1. Background

1.1 Introduction

Populations of coho salmon (*Oncorhynchus kisutch*) once ranged across the western part of North America from the coastal river basins of Alaska to interior areas of Washington and probably inhabited most coastal streams in Washington, Oregon, and northern and central California (62 FR 24588, May 6, 1997). These populations were sufficiently large that they were able to withstand changing environmental conditions. Fisheries for these and other salmonids supported vibrant communities across the Pacific Northwest. Salmon were a critical part of healthy ecosystems in rivers and the ocean.

Part of the range of coho salmon occurs in the Southern Oregon/Northern California Coast (SONCC) Recovery Domain, which encompasses the rivers from Punta Gorda, California to Cape Blanco, Oregon. The coho salmon which occupy this area make up the SONCC coho salmon Evolutionarily Significant Unit (ESU). An ESU is a population of organisms that is considered distinct for purposes of conservation. An ESU must meet two criteria: it must be substantially reproductively isolated from other nonspecific population units, and it must represent an important component of the evolutionary legacy of the species (57 FR 58612, November 20, 1991).

In the late 1990s, the populations that make up the SONCC Coho Salmon ESU were small and poorly distributed and subject to factors that threatened their continued existence. Consequently, the ESU was first listed as threatened under the Endangered Species Act (ESA) in 1997. “Threatened” status means the species is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (ESA Section 3(20)). An “endangered” species is one that is in danger of extinction throughout all or a significant portion of its range (ESA Section 3(6)). The status of the species has continued to worsen since listing (Good et al. 2005, Williams et al. 2011), despite fishing prohibitions and habitat improvements.

The Rogue River has the longest time series of coho salmon adult abundance information in the ESU, and its populations are among those in the best condition. Nonetheless, coho salmon returns there are a small fraction of what they once were. Based on extrapolations from cannery pack data, up to 114,000 adult coho salmon returned to the Rogue River in the late 1800s even after heavy fishing pressure had occurred for years (Meengs and Lackey 2005). Figure 1-1 shows the estimated number of adult coho salmon spawners that returned to the Rogue River from 1980 to 2010, based on counts at Huntley Park (Oregon State University (OSU) 2010), as well as the recovery target for all populations in the Rogue River as presented in this recovery plan. The number of adults has been consistently below that needed for the Rogue River to play its role in recovery of the SONCC coho salmon ESU.

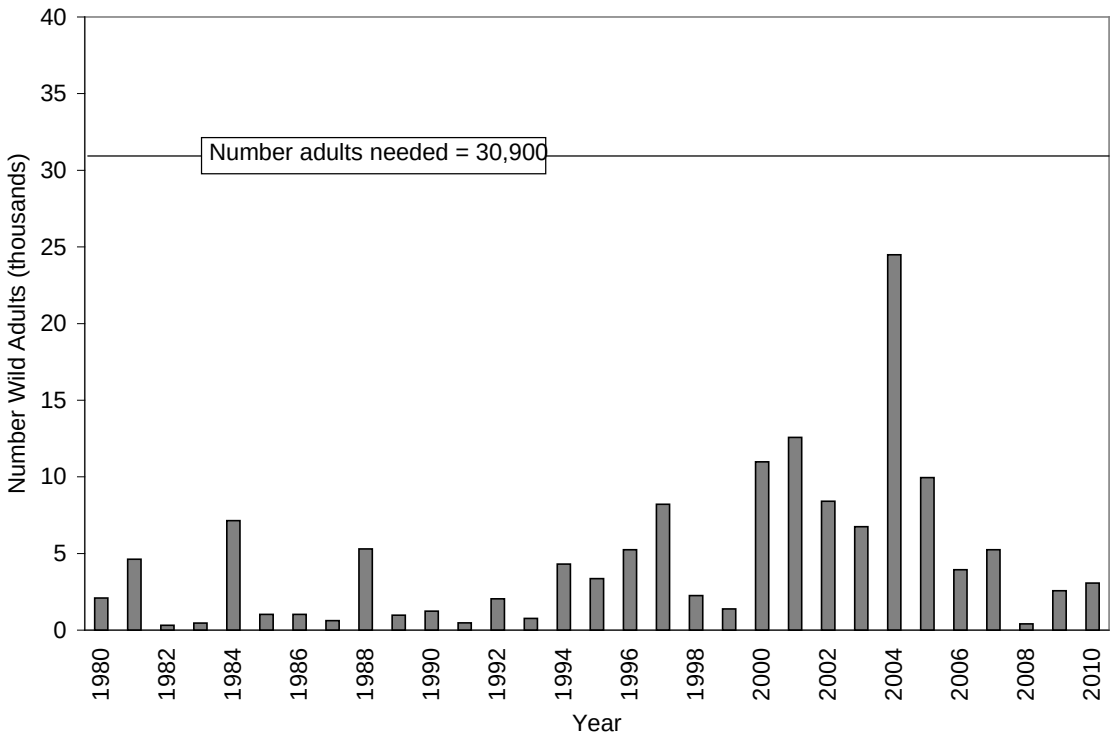

Figure 1-1. Estimates of the run size of wild Rogue basin coho salmon past Huntley Park, 1980-2010 (ODFW 2011), compared to number needed from Rogue River for ESU recovery.

1.2 What is a recovery plan?

"Recovery" is the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the ESA are no longer needed (NMFS 2004). When a species is listed under the ESA, a recovery plan generally must be prepared (ESA Section 4(f)(1)). The ESA envisions recovery plans as the central organizing tool for guiding each species' recovery process. The recovery plan is a road map to recovery – it lays out where we need to go and how best to get there. The plan organizes, coordinates, and prioritizes the many possible actions that may be taken to achieve recovery of a species. Use of a recovery plan ensures that recovery efforts target limited resources effectively and efficiently.

Recovery plans are guidance documents. No agency or entity is required by the ESA to implement a recovery plan. However, recovery plans describe how Federal agencies can best meet their responsibilities under the ESA. Specifically, section 7(a)(1) of the ESA calls on all Federal agencies to "utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species…" In addition to outlining strictly proactive measures to achieve the species' recovery, plans provide context and a framework for implementation of other provisions of the ESA with respect to a particular species, such as section (7)(a)(2) consultations on Federal agency activities, development of Habitat Conservation Plans or Safe Harbor agreements under Section 10, or special rules for threatened species under section 4(d).

1.3 Achieving Recovery

Even with NMFS and other Federal agencies doing all within their power to achieve recovery of SONCC coho salmon, recovery will likely not occur. Federal agencies have neither the funds nor the authority to bring about all the actions necessary to sufficiently improve the condition of this species. Partnerships are a critical component of SONCC coho salmon recovery: partnerships between private landowners, tribes, and local, state, and federal government agencies; between non-governmental organizations and landowners; and between federal, state, and local agencies. A recovered ESU can provide ecosystem, recreation, and economic benefits to communities. All of these entities have a common interest in bringing healthy coho salmon populations and their ecosystems back to California's north coast. The states of California and Oregon have been proactive in determining the recovery needs of coho salmon.

1.3.1 Oregon Plan for Salmon and Steelhead

The Oregon Coastal Salmon Restoration Initiative (OCSRI) is a planning process which began in 1995 with the following mission " To restore our coastal salmon populations and fisheries to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits." In 1997, the State of Oregon released the Oregon Plan, a conservation plan designed to restore salmon to a level at which they can once again be a part of people's lives (State of Oregon 1997). The Oregon Plan included the following goals:

- Goal 1: An infrastructure will exist to provide long-term continuity in leadership, direction, and oversight of salmon restoration.
- Goal 2: Opportunities will exist for a wide range of natural resource uses that are consistent with salmon restoration.
- Goal 3: Achievement of overall OCSRI goals will be based to the greatest extent on existing laws and environmental protections, rather than new ones.
- Goal 4: An adequate funding base will be established and maintained to support the OCSRI.
- Goal 5: Oregon's expectations for sustainability of interrelated natural resources will more accurately reflect a scientific understanding of the physical and biological constraints of the ecosystem.
- Goal 6: Sufficient freshwater and estuarine habitat will be available to support healthy populations of anadromous salmonids throughout coastal riverbasins.
- Goal 7: Populations of salmonids in coastal river basins will achieve levels of natural production consistent with overall restoration goals.
- Goal 8: A science-based system will support evaluation of progress of the OCSRI Conservation Plan and will provide a basis for making appropriate future changes to management programs.

ODFW concerns with recovery framework

ODFW has concerns that the methods used to produce Williams et al. (2006) may overestimate the extent of historic coho production in the populations within the Northern Coastal and Interior Rogue diversity strata. Further, ODFW believes these methods may have led to inaccurate characterizations of historic populations as larger than they likely were. Finally, ODFW believes the low-risk targets for core populations may not need to be achieved if the other 3 VSP criteria are being met. This has been identified as a critical research need in Chapter 5 and ODFW intends to reevaluate the population structure, and associated recovery criteria, within the Northern Coastal and Interior Rogue diversity strata as part of a conservation planning process. ODFW is in general agreement with NMFS on the recovery actions needed for Oregon populations, including a recovery action (present in all populations) which calls for refinement of the methods used to delineate populations and set population targets.

Report of Oregon Expert Panel

ODFW (2008b) convened a panel of fisheries and watershed scientists as an initial step in their development of a recovery plan for Oregon's SONCC coho salmon populations. Deliberations of the expert panel provided ODFW with initial, strategic guidance on limiting factors and threats to recovery. The panel identified limiting factors and threats affecting each SONCC coho independent and dependent population in Oregon by considering the impacts across the entire life cycle. The results of the expert panel deliberations are described in each Oregon population profile.

1.3.2 Recovery Strategy for California Coho Salmon

Coho salmon north of San Francisco were listed as threatened under the California Endangered Species Act in 2002. In 2004, the California Fish and Game Commission approved the Recovery Strategy for California Coho Salmon (CDFG 2004). The plan identified six goals to achieve delisting:

- Goal I: Maintain and improve the number of key populations and increase the number of populations and cohorts of coho salmon.
- Goal II: Maintain and increase the number of spawning adults.
- Goal III: Maintain the range, and maintain and increase distribution of coho salmon.
- Goal IV: Maintain existing habitat essential for coho salmon.
- Goal V: Enhance and restore habitat within the range of coho salmon.
- Goal VI: Reach and maintain coho salmon population levels to allow for the resumption of Tribal, recreational, and commercial fisheries for coho salmon in California.

1.4 Listing of Species

The SONCC coho salmon ESU was listed as threatened in 1997, and this status was reaffirmed in 2005 (62 FR 24588, May 6, 1997 and 70 FR 37160, June 28 2005). This ESU includes all coho salmon populations between Punta Gorda, California and Cape Blanco, Oregon) and all coho salmon produced by hatcheries in that range in 2005. The decision to list the SONCC coho salmon ESU was largely based on information regarding decreased abundance, reduced distribution, and degraded habitat. There are far fewer streams and rivers supporting coho salmon in this ESU now compared to historic conditions, and numerous basin-specific extirpations of coho salmon have been documented (Brown et al. 1994, NMFS 1996, CDFG 2004, Good et al. 2005, Gustafson et al. 2007). At the time of listing, the major factors in the decline of the species were thought to originate from long-standing, human-induced actions (e.g., habitat degradation, harvest, water diversions, and artificial propagation), combined with natural environmental variability (62 FR 24588, May 6, 1997). .

The SONCC coho salmon ESU is made up of 45 ephemeral, dependent, and independent populations (Williams et al. 2006). Five of these populations are not part of the recovery strategy described in this plan: Three were excluded due to reductions in IP (see Appendix A), and two are ephemeral.

According to Section 4(a)(1) of the ESA and NMFS listing regulations (50 CFR Part 424), a species may be found to be endangered or threatened based on any one or a combination of five factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; and (E) other natural or human-made factors affecting its continued existence. The effect of these factors on SONCC coho salmon was considered when the species was listed. The descriptions of each of the factors that follow summarize the final rule from the listing of the SONCC coho salmon ESU (62 FR 24588, May 6, 1997). Chapter 3, as well as Chapters 8 to 48, describe the state of current stresses and threats.

1.4.1 Factor A: Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range

The habitat factors for the decline of SONCC coho salmon are as follows: Channel morphology changes, substrate changes, loss of instream roughness, loss of estuarine habitat, loss of wetlands, loss/degradation of riparian areas, declines in water quality (e.g., elevated water temperatures, reduced dissolved oxygen, altered biological communities, toxics, elevated pH, and altered stream fertility), altered streamflows, fish passage impediments, elimination of habitat, and direct take (62 FR 24588, May 6, 1997). The major activities responsible for the decline of coho salmon were identified as follows: logging, road building, grazing and mining activities, urbanization, stream channelization, dams, wetland loss, beaver trapping, water withdrawals, and unscreened diversions for irrigation (62 FR 24588, May 6, 1997).

1.4.2 Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overfishing in non-tribal fisheries was identified as a significant factor in the decline of coho salmon (62 FR 24588, May 6, 1997). Significant overfishing occurred from the time marine survival turned poor for many stocks (ca. 1976) until the mid-1990s when harvest was substantially curtailed. This overfishing compromised escapement levels. The contribution of recreational fisheries to the decline was unknown at the time of listing. Tribal harvest was not considered to be a major factor for the decline of coho salmon in either the Klamath River basin or Trinity River basin (62 FR 24588, May 6, 1997). Collection for scientific research and educational programs was believed to have little or no impact on coho salmon populations in the SONCC coho salmon ESU at the time of listing (62 FR 24588, May 6, 1997).

1.4.3 Factor C: Disease or Predation

At the time of listing, disease and predation were not believed to be major factors contributing to the overall decline of coho salmon, although it was recognized that they may have had substantial impacts in local areas (62 FR 24588, May 6, 1997).

1.4.4 Factor D: Inadequacy of Existing Regulatory Mechanisms

Habitat Management

Federal lands owned by the U.S. Forest Service (in California and Oregon) and Bureau of Land Management (in California) are managed under the Northwest Forest Plan. NMFS determined the Northwest Forest Plan has important benefits for coho salmon, but that its overall effectiveness in conserving SONCC coho salmon is limited by the extent of federal lands and the fact that Federal land ownership is often not uniformly distributed. Federal lands are often located in the upper reaches of watersheds or river basins, upstream of much of the most suitable coho salmon rearing habitat. In addition, in some areas Federal lands are distributed in a checkerboard fashion, which results in fragmented landscapes.

NMFS determined California's forest practice rules (CFPRs) contained provisions that can be protective of coho salmon if fully implemented, but found the ability of these rules to protect coho salmon could be improved (62 FR 24588, May 6, 1997). In particular, the CFPRs did not adequately address large woody debris recruitment, streamside tree retention to maintain bank stability, and canopy retention standards that assure stream temperatures are properly functioning for all life stages of coho salmon. NMFS was not able to assess the adequacy of the CFPRs due to the lack of published documentation that the CFPRs are functioning to protect coho salmon (62 FR 24588, May 6, 1997). The CFPRs were revised in 2009 and renamed the Anadromous Salmonid Protection Rules, which are described in Chapter 3.

NMFS determined that Oregon's Forest Practices Act (OFPA) did not have implementing rules that adequately protect coho salmon habitat. NMFS determined that there was a low probability that adequate LWD recruitment could be achieved under the requirements of the OFPAs. The OFPA was also found to not adequately consider and manage timber harvest and road construction on sensitive, unstable slopes subject to mass wasting, nor did it address cumulative

effects. In particular, the OFPA was found to not provide adequate protection for the production and introduction of large woody debris (LWD) to medium, small, and non-fish bearing streams.

The Army Corps of Engineers regulates removal and fill activities under section 404 of the Clean Water Act (CWA), and the Oregon Division of State Lands (DSL) manages the state-permitted portion of the removal fill laws. At the time of listing, neither the ACOE nor the DSL had in place any process to address the additive effects of the continued development of waterfront, riverine, coastal, and wetland properties (62 FR 24588, May 6, 1997).

Implementation of the CWA was found to have not been effective in adequately protecting fishery resources, especially with respect to non-point sources of pollution (62 FR 24588, May 6, 1997). Total Maximum Daily Loads (TMDLs) are calculations of the maximum amount of pollutant (e.g., sediment, temperature) that a waterbody can receive and still safely meet water quality standards. TMDLs are a method for quantitative assessment of environmental problems which affect drinking water, aquatic life, recreation, and other uses of rivers, lakes, and streams. The ability of TMDLs to protect SONCC coho salmon was expected to be significant in the long-term, but their effectiveness was as yet unknown because few, if any, TMDLs had been developed for water bodies in the range of SONCC coho salmon at the time of listing (62 FR 24588, May 6, 1997).

At the time of listing, the impacts to fish habitat from agricultural activities had historically not been closely regulated, but Oregon's Department of Agriculture had recently completed guidance for development of Agricultural Water Quality Management Plans (AWQMPs). It was unknown whether AWQMPs would adequately address salmonid habitat factors (62 FR 24588, May 6, 1997).

Harvest Management

The final rule described fishery regulations implemented in 1994 which are more protective of SONCC coho salmon than were historical regulations (62 FR 24588, May 6, 1997). Specifically, in 1994 the Pacific Fishery Management Council (PFMC) recommended harvest rates below those allowed, and the PFMC recommended prohibiting the retention of coho salmon south of Cape Falcon, Oregon, resulting in the closure of commercial ocean fishing for coho salmon in California in 1994. Oregon began marking all hatchery fish, to aid in more accurate estimates of natural returns. State regulations for ocean fisheries within 3 miles of shore had generally conformed to these more protective regulations. In 1995, ocean recreational fishing was closed from Cape Falcon to Horse Mountain. Amendment 13 to the Pacific Fishery Management Council (PFMC) Fishery Management Plan (FMP), approved in 1999, limited marine fishery impacts on SONCC coho to no more than 13.0 percent (PFMC 1999).

1.4.5 Factor E: Other Natural or Human-made Factors

NMFS determined that long-term trends in rainfall and marine productivity associated with atmospheric conditions in the North Pacific Ocean likely have a major influence on coho salmon production (62 FR 24588, May 6, 1997). The effects of extended drought on water supplies and water temperatures were recognized as a major concern for California populations of coho

salmon. Poor ocean conditions were believed to have played a prominent role in the decline of coho salmon populations in Oregon and California (62 FR 24588, May 6, 1997).

The widespread use of artificial propagation of coho salmon was recognized to have had a significant negative impact on the production of West Coast coho salmon (62 FR 24588, May 6, 1997). Potential problems associated with hatchery programs include: genetic impacts on indigenous, naturally-reproducing populations, disease transmission, predation on wild fish, depletion of wild stock to increase brood stock, and replacement rather than supplementation of wild stocks through competition and continued annual introduction of hatchery fish. Advancement and compression of run timing has also been a common effect of hatchery programs.

1.5 Critical Habitat Designation

Critical habitat for SONCC coho salmon was designated as all accessible reaches of rivers (including estuarine areas and tributaries) between the Cape Blanco, Oregon, and Punta Gorda, California (64 FR 24049, May 5, 1999) . Critical habitat includes all waterways, substrate, and adjacent riparian zones below longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Tribal lands that were excluded in the critical habitat designation include: Big Lagoon Rancheria, Blue Lake Rancheria, Elk Valley Rancheria, Hoopa Valley Indian Reservation, Karuk Reservation, Laytonville Rancheria, Quartz Valley Reservation, Resighini Rancheria, Round Valley Reservation, Sherwood Valley Rancheria, Smith River Rancheria, and Yurok Reservation.

In the critical habitat designation, NMFS identified five essential habitat types for SONCC coho salmon: (1) spawning areas; (2) adult migration corridors; (3) juvenile summer and winter rearing areas; (4) juvenile migration corridors; and (5) areas for growth and development to adulthood. Spawning and rearing are often located in small headwater streams and side channels. Adult and juvenile migration corridors include these tributaries as well as mainstem reaches and estuarine zones. Growth and development to adulthood occurs primarily in near-and off-shore marine waters, although final maturation takes place in freshwater tributaries when the adults return to spawn (64 FR 24049, May 5, 1999). Within these areas, essential features of coho salmon critical habitat include adequate substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions. In addition, designated freshwater and estuarine critical habitat includes riparian areas that provide the following functions: shade, sediment, nutrient or chemical regulation, stream bank stability, and input of large woody debris or organic matter (64 FR 24049, May 5, 1999).

1.6 4(d) Protective Regulation

NMFS regulations under ESA Section 4(d) of the ESA (50 CFR § 223.203) exempt or “limit” a range of activities from the take prohibitions for certain threatened salmon, including SONCC coho salmon. Section 4(d) of the ESA directs NMFS to issue regulations to conserve species listed as threatened. This applies particularly to “take”. The ESA prohibits any take of species listed as endangered, but some take of threatened species that does not interfere with salmon survival and recovery can be allowed. NMFS initially promulgated a 4(d) protective regulation

for this ESU in 2000 (65 FR 42422, July 10, 2000) and subsequently amended the regulations which are codified at 50 CFR § 223.203.

The rule's principal function is to prohibit actions that take threatened species without a specific approval or authorization (NMFS 2003). The rule applies to ocean and inland areas and to any authority, agency, or private individual subject to U. S. jurisdiction. The rule does not prohibit actions or programs—it prohibits illegal take. Activities that do not kill or injure protected salmon and steelhead do not require any special authorization and are not affected by the rule. The limits can be thought of as exceptions to the take prohibitions. To be approved for a limit on ESA take prohibitions, a program must adequately contribute to the conservation of salmon and meet their biological requirements. The limits represent programs or activities, or criteria for future programs or activities, for which take prohibitions are not applied.

1.7 Addition of hatchery stocks to SONCC coho salmon ESU

NMFS established a policy on the role of artificially propagated Pacific salmon and steelhead in listing determinations under the ESA (70 FR 37204, June 28, 2005). Specifically, this policy: (1) establishes criteria for including hatchery stocks in ESUs and DPSs; (2) provides direction for considering hatchery fish in extinction risk assessments of ESUs and DPSs; (3) requires that hatchery fish determined to be part of an ESU be included in any listing of an ESU or DPS; (4) affirms our commitment to conserving natural salmon and steelhead populations and the ecosystems upon which they depend; and (5) affirms our commitment to fulfilling trust and treaty obligations with regard to the harvest of some Pacific salmon and steelhead populations, consistent with the conservation and recovery of listed salmon ESUs and steelhead DPSs.

To determine whether a hatchery program was part of an ESU or DPS, NMFS convened the Salmon and Steelhead Hatchery Advisory Group (SSHAG), which divided existing hatchery programs into categories (SSHAG 2003). Because the new hatchery listing policy changed the way NMFS considered hatchery fish in ESA listing determinations, we completed new status reviews and ESA-listing determinations for many West Coast salmon ESUs and steelhead DPSs. NMFS issued final listing determinations (70 FR 37160, June 28, 2005) for 16 ESUs of Pacific salmon, including the SONCC coho salmon ESU. This listing determination added three artificial propagation programs to the SONCC coho salmon ESU: The Cole Rivers Hatchery, Trinity River Hatchery, and Iron Gate Hatchery coho hatchery programs. NMFS determined these artificially propagated stocks were no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the ESU.

1.8 Status reviews

1.8.1 2005 Status Review

In 2004, NMFS convened a biological review team (BRT) to evaluate the status of SONCC coho salmon. The BRT report (Good et al. 2005) concluded that the SONCC Coho Salmon ESU remained at a threatened status. The BRT found that data did not suggest any marked change, either positive or negative, in the abundance or distribution of coho salmon within the SONCC coho salmon ESU. They stated that coho salmon populations continued to be depressed relative

to historical numbers, and there were strong indications that breeding groups had been lost from a significant percentage of streams within their historical range (Good et al. 2005). The BRT noted that the 2001 broodyear appeared to be one of the strongest perhaps of the last decade, following a number of relatively weak years (Good et al. 2005). Risk factors identified in previous status reviews such as severe declines from historical run sizes, the apparent frequency of local extinctions, long-term trends that were clearly downward, and degraded freshwater habitat and associated reduction in carrying capacity continued to concern the BRT. The BRT noted that several risk factors had been reduced, including termination of hatchery production of coho salmon at Mad River and Rowdy Creek and restrictions on recreational and commercial harvest of coho salmon since 1994 (Good et al. 2005). A new risk identified by the BRT was the introduction of nonnative Sacramento pikeminnow (*Ptychocheilus grandis*) to the Eel River (Good et al. 2005).

1.8.2 2011 Status Review

The most recent status review concluded the ESU remains threatened (NMFS 2011). Monitoring indicates that abundance of coho salmon decreased for many populations in the ESU since the last status review. Population trends are downward. Additionally, a majority of independent populations are well below low-risk abundance targets, and many may also be below the high-risk depensation thresholds. None of the seven diversity strata appear to support a single viable population. However, all of the diversity strata are occupied by coho salmon.

The authors of the status review expressed concern about these recent declines in abundance of coho salmon across the ESU, regardless of what the contributing factor(s) may have been (e.g., marine survival conditions and drought). The negative short-term trends observed in the limited number of time series were not unexpected given the apparent low marine survival in recent years (<1% for the 2004 to 2006 year classes). However, as population sizes have decreased other factors (e.g., small population dynamics) may be adversely affecting coho salmon populations in spite of the improved ocean conditions that occurred from 2007 to 2009. The declining abundance trends and low spawner abundance for most populations in the ESU underscore the importance of addressing freshwater habitat conditions across the ESU so that all populations are sufficiently resilient to withstand fluctuations in marine survival.

The threats discussed in the five factor analysis were found to be largely unchanged since the last status review with the exception of those associated with natural or manmade factors (NMFS 2011). In particular, threats from poor ocean conditions, drought, climate change, and small population size (depensation and stochastic processes) have or are likely to have increased and may be responsible for the observed declines in abundance. The marine survival of hatchery fish from the Cole Rivers Hatchery on the Rogue River was extremely low for the 2005 and 2006 brood years (i.e., 0.05% and 0.07%, respectively) and the average ocean conditions in 2010 (NWFSC 2011) suggest there may be poor marine survival for the 2011 spawning season. Drought conditions occurred for three consecutive years (2007-2009) that decreased instream flows and habitat conditions for juvenile coho salmon and very likely reduced their freshwater survival. Although whether significant habitat changes are occurring from climate change is unclear, the authors expect a wide range of future detrimental changes to coho salmon habitat. Lastly, because many coho salmon populations in this ESU are low in abundance, and may well be below their depensation thresholds, their risk of extinction may also be increasing.

1.9 Species Description and Taxonomy

The coho salmon generally 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, and then die. The run and spawning times vary between and within populations. Depending on river temperatures, 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 2 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.

1.9.1 Life History

Spawning and Incubation

Most coho salmon spawning streams flow directly into the ocean or are tributaries of large rivers. Females tend to prepare their redds (gravel nests) and spawn soon after arriving on spawning grounds between November and January with spawning timing varying by watershed within the ESU (Weitkamp et al. 1995). Coho generally choose sites to spawn in near the head of a riffle, just below a pool where there is abundant small to medium gravel (Shapovalov and Taft 1954) and the number of fertilized eggs deposited in each redd is based on the fecundity of the female and their individual fertilization success. Fecundity ranges between 1,400 to 3,000 eggs and these eggs are dispersed among pockets within the redd (Sandercock 1991). Larger females tend to produce larger and a greater number of eggs. Migration distance can also influence egg production, with longer migrations inhibiting egg size and/or quantity (Kinnison et al. 2001). All these differences drive population-specific differences in fecundity and egg size (Beacham 1982, Hjort and Schreck 1982,Taylor and McPhail 1985, Swain and Holtby 1989, Fleming and Gross 1990, Murray et al. 1990).

Once spawning is complete the female will cover the redd with gravel and guard it until she dies (approximately 4 to 15 days) (Weitkamp et al. 1995). Ultimately the success of reproduction depends on a number of environmental and biological factors that occur within the redd, the spawning site, and within the watershed. Many of these factors are linked to the timing of reproduction, one of the most critical adaptations coho salmon make to their spawning environment.

Embryonic development begins when the egg is fertilized and developmental rate and incubation period are inversely related to water temperature. In most streams in Oregon and California incubation takes place between November and April and lasts between 38 to 48 days depending on water temperature (Shapalov & Taft 1954). The time between hatching and fry emergence is also dependent on temperature and dissolved oxygen levels in the redd, and can last between 4 and 10 weeks. The percentage of eggs and alevins (a larval life stage dependent on food stored in a yolk sac) that survive to emergence is dependent on stream and riverbed conditions with winter flooding, with its associated scour and gravel movement accounting for a high proportion of losses. Low flows, freezing, heavy silt loads, bird and insect predation, and infections can

also lead to mortality. Over their entire lives, from egg to adult, the majority of salmon mortality takes place during this period in the gravel. Under very harsh conditions, no eggs or alevins will survive. Under average conditions between 15 to 27 percent will survive to emergence (Neave 1949, Crone and Bond 1976) and in favorable conditions between 65 to 85 percent will survive (Shapovalov and Taft 1954). Studies from California and Oregon found average survival to be between 27.1 percent and 74.3 percent (Briggs 1953, Koski 1966).

At the end of incubation, once the yolk sac absorption is nearly or fully complete, alevins emerge from the gravel at night as "fry". Emergence of coho salmon in California starts two to three weeks after hatching but can take up to 2 to 7 weeks longer for late developers. The total emergence period can last between 10 and 47 days. Fry emergence takes place between March and July, with peak emergence in March and May (Shapovalov and Taft 1954, Koski 1966). Fry are approximately 30 mm in length when they emerge with earlier emergence linked to larger size and greater growth opportunity (Mason and Chapman 1965,Sandercock 1991).

Rearing and Outmigration

After emergence, fry seek out shallow water along stream margins. The dominant life history pattern is for juvenile coho salmon to feed and rear within the streams of their natal watershed for a year before migrating to the ocean. However, they may spend up to two years rearing in freshwater (Bell and Duffy 2007), or emigrate to an estuary shortly after emerging from spawning gravels (Tschaplinski 1988). The occurrence of age-0 "ocean-type" coho salmon migrants to the estuary, stream-estuary ecotone, or lower main-stem reaches has been documented throughout the range of coho salmon and is thought to be another alternative life history (Chapman et al. 1961; Chapman 1962; Hartman et al. 1982; Murphy et al. 1984; Rodgers et al. 1987, Au 1972, Kahler et al. 2001, Ryall and Levings 1987). In California and Oregon some of these fish rear in the estuary during the summer then return upstream to overwinter (Miller and Sadro 2003). This primarily occurs in watersheds with adequate estuarine rearing habitat (Merrell and Koski 1978). Extended freshwater residence in California streams has also been recently documented for age-1+ coho salmon (Ransom 2007). The proportion of a cohort that exhibited extended rearing ranged from 0 percent to almost 30 percent among streams and was linked most strongly to peak winter streamflow. Coho salmon have also been shown to utilize non natal streams for rearing and to redistribute into riverine ponds following fall rains (Peterson 1982). The extent to which fish utilizing these alternative life history patterns contribute to adult returns is not known. However, they demonstrate the diversity of strategies that are potentially used by juvenile coho salmon in the ESU.

For juvenile coho salmon that spend at least a year rearing in freshwater streams, this habitat offers the opportunity to grow prior to migration to larger rivers and the ocean. While rearing in such environments, salmon experience slow growth but a relatively low predation risk compared with downstream habitats (Quinn 2005). Depending on the size of the stream in which it emerged, coho salmon fry may move upstream or downstream to rear after emergence. The most productive coho areas tend to be small streams but other rearing areas include lakes, sloughs, side channels, estuaries, beaver ponds, low-gradient tributaries to large rivers, and large areas of slack water (PFMC 1999). During this time, juveniles set up territories for feeding, especially in pool areas of streams (Hartman 1965). The abundance of coho salmon in streams is

limited by the number of suitable territories available and streams with more complex habitat support larger numbers of fry (Scrivener and Andersen 1982, Larkin 1977).

During summer, juvenile coho move into deep pools and areas with dense shade and large woody debris (LWD) for refuge from high summertime temperatures (Nickelson et al. 1992; Brown et al. 1994). A study of coho salmon occurrence in tributaries of the Mattole River suggested that a MWMT (maximum weekly maximum temperature) greater than 18.1°C or a MWAT (highest average of mean daily temperature over any seven-day period (MWAT) greater than16.8°C would preclude the occurrence of coho salmon.

During winter, subyearling coho salmon depend on smaller tributary streams, deeper pools, and other types of flow refugia for survival (Tripp and McCart 1983, Skeesick 1970, Narver 1978). During this period of stream rearing the most factors influencing survival and growth include water discharge rate, temperature, and predation. Predation rates and predators vary by stream but important predator species include rainbow trout and cutthroat trout. Most mortality takes place in the first summer. Fry-to-smolt survival rates average between 1.27 percent and 1.71 percent (Godfrey 1965).

Weitkamp et al. (1995) found no regional pattern for either smolt outmigration timing or smolt size for West Coast coho salmon. Downstream migration of coho salmon in the SONCC coho salmon ESU begins in the spring sometime between April and May and continues into June. Most smolts measured between 90 and 115 mm fork length. Factors affecting the onset of emigration include the size of the fish, flow conditions, water temperature, dissolved oxygen (DO) levels, day length, and the availability of food (Shapovalov and Taft 1954). Because of smolt size and migration timing are related to small-scale habitat variability, size and migration timing have been shown to be affected by anthropogenic activities, including habitat degradation (Moring and Lantz 1975, Scrivener and Andersen 1984, Holtby and Scrivener 1989), habitat restoration (Johnson et al. 1993, Rodgers et al. 1993), and flow control (Fraser et al. 1983). Variability in these conditions leads to strong inter-annual and stream-specific differences in smolt size and migratory timing (Weitkamp et al. 1995).

A juvenile's downstream migration to the ocean is accompanied by a series of internal changes in morphology, physiology, and behavior needed for a transition to saltwater. Travel rates to reach the ocean are determined by flow rates, date, and distance as well as individual based characteristics such as the extent of parr-smolt transformation. Travel rates increase with flow rates and travel distance. Fish migrating later in season also move faster than fish migrating earlier in the year (Dawley et al. 1986). Mortality from downstream migration is positively correlated to the distance traveled and has been linked to predation and hydropower operations in past studies (Quinn 2005). Once fry reach the estuary they will spend a variable amount of time completing the fry-to-smolt transformation. Estuarine residence is variable and is dependent on variety of factors, many of which remain unknown for this species of salmon. Growth rates in estuaries are generally higher than freshwater habitats and many juvenile coho salmon take advantage of feeding opportunities and time to transition to salt water while in the estuary. Depending on the opportunity and capacity of the estuary, coho salmon on the Oregon and California coast will spend anywhere from a few days to a few weeks in the estuary (Miller and Sadro 2003).

The synchrony of arrival timing in coastal waters and the availability of food is especially critical for determining the survival rates of different cohorts (Walters et al. 1978). Many studies have shown that the timing of outmigration can have a large impact on the survival of coho salmon at sea (Pearcy 1992). Depending on marine productivity and food availability when coho salmon first enter the ocean (based on strong winds, upwelling, and cool water), conditions will either reduce or enhance survival and growth. Because these conditions can be highly variable year to year, the ideal ocean entry date varies as well. The SONCC coho salmon ESU has evolved to have multiple life history strategies with a range in timing of outmigration. The earliest outmigration in the SONCC coho salmon ESU occurs in Roach Creek on the Klamath River and Ten Mile Creek on the Eel River (March or earlier). The latest occur in the South Fork of the Eel River (mid June or later). Because of this, the Eel River has the broadest range of outmigrant timing (March to August) (Weitkamp et al. 1995). The average size of outmigrating coho salmon is approximately 128 mm with the largest smolts originating from the Trinity River (mean 147 mm) and the smallest originating from Blue Creek on the Klamath River (mean 104 mm). The large sizes of Trinity River smolts likely results from hatchery operations in that basin, which produce larger than average smolts. The range of smolts sizes in the SONCC coho salmon ESU is between 90 and 200 mm (Weitkamp et al. 1995).

Ocean Migration

Early ocean migration patterns of young coho salmon have been described in a number of studies (e.g., WeitkampBrodeur et al. 2004, Van Doornik et al. 2007, Weitkamp et al. 1995). By the beginning of their first winter at sea, coho salmon begin to move more broadly into feeding grounds. Studies using coded wire tags (CWT) have shown that this dispersal at sea is regionally-specific with coho salmon from northern California and Oregon south of Cape Blanco dispersing locally (Weitkamp and Neely 2002). These fish were recovered primarily in California (65 to 92 percent), with some recoveries in Oregon (7 to 34 percent) and almost none (<1 percent) further north. Compared with other coho salmon populations, the SONCC coho salmon ESU has a comparatively small marine distribution. Coho salmon occur in the upper part of the water column in the open ocean, at observed depths of from about 10 to 25 m (summarized by Quinn 2005).

One potential reason SONCC coho salmon do not move farther north is the productivity associated with upwelling areas off the coast of California, which provide high densities of food (Moyle 2002). When they first enter coastal areas, coho salmon feed primarily on marine invertebrates; as they grow larger, they shift to more piscivorous diets (Shapovalov and Taft 1954). Coho salmon feed opportunistically on a variety of prey items including small pelagic fishes, shrimp, crab and crab larvae, and other pelagic invertebrates (Sandercock 1991). Growth associated with feeding opportunities at sea is rapid and most fish can double their length and increase their weight more than tenfold their first summer.

While there are many opportunities for growth at sea, coho salmon experience high predation pressures and steep mortality. Studies of smolt-to-adult survival place estimates between 1 percent and 10 percent with the greatest mortality during the first summer at sea. Factors such as size, physiological condition, migration date, and ocean conditions can all influence mortality and under optimum conditions survival can be as high as 40 percent (Sandercock 1991). In addition to ocean entry timing as a factor influencing survival (as discussed above), size is also

important in minimizing mortality since much of the predation that occurs at sea is size-selective (McGurk 1996, Shapavalov and Taft 1954). Generally, small fish have higher mortality rates than larger fish up until about 100 mm (Koenings et al. 1993). Predation is also thought to be an important cause of mortality on smaller fish in their first year at sea and has less of an impact on adult populations.

Maturation

The growth and survival of adult coho salmon is closely linked to marine productivity, which is controlled by complex physical and biological processes that are highly dynamic and vary greatly over space and time. Shifts in salmon abundance due to climatic variation are known to be large and sudden (Beamish et al. 1999). Short and long-term cycles in climate [e.g., El Niño/La Niña and the Pacific Decadal Oscillation (PDO)] are thought to affect adult coho salmon size, abundance, and distribution at sea, as does inherent year-to-year variation in environmental conditions not associated with climatic cycles. Several studies have related ocean conditions specifically to coho salmon production (Cole 2000), ocean survival (Ryding and Skalski 1999, Koslow et al. 2002), and spatial and temporal patterns of survival and body size (Hobday and Boehlert 2001, Wells et al. 2006). The link between survival and climate could be operating via the availability of nutrients regulating the food supply and hence competition for food (Beamish and Mahnken 2001). For example, the 1983 El Niño event off the Pacific coast of North America resulted in increased adult mortality and decreased average size for Oregon's returning coho salmon. Juvenile coho salmon entering the ocean in the spring of 1983 also had low survival, resulting in low adult returns in 1984 (Johnson 1988). Larger-scale decadal to multi-decadal events also have been shown to affect ocean productivity and coho salmon (Hare and Francis 1995; Mantua et al 1997; Beamish et al. 1997a; Beamish et al. 1999; Pearcy 1992; Lawson 1993). Although salmon evolved in this variable environment and are well suited to withstand climactic changes, the resiliency of the adult population has been reduced by the loss of life history diversity, lower population abundance, cohort loss, and fragmentation of the spatial population structure. Changes in the freshwater environment (e.g., loss and degradation of habitat) have also weakened the ability of coho salmon to respond to the natural variability in ocean conditions.

The age composition and size of coho salmon at maturity is influenced by a number of factors including growth rate, sex, origin (either hatchery or wild and population), and genetics (Quinn 2005). Based on these factors, coho salmon exhibit a range of ages and sizes at maturation. The most common life history strategy for coho salmon in the SONCC coho salmon ESU is a fairly strict 3-year life cycle, with most coho salmon spending approximately 18 months at sea before returning to their natal rearing grounds to spawn (Gilbert 1912, Briggs 1953, Shapovalov and Taft 1954, Loeffel and Wendler 1968, Weitkamp et al. 1995). The most recent data show that the average size of returning adults in Oregon and California is between 56.4 and 64.6 cm (average 62.7). Variations to this life history do exist and some fish return after only 5 to 7 months at sea. These "jacks" that return early act to keep runs from being genetically isolated based on a strict 3-year return year. In general, coho salmon that migrate earlier than average and at a size larger than average are believed to produce a higher rate of jack returns (Bilton et al. 1984). The proportion of jacks returning to spawn is more common in populations at the southern range of the ESU and the proportion of jacks is higher than those in other coho salmon ESUs. Studies have shown highly variable numbers of returning jacks to Oregon and California

streams. Jacks in the Klamath River made up to 97 percent of returns in one year between 1984 and 1987 (average 59 percent) (Hopelain 2001). Other studies have shown the jacking rate ranges from 7 percent to 34 percent (e.g., Murphy 1952).

The size of coho salmon when they reach maturity also exhibits spatial and temporal variability along with the age at maturity. Size is dependent on factors related to growth and genetic heritage with the sex, origin, age, and run timing all influencing the size of a fish when it reaches maturity. In general, coho salmon in later runs tend to be larger than those in earlier runs (Sandercock 1991), coho salmon from mainstem areas are often larger than those spawning in tributaries (Lister et al. 1981), males tend to be larger than females, and older fish are larger than younger fish. Of available data from southern Oregon and northern California streams and rivers, the smallest spawners tend to come from the Rogue River (average 56 cm between 1976 to 1986) and the largest tend to come from Redwood Creek (average 76.1 cm between 1950 to 1951). The range for this area is between 30 and 91 cm (Weitkamp et al. 1995).

One overall trend across the range of coho salmon is the observed decrease in size of mature fish over the past 50 years. Harvest practices, effects of fish culture, declining ocean productivity, and density-dependent effects in the marine and freshwater environments attributable to large numbers of hatchery releases are potential factors leading to this decline. Weitkamp et al. (1995) noted that the rate of this decline are population, or area, specific with the highest rates of decline in Oregon and California being observed in Rogue River spawners (Slope = -1.50). The CA and OR troll data on coho size also supports a regional decline in size (Slope = -0.05). In the few creeks within the SONCC coho salmon ESU with historic and current data for comparison, average declines averaged between 1.1 and 4.2 cm per decade. These declines in adult size have direct implications for individual reproductive success and population viability because smaller spawners have lower fecundity.

Homeward Migration and Spawning

Timing and location of reproduction are two of the most critical adaptations salmon populations make to their environment. Salmon are uniquely evolved in their ability to take advantage of feeding and growth opportunities at sea and optimal spawning conditions in freshwater streams and rivers. Once a salmon starts the process of maturation, it begins a homeward migration to the location in which it was spawned. Once adult coho salmon reach nearshore and estuarine waters they are able to use imprinted chemical cues to help guide them. Imprinting in fry occurs shortly after emergence and is based on stream-specific or population-specific characteristics of their natal stream.

About 95 to 99 percent of all salmon return to their natal stream using these imprinted cues, however a small percentage (the magnitude of which varies temporally and by population) are “strays,” meaning they exhibit non-natal spawning (Quinn 2005). Whether this characteristic of adult coho salmon is genetically, behaviorally, or environmentally influenced is unknown, but ultimately the occurrence of straying contributes to the persistence and distribution of populations and the entire ESU. As a general rule, straying is linked to the stability and degree of specialization of a population or its spawning habitat. Populations occupying “flashy” or steep, unstable coastal streams are more likely to exhibit non-natal rearing as are small ubiquitous coastal streams that require little or no specialization for spawning. Information on

straying rates for coho salmon in California are sparse but Shapavalov and Taft (1954) reported values between 15 percent and 27 percent for Scott and Waddell Creek. Other genetic studies of California coho salmon populations show differences among populations that suggest lower effective straying rates. Fish that do stray are most commonly found in spawning areas near their natal stream (Shapovalov and Taft 1954, Jacobs 1988, Labelle 1992).

Upriver migration of adults to spawning areas normally occurs from October to March for populations in the SONCC coho salmon ESU, with a peak between November and January. For most populations, the duration of spawning migration is at least three months or more. Coho salmon river entry timing is influenced by many environmental and genetic factors, the most important of which is river flow (Shapovalov and Taft 1954, Salo and Bayliff 1958, Sumner 1953, Eames et al. 1981, Lister et al. 1981). Coho salmon generally wait for freshets before entering rivers, so a delay in fall rains delays river entry and, potentially, spawn timing as well. Many of the small coastal streams in California are barred over by sand at their mouths, and coho salmon in these streams have to wait to ascend until the sand barriers are breached by high stream flows that follow heavy winter rains. Once a fish enters a river, if conditions in the stream are unsuitable for entry, fish will often hold in the vicinity of the stream mouth for conditions to change, usually marked by a decreasing temperature and increasing flow. This holding allows coho salmon to reach further into headwater streams where good spawning and rearing conditions may exist.

Because of the environmental drivers affecting run timing, this trait shows considerable spatial and temporal variability. Large river systems are especially diverse in terms of coho salmon run timing. For example coho salmon runs in the Klamath River can last over four months with various populations entering the system from late August to mid January (Washington Department of Fisheries (WDF) 1951, Leidy and Leidy 1984, WDF et al. 1993, Polos 1994 App.). In terms of large-scale spatial patterns in run timing, Weitkamp et al. (1995) found some regional patterns that define the SONCC coho salmon ESU. Coho populations in southern Oregon and northern California tend to have later run timing than population to the north. There also appears to be a wider range of timing, with some runs starting in late August (Klamath) and most lasting into mid January.

Once conditions are favorable, adult coho salmon migrate into spawning areas along the coast and in small tributaries of larger rivers. Coho migrate further upstream than chum salmon but not usually as far as Chinook. In general, coho spawning grounds are within 240 km of the coast (Godfrey 1965). Large river systems like the Rogue, Trinity, Klamath, and Eel all historically supported coho salmon in their upper tributaries. Once adult fish reach the spawning grounds, they can spend days, weeks, or months waiting to spawn. During this time salmon are subject to predation and disease prior to spawning.