stocks of bull trout, maturing adults may begin migrating to the spawning grounds in the spring or early summer. Female bull trout may deposit up to 5,000 or 10,000 eggs in the redds they build, depending on their size. The embryos incubate during the fall, winter, and spring; and the surviving fry emerge from the redds in April and May. The rate of embryo development is dependent upon temperature. After they emerge, the young bull trout disperse up and down stream to find suitable areas to feed. Feeding areas for Coastal/Puget Sound bull trout include estuaries and nearshore marine waters. Young fish feed primarily on aquatic invertebrates in the streams during their first 2 or 3 years but become more piscivorous as they get larger.

The bull trout has been eliminated from some of its native range and seriously reduced in abundance in most of the remaining drainages. Excessive exploitation, habitat degradation, and introductions of exotic species are probably the major causes of the declines.

Bull trout have more specific habitat requirements compared to other salmonids (Rieman and McIntyre 1993). Habitat components that appear to influence bull trout distribution and abundance include water temperature, cover, channel form and stability, valley form, spawning and rearing substrates, and migratory corridors (Oliver 1979; Pratt 1984, 1992; Fraley and Shepard 1989; Goetz 1989; Hoelscher and Bjornn 1989; Sedell and Everest 1991; Howell and Buchanan 1992; Rieman and McIntyre 1993, 1995; Rich 1996; Watson and Hillman 1997). Bull trout typically spawn from August to November during periods of decreasing water temperatures. However migratory bull trout frequently begin spawning migrations as early as April. Bull trout require spawning substrate consisting of loose, clean gravel relatively free of fine sediments (Fraley and Shepard 1989). Depending on water temperature, incubation is normally 100 to 145 days (Pratt 1992), and after hatching, juveniles remain in the substrate. Time from egg deposition to emergence may surpass 200 days. Fry normally emerge from early April through May depending upon water temperatures and increasing stream flows (Pratt 1992, Ratliff and Howell 1992). Bull trout are opportunistic feeders with food habits primarily a function of size and life history strategy. Resident and juvenile migratory bull trout prey on terrestrial and aquatic insects, macro zooplankton and small fish (Boag 1987; Goetz 1989; Donald and Alger 1993). Adult migratory bull trout are primarily piscivorous, known to feed on various fish species (Fraley and Shepard 1989; Donald and Alger 1993).

Below is a description of the two Distinct Population Segments (DPSs) for bull trout as defined by USFWS.

Coastal/Puget Sound Bull Trout DPS

(Threatened – Critical Habitat "Not proposed or designated at this time")

The Coastal/Puget Sound bull trout population segment encompasses all Pacific Coast drainages within Washington, including Puget Sound. This population segment is discrete because the Pacific Ocean and the crest of the Cascade Mountain Range geographically segregate it from subpopulations. The population segment is significant to the species as a whole because it is thought to contain the only anadromous forms of bull trout in the conterminous U.S., thus, occurring in a unique ecological setting. No bull trout exist in coastal drainages south of the Columbia River.

A 1998 WDFW study found 80 bull trout/Dolly Varden populations in Washington: 14 (18 percent) were healthy; two (3 percent) were in poor condition; six (8 percent) were critical and the status of 58 (72 percent) of the stocks were unknown. Bull trout are estimated to have occupied about 60% of the Columbia River Basin, and presently occur in 45% of the estimated historical range (Quigley and Arbelbide 1997).

Land and water management activities that degrade bull trout habitat and continue to threaten all of the bull trout population segments include dams, forest management practices, livestock grazing, agriculture, and roads and mining (Beschta et al. 1987; Chamberlain et al. 1991; Furniss et al. 1991; Meehan 1991; Nehlsen et al. 1991; Sedell and Everest 1991; Craig and Wissmar 1993; MBTSG 1998). Fish barriers, timber harvesting, agricultural practices, and urban development are thought to be major factors affecting “native char” in the Coastal/Puget Sound DPS (Fed Register 1999e).

Columbia River Bull Trout DPS

(Threatened - Critical Habitat “Not proposed or designated at this time”)

The Columbia River DPS includes bull trout residing in portions of Oregon, Washington, Idaho, and Montana. Bull trout are native throughout the Pacific Northwest and historically occurred throughout the Columbia River Basin, east to western Montana, south to the Jarbidge River in northern Nevada, the Klamath Basin in Oregon, the McCloud River in California and north to Alberta, British Columbia and possibly southeastern Alaska. Although the species was once abundant and widespread, bull trout now exist primarily in upper tributary streams and several lake and reservoir systems. The main populations remaining in the lower 48 states are in Montana, Idaho, Oregon and Washington, with a small population in northern Nevada.

Bull trout historically occurred in major river drainages in the Pacific Northwest from about 41 deg. N to 60 deg. N latitude, from the southern limits in the McCloud River in northern California and the Jarbridge River in Nevada to the headwaters of the Yukon River in Northwest Territories, Canada (Cavender 1978; Bond 1992). To the west, bull trout range included Puget Sound, various rivers of British Columbia, Canada, and southeast Alaska (Bond 1992). Bull trout are widespread throughout the tributaries of the Columbia River basin, including its headwaters in Montana and Canada (Cavender 1978). Bull trout are estimated to have occupied about 60% of the Columbia River Basin, and presently occur in 45% of the estimated historical range (Quigley and Arbelbide 1997). Bull trout passage is prevented or inhibited at hydroelectric, flood-control, or irrigation dams in almost every major river in the Columbia River basin.

Within the Columbia River population segment, 66 percent of bull trout subpopulations are isolated by dams or indirectly by dam or water diversion operations that alter habitat conditions (i.e., flow, sediment and temperature regimes, migration corridors, and interspecific interactions). Individuals that pass downstream over or through dams are often lost from the upstream subpopulations. Dams have converted historic rearing habitats for migratory fish in the larger river systems to reservoirs with conditions that frequently are unsuitable for bull trout (MBTSG 1996b), especially where non-native salmonids occur. Although the predominant effects of dams affect the long term viability of bull trout populations (Rieman and McIntyre 1993; Gilpin, in litt. 1997), dams can benefit bull trout by preventing introduced non-native species access to upstream areas.

7. Southwest Washington/ Columbia Cutthroat Coastal Trout DPS

(Proposed Threatened–Critical Habitat "Not proposed or designated at this time")

General Life History

The proposed boundaries of the DPS for *Oncorhynchus clarki clarki* are similar to those of the lower Columbia River/southwest Washington Coast coho salmon ESU. The DPS comprises cutthroat trout in the Columbia River and its tributaries downstream from the Klickitat River in Washington and Fifteen Mile Creek in Oregon and the Willamette River and its tributaries downstream from Willamette Falls. This DPS also includes cutthroat trout in Washington coastal drainages from the Columbia River to Grays Harbor (inclusive).

The coastal cutthroat trout differs from all other trout by its profusion of small to medium-size spots of irregular shape (not round, as on most interior cutthroat subspecies), which are distributed more or less evenly over the sides of the body, onto the head, and often onto the ventral surface and anal fin. Of all interior subspecies, only the Lahontan cutthroat trout has spots distributed like those of the coastal subspecies, but the spots of Lahontan cutthroat trout are larger, rounder, and fewer. The spots on coastal cutthroat trout are densely packed.

The coastal form does not develop the brilliant colors of some interior subspecies. Sea-run individuals are silvery, and the silvery skin deposits often obliterate or make body spots. Resident freshwater fish tend to be darker with a coppery or brassy sheen. Pale yellowish to orange-red. A rose tint is sometimes apparent on the sides and ventral regions of sexually mature fish, especially in lake-dwelling stocks.

The life history of coastal cutthroat trout is perhaps the most complex of the Pacific salmonids (Northcote 1997a), with reproductive and migratory behaviors at least as diverse as those of steelhead and sockeye salmon and perhaps more similar to some species in the genera *Salmo* (e.g., Atlantic salmon *[S. sala*r] and brown trout *[S. trutt*a]*),* *Salvelinus* (e.g., bull trout *S. confluentu*s], Dolly Varden *[S. malm*a], and Arctic char *[S. alpinu*s]*),* and *Hucho* (Stearley and Smith 1993). Unlike many Pacific salmonids where all (e.g., chum or pink salmon) or almost all (e.g., coho and chinook salmon and steelhead) members are anadromous, coastal cutthroat trout populations may contain both migratory and nonmigratory individuals within the same population (reviewed in Hall et al. 1997). Although all coastal cutthroat trout populations with access to the sea are believed to have an anadromous component, not all members of the subspecies migrate to the sea (Giger 1972, Sumner 1972, Trotter 1989). Most cutthroat trout that do enter seawater do so as 2- or 3-year-olds, but some remain in fresh water for up to 5 years before entering the sea (Giger 1972, Sumner 1972). Other coastal cutthroat trout never outmigrate at all, but remain in small headwater tributaries. Still others migrate only into rivers or lakes (Nicholas 1978a, b; Tomasson 1978; Moring et al. 1986; Trotter 1989) even when they have seawater access (Tomasson 1978). For example, anadromous, freshwater migratory, and nonmigratory life-history forms of coastal cutthroat trout have all been reported in southern Oregon's Umpqua River Basin (Trotter 1989, Loomis and Anglin 1992, Loomis et al. 1993, Hooton 1997).

Multiple life-history forms frequently coexist within the same watershed and even the same stream (June 1981, Johnston 1982). Where multiple forms exist together, spatial and temporal differences in reproductive behaviors may be large enough to promote genetic differentiation (June 1981, Zimmerman 1995). On the other hand, similar environmental conditions (such as water temperature and velocity) may facilitate reproductive overlap of life-history forms. Allelic and meristic variation among coastal cutthroat trout populations in the Nisqually River's Muck Creek basin led Zimmerman (1995) to suggest that the expression of anadromy probably differs among populations within a basin even when no geologic barrier exists. Thus, some populations may be entirely anadromous, some may be entirely freshwater forms, and some may have multiple life-history forms.

Direct comparisons of coastal cutthroat trout life-history traits among populations or individuals have not been made under controlled conditions; even so, it is unclear to what extent such comparisons would be applicable to natural populations. Information from other species suggests that anadromous forms may occasionally have nonanadromous progeny, and vice versa (Nordeng 1983, Kaeriyama et al. 1992, Burgner et al. 1992, and Mullan et al. 1992). Both of these relationships may occur in coastal cutthroat trout, according to otolith microchemistry analysis of fish in Oregon's Elk River (Griswold 1996). Griswold (1996) found that some sea-run cutthroat trout had signals in the otolith primodia that indicated their maternal parent was in fresh water at the time of yolk formation and that they migrated to the marine environment. Other fish had strontium/calcium signals that indicated their maternal parent was in the marine environment at the time of yolk formation and that they also migrated to the marine environment.

The migratory patterns of coastal cutthroat trout suggest that patterns may vary within as well as among populations. Some populations of coastal cutthroat trout are split into migratory and nonmigratory individuals; a phenomenon termed “partial migration” by Jonsson and Jonsson (1993).

These studies illustrate that while the vast majority of fish within a population probably behave similarly, some individuals may exhibit migratory behaviors that differ from their cohorts. The notion that all fish in a population fit neatly into one category or the other may not be true (Gowan et al. 1994). In a study on brown trout, Harcup et al. (1984) found no evidence to suggest that the migratory component of the population was composed of permanently mobile individuals. Rather, they found that individual brown trout switched between migrating and not migrating, and migratory fish were no more likely to move in subsequent sampling periods than nonmigratory fish.

Environmental conditions, particularly those affecting growth rate, have been shown to markedly alter the degree of residency expressed in some salmonid species (Jonsson 1985,Hindar et al. 1991, Northcote 1992). In an intensive study on Arctic char, Nordeng (1983) reared the progeny of experimentally produced crosses of freshwater and anadromous individuals under different feeding regimes and found that increasing the amount of food significantly increased the proportion of freshwater individuals to anadromous fish. Not only could each form produce progeny of any form, but single individuals could also change forms during their lifetimes. The age at sexual maturity of the parents, however, influenced the age at sexual maturity of their offspring. Thus, the offspring of small freshwater fish produced earlier maturing (nonmigratory) offspring and fewer smolts than did the offspring of anadromous parents (Nordeng 1983).

Some salmonids, as illustrated in the above example, have a behavioral flexibility that allows them to respond to environmental conditions. There is some empirical evidence to suggest that coastal cutthroat trout migratory behaviors may be flexible, but the extent to which such a strategy occurs is unknown. In an ongoing study that began in the spring of 1997, the Alaska Department of Fish and Game (ADFG) started PIT (passive integrated transponder) tagging coastal cutthroat trout as they outmigrated to sea from Auke Lake (D. Jones 7). During the fall of 1997, an upstream migrant trap was operated and all immigrating coastal cutthroat trout were counted. Previously tagged fish were individually identified and recorded by their PIT tag number and immigration date. Again, in the spring of 1998 coastal cutthroat trout were recorded leaving the lake and all unmarked fish were tagged. During the summer of 1998, ADFG surveyed the lake for freshwater forms of coastal cutthroat trout and found three fish that had been PIT tagged on their emigration to sea in 1997, returned to the lake in the fall of 1997, and apparently opted to remain in the lake in 1998.

Other empirical evidence supports the idea that life-history patterns can vary within individual coastal cutthroat trout over time. For example, some sea-run cutthroat trout may spawn before their first saltwater migration (Giger 1972, Tomasson 1978, Fuss 1982, Jones footnote 7), and others may not return to sea after spawning but may instead remain in fresh water for a year (Tomasson 1978).

This diversity in life history may reflect an adaptive generalist strategy that allows coastal cutthroat trout to exploit habitats not fully utilized by other salmonids (Johnston 1982, Northcote 1997a). For example, their small size at maturity may give coastal cutthroat trout an adaptive advantage for using small streams for spawning and rearing and reduce interspecific competition with other anadromous spawning salmonids (Pearcy et al. 1990). Conversely, post-spawning coastal cutthroat trout or those on feeding migrations are larger than outmigrating juveniles of other Pacific salmon species, which allows coastal cutthroat trout to prey on these fish in a variety of freshwater and estuarine habitats (Pearcy et al. 1990, Northcote 1997a). For these reasons, Northcote (1997a) suggested that, historically, coastal cutthroat trout were probably present year round in a wider variety of climatological conditions and diversity of marine and freshwater habitats than any other salmonid in the coastal Pacific Northwest (Northcote 1997a).

The diversity of migratory behaviors in coastal cutthroat trout makes identification of fish by life-history form particularly challenging. One way to separate coastal cutthroat trout into population groupings is to classify them by the physical locations where they are caught (e.g., Wyatt 1959, Tomasson 1978, June 1981, Moring et al. 1986). These classifications, however, are somewhat arbitrary as fish may move from one area to another (Northcote 1997a). Consequently, the location and timing of sampling may affect which life-history category migratory individuals are chosen to represent (Fausch and Young 1995). For instance, coastal cutthroat trout believed to be freshwater forms one year may migrate to sea another year (e.g., some fish do not make their initial migration to sea until age 6 (Sumner 1962, Giger 1972) and some sea-run cutthroat trout may not enter saltwater every year after their initial smolt migration, but may instead stay in fresh water (Tomasson 1978, Jones footnote 7). For these reasons, we define the three general life-history forms of coastal cutthroat trout as follows.

Nonmigratory coastal cutthroat trout — This life-history form includes fish generally found in small streams and headwater tributaries near spawning and rearing areas. These fish typically undertake only small-scale migrations and maintain relatively small home territories compared to forms that make more extensive migrations. In general, nonmigratory coastal cutthroat trout appear to grow more slowly than other life-history forms of trout (Tomasson 1978, Trotter 1989), are smaller at maturity (seldom larger than 150-200 mm in length), and rarely live longer than 2 to 3 years (Wyatt 1959, Nicholas 1978a, June 1981). However, as June (1981) points out, the lack of older fish in his study may be due not only to age-dependent mortality, but also to scale-aging problems or outmigration of older larger fish from the study area.

Freshwater-migratory coastal cutthroat trout — This freshwater or potamodromous (e.g., Myers 1949, Tomasson 1978) life-history form includes fish that migrate entirely within fresh water. A variety of distinctive population migrations are frequently recognized within this general classification, including populations that migrate from large tributaries to small tributaries to spawn (fluvial-adfluvial), populations that inhabit lakes and migrate upstream to spawn in the lake inlet (lacustrine-adfluvial), and populations that live in lakes and migrate downstream to spawn in the lake outlet (allucustrine) (Varley and Gresswell 1988, Trotter 1991).

These freshwater-migratory populations are best documented in rivers and lakes with physical barriers to anadromous fish, such as above Willamette Falls in the Willamette River. Historically, these falls apparently barred access of anadromous fish to the upper river; above this barrier, schools of coastal cutthroat trout were found to migrate from natal spawning areas to mainstem feeding areas and back (Dimick and Merryfield 1945; Nicholas 1978a,b; Moring et al. 1986). River-migrating coastal cutthroat trout have also been reported as schooling in large streams above migration barriers in southwest Oregon (e.g., upper Chetco River and upper Silver Creek [Illinois Basin]) (ODFW 1993b).

Saltwater-migratory coastal cutthroat trout — In most areas, this is the most familiar life-history form of coastal cutthroat trout, and most of the biological information presented in "General Biology" and the following sections was derived from studies on saltwater migratory individuals. The juvenile fish migrate from freshwater natal areas in the late winter and spring to feed in marine environments (estuarine or nearshore) during the summer. They then enter fresh water in the winter to feed, seek refuge, or spawn, typically returning to seawater in the spring.

Trophic migratory model — The classification of coastal cutthroat trout into life-history forms may be based more on convenience than on true biological categories (e.g., Gross 1987), considering the inherent difficulty in distinguishing between forms and the wide variability in migratory patterns. One way to consider migratory movement in coastal cutthroat trout is proposed by Northcote (1997a) in terms of functional processes in a "migratory/residency spectrum" or cycle. In Northcote's model (1997a), juveniles migrate from natal rearing areas to feeding habitats, which may be an ocean, estuary, river, or small headwater tributary. They may then migrate to a refuge area for overwintering; the migration may be from the sea to the river or from the river to the headwater tributary. In the spring, the individual may migrate back to a feeding habitat (and repeat this for several years), or may migrate to the spawning area and begin the cycle all over again. This individual behavior does not exclude the likelihood that natural selection has led to adaptations in some populations primarily for anadromous migrations or for remaining in headwater areas.

Mechanisms of life-history expression — For any organism, life-history diversity represents both opportunities for and constraints to adaptive evolution. An organism's life history is its repertoire of attributes affecting its fitness (Roff 1992, Stearns 1992), what Williams (1966) called its "design for survival." These attributes are those affecting development, growth, dispersal, and reproduction, including traits such as fecundity, offspring size, migratory propensity, size and age at maturity, and reproductive schedule. The high degree of genetic differentiation (at presumably neutral genes) among some coastal cutthroat trout populations demonstrates that there is also ample opportunity for local adaptations to arise. The complexity of life-history variation in coastal cutthroat trout undoubtedly reflects in part such adaptations, but major life-history trait variations also can occur due to genetic drift in isolated populations or in those founded by few individuals. Understanding the underlying basis of variation in life-history traits is necessary in order to make predictions about the responses of coastal cutthroat trout populations to changes in their environment.

There is evidence that at least some individual coastal cutthroat trout adopt a complex (and perhaps plastic) migratory strategy. For example, an individual might spend several years in a nonmigratory or freshwater migratory phase before migrating to seawater for a period of up to a few months, return to fresh water to spawn or overwinter, and then repeat this cycle (or a variation of it) one or more times (see Giger 1972, Tomasson 1978, Fuss 1982). This diversity expressed by individual fish may represent several possible responses to environmental conditions, options that are rare in Pacific salmon. It is possible that Pacific salmon exhibit fewer migratory behaviors because reproductive options are limited, especially after smoltification (Thorpe 1987).

The observed complexity in life-history traits in coastal cutthroat trout likely reflects (at least in part) unique adaptations to local environments–attributes that are important to the diversity of a DPS.

Life History Stages

Spawning-Anadromous cutthroat trout spawning typically starts in December and continues through June, with peak spawning in February (reviewed in Pauley et al. 1989, Trotter 1989). In California, spawning is reported to begin in November, with peak spawning in late December in larger river basins and late January and February in the smaller coastal rivers and streams (e.g., Howard and Albro 1995, 1997; Gale 1996, 1997; Taylor 1997). Redds are primarily built in the tails of pools in streams with low stream gradient and low flows, usually less than 0.3 cubic meters/second during the summer (Johnston 1982).

Generally, spawning occurs upstream of coho salmon and steelhead spawning zones, although some overlap may occur (Lowry 1965, Edie 1975, Johnston 1982). It is believed that this choice by coastal cutthroat trout of spawning sites in small tributaries at the upper limit of spawning and rearing sites of coho salmon and steelhead has evolved to reduce competition for suitable spawning sites and reduce competitive interactions between young-of-the-year coastal cutthroat trout and other salmonids. Reduction of juvenile competition may be particularly important at this early life-history stage, as coastal cutthroat trout typically emerge later and at a smaller size than fry of these other species (Johnston 1982). These spatial separations may limit hybridization between coastal cutthroat trout and rainbow trout or steelhead. In many drainages where rainbow and coastal cutthroat trout coexist, a slight difference in spawn timing between the two species is believed to reduce the opportunity for hybridization (Cramer 1940, DeWitt 1954, Sumner 1972, Glova and Mason 1977, Johnston 1982).

Cutthroat trout are iteroparous, and the incidence of repeat spawning appears to be higher than in steelhead (Sumner 1953, Giger 1972, and Busby et al. 1996). Some fish have been documented to spawn each year for at least 5 years (Giger 1972), although some do not spawn every year (Tomasson 1978) and some do not return to seawater after spawning but instead remain in fresh water for at least a year (Giger 1972, Tomasson 1978). In general, coastal cutthroat trout exhibit considerable variation in age and size at maturity. Nonmigratory coastal cutthroat trout typically mature at an early age (2 to 3 years) whereas sea-run cutthroat rarely spawn before age 4 (Trotter 1991). Larger fish, because of their size, can obtain the best spawning sites and produce larger eggs (Trotter 1997). Although large males tend to be the principal spawners in most populations, small males can dart in and fertilize some of the eggs. This tactic could be particularly successful for coastal cutthroat trout because they spawn in small streams that often have numerous places for a small male to hide near a spawning pair (Jonsson et al. 1984). When large migrant males are absent, small males may become principal spawners (Jonsson 1985).

Spawners may experience high post-spawning mortality due to weight loss of as much as 38% of pre-spawning mass (Sumner 1953) and other factors (Cramer 1940, Sumner 1953, Giger 1972, Scott and Crossman 1973). Still, in one Oregon stream, over 39% of one year’s spawning population returned to spawn the next year, 17% for the third year, and 12% for the fourth year (Sumner 1953). However, in another stream with an intense sport fishery, only 14% returned to spawn in the second year (Giger 1972).

Cutthroat trout are among the salmonids most vulnerable to overharvest by angling (Gresswell and Harding 1997), especially during post-spawning outmigrations to summer feeding areas. This relatively heavy harvest mortality on repeat spawners has been a concern of biologists in the Pacific Northwest for many years (Giger 1972, Johnston 1982, Gresswell and Harding 1997), especially as first-year coastal cutthroat spawners often have fewer and poorer quality eggs than do repeat spawners.

Incubation and emergence — Eggs begin to hatch within 6-7 weeks of spawning, depending on temperature; alevins emerge as fry between March and June, with peak emergence in mid-April (Giger 1972, Scott and Crossman 1973). At emergence, fry quickly migrate to channel margins and backwaters, where they remain throughout the summer (Glova and Mason 1976, Moore and Gregory 1988). Coastal cutthroat trout are found in streams with channel gradients that vary from low (< 2%) to moderate (2-3%) or steep (> 4%), with narrow widths (0.7-3.0 m) (Hartman and Gill 1968, Edie 1975, Glova 1978, Moore and Gregory 1988, Jones and Seifert 1997), and often in small watersheds with drainage areas under 13 km 2 (Hartman and Gill 1968).

Juvenile movements — Coastal cutthroat trout parr generally remain in upper tributaries until they are 1 year of age, when they may begin moving more extensively throughout the river system. Once these movements begin, it is difficult to determine whether fish caught in upstream or downstream traps are parr making a freshwater migration, or smolts on a seawater-directed migration; many unpaired coastal cutthroat trout of similar size caught in these traps have characteristics of either life-history stage or intermediate characteristics (Tomasson 1978, Fuss 1982). In Oregon, Lowry (1965) and Giger (1972) found that downstream-directed movement by juveniles in the Alsea River system began with the first spring rains, usually in mid-April with peak movement in mid-May. Giger (1972) also reported that some juveniles entered the estuary and remained there over the summer but apparently did not smolt or migrate to the open ocean. He was unable to determine how many of these “parr” continued moving seaward and how many remained in the estuaries. Such movement further confounds the difficulty in separating nonanadromous downstream migrations from seaward migrations.

In Oregon, Washington, and British Columbia, upstream movement of juveniles with parr marks from estuaries and mainstems to tributaries began with the onset of winter freshets during November (Giger 1972, Moring and Lantz 1975, Cederholm and Scarlett 1982, Hartman and Brown 1987, Garrett 1998) and continued through the spring, frequently peaking during late winter and early spring (Cederholm and Scarlett 1982, Hartman and Brown 1987, Garrett 1998). Many of these yearling fish averaged less than 200 mm in length (Moring and Lantz 1975, Garrett 1998) and were found in streams that ran through ponds or sloughs (Hartman and Gill 1968, Garrett 1998).

Smoltification and seawater entry — Smoltification involves a number of behavioral, morphological, and physiological changes that prepare juvenile salmonids for their trophic migration to the sea (Fontaine 1975, reviewed in Clarke and Hirano 1995). Some authors consider the transformation of juvenile salmon from freshwater parr to seaward-migrating smolt as a “metamorphosis” (Wald 1958). An essential part of smoltification is an increase in euryhalinity, which allows the smolt to live in salinities varying from fresh water to full-strength seawater. Visually, smoltification is characterized by morphological changes in color and body shape. The first change is most obvious: smolts lose their juvenile parr marks (oval-shaped and darkly pigmented melanin bars on the lateral surface) and take on a silvery sheen caused by the accumulation of guanine and purine in the scales and superficial dermal layers of the skin. Secondly, the weight-to-length ratio declines, resulting in a more streamlined body shape.

No studies have been conducted to develop a biochemical “smoltification index” for coastal cutthroat trout. Furthermore, some coastal cutthroat trout migrate to estuaries in the spring and, at least on the Oregon coast (Giger 1972, Sumner 1972, Tomasson 1978) and in the Cowlitz River on the Lower Columbia River (Tipping 1981), will remain in the estuary throughout the summer, returning to fresh water in the fall. In the Rogue River, Tomasson (1978) concluded from chemical analysis of scales that coastal cutthroat trout did not enter the open sea, but remained in the estuary throughout the summer. Tomasson (1978) speculated that sea-run Rogue River coastal cutthroat trout may remain in the estuary to avoid predation by steelhead called “half-pounders” that do not conduct long oceanic migrations, instead residing during the summer in the nearshore ocean where sea-run cutthroat trout usually occur. Still, all fish that enter and reside in an estuary for several months need to be able to adapt to varying concentrations of salt water, especially during summer months when freshwater flow and runoff is minimal.

Some coastal cutthroat trout do undergo complete smoltification, and these fish have been best identified from open ocean samples. Loch and Miller (1988) and Pearcy et al. (1990) both report capturing sea-run cutthroat trout as far as 66 km offshore that lacked the marking of sea-run *O. c. clarki* caught in estuaries. The fish caught in the open ocean were “very silvery, and could only reliably be distinguished from steelhead by the presence of basibranchial teeth” (Pearcy 1997).

As discussed previously, researchers have found that coastal cutthroat trout that enter the sea generally do so after 2-4 years in the freshwater environment (Sumner 1962, Lowry 1965, Giger 1972, Michael 1980, Fuss 1982). Notable exceptions to this are summarized in studies from Alaska that indicate a majority of the emigrants are between 4 and 6 years of age at initial seawater entry (Armstrong 1971, Jones 1978). Time of initial seawater entry of smolts bound for the ocean generally occurs between March and July, varies by locality, and may be related to marine conditions or food sources (Sumner 1953, 1972; Lowry 1965, 1966; Giger 1972; Johnston and Mercer 1976; Trotter 1989). In Washington and Oregon, entry begins as early as March, peaks in mid-May, and is essentially over by mid-June (Sumner 1953, 1972; Lowry 1965; Giger 1972; Moring and Lantz 1975; Johnston 1982).

It has been suggested that seaward migration of smolts to more protected areas (e.g., Puget Sound or the Columbia River) occurs at an earlier age and smaller size than migration to more exposed areas (e.g., the outer Washington coast) (Johnston 1982). Johnston (1982) also reported that in Puget Sound and the Columbia River smolts make their first migration at age 2, at a mean size of about 160 mm. On the California, Oregon, and Washington coasts, coastal cutthroat trout make their initial seawater migration between ages 2 and 3, with a few age-4 migrants of mean sizes ranging from 150 to 255 mm (Lowry 1965; Giger 1972; Sumner 1972; Fuss 1982; Redwood National Park 1983, 1988-93; USFWS 1995). However, studies on age and size at initial seawater entry are rare.

The relatively brief exposure of sea-run cutthroat trout to seawater, compared to other anadromous salmonids, should not necessarily be construed as an indication that the marine phase of the life cycle is less important for sea-run cutthroat trout. The relative importance of the marine phase may vary among populations, at least on relatively large geographic scales, depending on conditions in estuaries and nearshore habitats (Reeves et al. 1997). In some coastal cutthroat trout populations, only a small proportion of the individuals may be anadromous (DeWitt 1954, Gerstung 1997), a condition also found in *O. nerka* and *O. mykiss* but rare in other Pacific salmonid species. Thus, although the marine phase can be very important to sea-run cutthroat trout in enhancing opportunities for growth and dispersal to neighboring drainages, the freshwater phase may be relatively more important for juvenile growth and survival in sea-run cutthroat trout than for other anadromous salmonids, at least in some populations where estuaries are small or nearshore habitat is limited.

Adult freshwater migrations — Coastal cutthroat trout may return to freshwater feeding/spawning areas from late June through the following April. Re-entry timing has been found to be temporally consistent from year to year within streams, but varying widely between streams (Giger 1972). As in other species of anadromous salmonids, entry to large rivers seem to occur consistently earlier than to shorter coastal rivers (Giger 1972, Johnston and Mercer 1976, Johnston 1982). In small streams, such as Carnation Creek in British Columbia, Minter Creek in Washington, and Sand Creek in Oregon, peak returns occur in December and January, and fish may continue to return through March (Sumner 1953, Anderson and Narver 1975, Johnston 1982). These streams usually have low flows (< 0.6 cubic meters/second).

In large river systems within Washington and Oregon (such as the Stillaguamish, Columbia, Cowlitz, Alsea, and Umpqua rivers), coastal cutthroat trout return migrations usually begin as early as late June and continue through October, with peaks in late September and October (Lavier 1963; Bulkley 1966; Hisata 1971, 1973; Duff 1972; Giger 1972; Wright 1973; Tipping and Springer 1980; Tipping 1981, 1986; ODFW 1993a).

Temperature Tolerance in Coastal Cutthroat Trout

Coastal cutthroat trout are exposed to a wide range of water temperatures across their distribution and, relative to other salmonids, little information on their habitat requirements is available (Hunter 1973, Golden 1975, Bjornn and Reiser 1991). Still, like other salmonids, coastal cutthroat trout have evolved to take advantage of temperature regimes in their home ranges. When abrupt changes occur in water temperatures or other physical factors, the fish usually compensate by seeking refugia, but changes from the normal pattern can reduce their survival (Golden 1975, Bjornn and Reiser 1991).