# Scientific Conclusions of the Status Review for Oregon Coast Coho Salmon (*Oncorhynchus kisutch*)

**Draft Revised Report of the Biological Review Team**

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# Executive Summary

Beginning in the 1990s, the National Marine Fisheries Service (NMFS or NOAA Fisheries Service) conducted a series of reviews of the status of West Coast populations of Pacific salmon and steelhead (*Oncorhynchus* spp.) with respect to the U.S. Endangered Species Act (ESA). This report summarizes the scientific conclusions of the most recent status review of the Oregon Coast Coho Salmon Evolutionarily Significant Unit (ESU).

On August 10, 1998, NMFS first listed the Oregon Coast Coho Salmon ESU (OC coho salmon) as threatened under the ESA (NMFS 1998). From 2000 until 2008, considerable litigation surrounded the listing status of this species.[1] The OC coho salmon's listing status changed between "not warranted for listing" and "threatened" several times during this period. The most recent determination listed the ESU as threatened (NMFS 2008). As part of a legal settlement, NMFS agreed to initiate a new status review of OC coho salmon on April 29, 2009 (NMFS 2009a). To conduct the status review, NMFS formed a biological review team (BRT) to evaluate the risk of extinction of the OC Coho Salmon ESU based upon the best available information. NMFS asked the BRT to judge whether the ESU was at low, moderate, or high risk of extinction based on current biological status and existing and projected threats, and to give particular attention to the status and trend of freshwater habitat conditions and marine survival conditions.

The BRT used a variety of sources of information for this review, including information from the scientific literature, data and reports from federal, state, local and tribal government sources, and information submitted by non-governmental organizations. The BRT hosted a symposium in Corvallis, Oregon, on September 14, 2009, where the State of Oregon, co-managers, and other interested parties were invited to make presentations of scientific information related to OC coho salmon status. The BRT met September 15 and December 8-10, 2009, and released its preliminary report May 25, 2010, concluding that the OC coho salmon ESU was at moderate risk of extinction. Concurrent with the release of the preliminary status review report, NMFS proposed to retain the threatened listing of the OC coho salmon ESU and invited public comment on the proposal (NMFS 2010, FR 75:29489-29506). In addition, the BRT solicited technical review of the draft status report from nine independent scientists selected from the academic and scientific community. Each of these reviewers is an expert in salmon biology, risk assessment methodology, ocean/salmon ecology, climate trend assessment, or landscape-scale habitat assessment. Eight of the reviewers responded. This BRT report is a revision of the May 25, 2010, preliminary report. In revising the report, the BRT considered the comments from the expert reviewers, the scientific or technical comments submitted during the public comment period, updated spawner counts and other biological information that became available between May and December 2010, and the results of a joint Oregon Department of

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1 For more information, see: http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Alsea-Response/Alsea-OCC.cfm

Fishery and Wildlife (ODFW)/NMFS working group that reanalyzed freshwater habitat trend data. The BRT met on Jan 18, 2011, to discuss the updated information and analysis and to reach a conclusion on the extinction risk of the OC coho salmon ESU.

In the past, BRTs have used a variety of methods to evaluate different categories of risk contributing to overall risk to an ESU. After 2000, the method was standardized to use a "risk matrix" method based on the four major criteria identified in the NMFS viable salmonid populations (VSP) document (McElhany et al. 2000): abundance, growth rate/productivity, spatial structure, and diversity. For this analysis, the BRT followed that approach, but also included the work of the Oregon and Northern California Coast Technical Recovery Team (TRT) on historical population structure (Lawson et al. 2007) and biological recovery criteria (Wainwright et al. 2008) as additional sources of information on OC coho salmon status.

After considering the new and updated information, the BRT was uncertain about the status of the ESU, with opinion about evenly split between "moderate risk" and "not at risk", and a small minority indicating "high risk". Overall, a slight majority of BRT opinion considered the ESU to be at moderate or high risk of extinction. The uncertainty in risk status was largely due to the difficulty in balancing the clear improvements in some aspects of the ESU's status over the last ~15 years against persistent threats driving the longer term status of the ESU, which probably have not changed over the same time frame and are predicted to degrade in the future.

The BRT concluded that some aspects of the ESU's status have clearly improved since the initial status review in the mid-1990's (Weitkamp et al. 1995). In particular, spawning escapements were higher in some recent years than they had been since 1970. Recent total returns (pre-harvest recruits) were also substantially higher than the low extremes of the 1990s, but still mostly below levels of the 1960s and 1970s. The BRT attributed these increases largely to a combination of lower harvest rates, reduced hatchery production, and improved ocean conditions. The BRT also noted that the ESU contained relatively abundant wild populations throughout its range, and that additional improvements to status from ongoing and past reductions in hatchery production could be expected in the future.

Despite these positive factors, the BRT also had considerable concerns about the long-term viability of the ESU. Even with the recent increases, spawning abundance remains at ~10% of estimated historical spawning abundance. Despite some improvements in productivity in the early 2000's, the BRT was concerned that the overall productivity of the ESU remains low compared to what was observed as recently as the 1960's and 1970's. The BRT was also concerned that the majority of the improvement in productivity seen in the early 2000's was likely due to improved ocean conditions, rather than (presumably more lasting) improvements in freshwater conditions. The BRT noted that the legacy of past forest management practices combined with lowland agriculture and urban development has resulted in a situation in which the areas of highest potential habitat capacity are now severely degraded. The combined ODFW/NMFS analysis of freshwater habitat trends for the Oregon coast found little evidence for an overall improving trend in freshwater habitat conditions since the mid-1990s, and evidence of negative trends in some strata, a result which concerned the BRT. The BRT was also concerned that recent changes in the protection status of beaver, an animal which creates coho habitat, could result in further negative trends in habitat quality.

The BRT was particularly concerned that the long-term loss of high value rearing habitat has increased the vulnerability of the ESU to both near term and long term climate effects. In the short term, the ESU could rapidly decline to the low abundance seen in the mid-1990's when ocean conditions cycle back to a period of poor survival for coho salmon. The BRT was also concerned that global climate change will lead to a long-term downward trend in both freshwater and marine coho salmon habitat compared to current conditions. There was considerable uncertainty about the magnitude of most of the specific effects climate change will have on salmon habitat, but the BRT was concerned that most changes associated with climate change are expected to result in poorer and more variable habitat conditions for OC coho salmon in both freshwater and marine environments.

# Acknowledgments

We are grateful to the large number of people who participated in collecting and analyzing the information utilized in this status review. These include Kelly Christiansen and Kelly Burnett of the USFS, Eric Ward, Carol Volk, Jonathon Malstedt, Chris Moyer, Katie Barnas, Monica Diaz and David Hamm of the Northwest Fisheries Science Center. We also appreciate the assistance of Joy Vaughn of Oregon Department of State Lands, Andrew Herstrom, with the Oregon Department of Forestry and Habitat Trends Working Group members Kim Jones, Kara Anlauf and Jeff Rodgers with ODFW.

We are also grateful for the contributions of the participants in the September 2009 Oregon Coast Coho Salmon Symposium. These were: Kelly Moore and Kim Jones of ODFW, Suzanne Knapp with the Oregon State Governor's Office, Jim Paul with the Oregon Department of Forestry, Robert Kennedy with Oregon State University, Joe Ebersole with Environmental Protection Agency, Paul Engelmeyer with Native Fish Society, Chris Frissell with Pacific Rivers Council, David Loomis representing Douglas County Commissioners, Stan van de Wetering with the Confederated Tribe of Siletz Indians, and Joe Moreau with Bureau of Land Management.

# Abbreviations and Acronyms

BRT Biological Review Team

DPS Distinct Populations Segment

ESA U.S. Endangered Species Act

ESU Evolutionarily Significant Unit

FEMAT Forest Ecosystem Management Assessment Team

NMFS National Marine Fisheries Service (also referred to as NOAA Fisheries)

NOAA National Oceanic and Atmospheric Administration

NWFSC NMFS Northwest Fisheries Science Center

NWR NMFS Northwest Regional Office

OC coho salmon  Oregon Coast Coho Salmon

OCN Naturally produced Oregon Coast coho salmon.  Often used by ODFW to distinguish from hatchery-raised fish and includes fish from the SONCC ESU in Oregon.

ONCC TRT Oregon/Northern California Coasts Technical Recovery Team

OPI Oregon Production Index

PDO Pacific Decadal Oscillation

PVA population viability analysis

RIST Recovery Implementation Science Team

SONCC ESU Southern Oregon Northern California Coast ESU

TRT Technical Recovery Team

USFWS U.S. Fish and Wildlife Service

VSP viable salmonid population

# Introduction

Coho salmon (*Oncorhynchus kisutch*) is a widespread species of Pacific salmon, spawning and rearing in rivers and streams around the Pacific Rim from Monterey Bay in California north to Point Hope, Alaska; through the Aleutians; and from the Anadyr River in Russia south to Korea and northern Hokkaido, Japan (Godfrey et al. 1976, Laufle et al. 1986). From central British Columbia south, the vast majority of coho salmon adults return to spawn as 3-year-olds, having spent approximately 18 months in freshwater and 18 months in salt water (Gilbert 1912, Pritchard 1940, Sandercock 1991). The primary exceptions to this pattern are "jacks," sexually mature males that return to freshwater to spawn after only 5 to 7 months in the ocean. West Coast coho salmon smolts typically leave freshwater in the spring (April to June) and when sexually mature re-enter freshwater from September to November and spawn from November to December and occasionally into January (Sandercock 1991). Coho salmon spawning habitat consists of small streams with stable gravels. Summer and winter freshwater habitats most preferred by young salmon consist of quiet areas with low flow, such as backwater pools, beaver ponds, dam pools, and side channels (Reeves et al. 1989).

For purposes of ESA listings, the status of coho salmon has been reviewed repeatedly beginning in 1990. The first two reviews occurred in response to petitions to list coho salmon in the lower Columbia River and Scott and Waddell creeks in central California. Based on these reviews NMFS concluded that there were no populations that warranted protection under the ESA in the lower Columbia River (Johnson et al. 1991, NMFS 1991a), and that the Scott and Waddell Creek populations were part of a larger, undescribed Evolutionarily Significant Unit (ESU) (Bryant 1994, NMFS 1994).

Oregon Coast coho salmon were first petitioned for listing in 1993 (NMFS 1993). For a chronology of the legal history of this species, see Table 1. This and other petitions led NMFS to initiate a review of West Coast (Washington, Oregon, and California) coho salmon populations. This 1995 coast-wide review identified six coho salmon ESUs (Fig. 1): the three southernmost ESUs (Central California, Northern California/Southern Oregon and Oregon Coast) were proposed for listing, two ESUs (Puget Sound/ Strait of Georgia and Lower Columbia River/Southwest Washington) were identified as candidates for future consideration for listing, and one ESU (Olympic Peninsula) was deemed "not warranted" for listing (NMFS 1995, Weitkamp et al. 1995). In 1996, the BRT updated the status review for both proposed and candidate coho salmon ESUs (NMFS 1996a, 1996b, 1996c). However, because of the scale of the review, requests from comanagers for additional time to comment on the preliminary conclusions, and the legal obligations of the NMFS, the status review was finalized for proposed coho salmon ESUs in 1997 (NMFS 1997a) but not for candidate ESUs. In May 1997, NMFS listed the Southern Oregon/Northern California Coast (SONCC) Coho Salmon ESU as threatened (NMFS 1997b), while it announced that listing of the Oregon Coast Coho Salmon ESU was not warranted due to conservation measures in the Oregon Coastal Salmon Restoration

Initiative (OCSRI) plan (NMFS 1997b). This finding for OC coho salmon was overturned by the Federal District Court for Oregon in August 1998, and the ESU was listed as threatened (NMFS 1998).

On 10 September 2001, Judge Michael R. Hogan, ruling in *Alsea Valley Alliance v. Evans* for the U.S. District Court for the District of Oregon, found that, for the OC Coho Salmon ESU, "NMFS's listing decision is arbitrary and capricious, because the Oregon Coast ESU includes both 'hatchery spawned' and 'naturally spawned' coho salmon, but the agency's listing decision arbitrarily excludes 'hatchery spawned' coho. Consequently, the listing is unlawful" (161 F. Supp. 2d 1154, D. Oreg. 2001). The lawsuit was brought by the Alsea Valley Alliance, partly in response to an action by ODFW to terminate a domesticated coho salmon brood stock at the Fall River Hatchery on the Alsea River.

The effect of the ruling was to delist the OC Coho Salmon ESU. The ruling was appealed by the appellant interveners to the U.S. Court of Appeals for the Ninth Circuit. On 14 December 2001 the Court stayed the District Court ruling pending final disposition of the appeal (*Alsea Valley Alliance v. Evans*, Ninth Circuit appeal, No. 01-36071, 14 December 2001). This returned the OC Coho Salmon ESU to threatened status under the ESA. In response, NMFS initiated development of a new hatchery policy to address issues raised in the ruling.

In November of 2002, NMFS convened the Oregon Coast Coho Salmon Workgroup, a subcommittee of the Oregon/Northern California Coast Technical Recovery Team (ONCC TRT). This group was charged with establishing biologically based recovery criteria and ESA recovery goals as well as providing scientific advice to recovery planners. Results of the Workgroup deliberations are published in Lawson et al. (2007) and Wainwright et al. (2008). In October 2003, Oregon began its Coastal Coho Project to evaluate the effectiveness of the Oregon Plan at recovering OC coho salmon.[2]

The next coho salmon BRT met in January, March, and April 2003 as part of a coast-wide review of listed species to determine what portions of the artificially propagated salmon in each ESU should be listed with natively spawned fish and to discuss new data and determine whether conclusions of the original BRTs should be modified as the result of new information. In June, 2004, NOAA published the proposal to list the OC Coho Salmon ESU as threatened under the federal ESA (NMFS 2004a) and issued its draft hatchery policy (NMFS 2004b). The hatchery policy was finalized in 2005 (NMFS 2005a).

In May, 2005, Oregon released the final Coast Coho Assessment (Nicholas et al. 2005), concluding that the OC Coho Salmon ESU was viable and likely to persist into the foreseeable future. Subsequently, in January 2006 NMFS concluded that OC coho salmon are "not likely to become endangered" in the foreseeable future and therefore listing them under the ESA was not warranted and withdrew its listing proposal (NMFS 2006a).

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[2] Comments from the Workgroup on the Oregon Coastal Coho Conservation Plan can be found at http://www.oregon.gov/OPSW/cohoproject/PDFs/NOAA_Conservation_Plan_comments.pdf

In June 2006, Trout Unlimited challenged NMFS's decision not to list the OC Coho Salmon ESU. In July of 2007, a U.S. District Court in Oregon invalidated the January 2006 decision not to list the OC Coho Salmon ESU. In February of 2008, in accordance with the court's decision, NMFS listed the ESU as "threatened" under the ESA (NMFS 2008) and declared critical habitat (Fig. 2).

In 2008, NMFS, NWR and NWFSC formed the Recovery Implementation Science Team (RIST), a regional science team that provides scientific advice related to recovery plan implementation. Several TRTs, including the ONCC TRT continued to provide local science support as subteams of the RIST. In April of 2009, NMFS announced a new status review for the OC Coho Salmon ESU (NMFS 2009a). This BRT met in September and December of 2009. This report summarizes new information and the preliminary BRT conclusions on the OC Coho Salmon ESU.

This report is intended as a summary of the information considered by the BRT in making their conclusion. It does not include specific recommendations for management; that is the role of the recovery plan. Many large sets of past analyses and conservation documents are included in this information and it is the goal of this presentation to include their information by reference to keep this document to a reasonable size. Details of previously published analytical methods are referred to in citations; details of those analyses can be found in the previously published documents. However, the BRT has utilized some analyses not previously published in this particular format, so a more detailed description of those is included in the appendices.

# Summary of Previous BRT Conclusions

The Oregon Coast Coho Salmon ESU has been the subject of detailed assessments in three previous status reviews—one in 1994 (Weitkamp et al. 1995), another in 1996 (NMFS 1997a) and a third in 2003 (Good et al. 2005).

## ESU Determination

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. However, the ESA provides no specific guidance for determining what constitutes a distinct population. To clarify the issue for Pacific salmon, NMFS published a policy describing how the agency will apply the definition of "species" in the ESA to anadromous salmonid species, including sea-run cutthroat trout and steelhead (NMFS 1991b). A more detailed discussion of this topic appeared in the NMFS "Definition of Species" paper (Waples 1991).

The NMFS policy stipulates that a salmon population (or group of populations) will be considered "distinct" for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component of the evolutionary legacy of the species. The term "evolutionary legacy" is used in the sense of "inheritance"—that is, something received from the past and carried forward into the future. Specifically, the evolutionary legacy of a species is the genetic variability that is a product of past evolutionary events and that represents the reservoir upon which future evolutionary potential depends. Conservation of these genetic resources should help to ensure that the dynamic process of evolution will not be unduly constrained in the future.

The NMFS policy identifies a number of types of evidence that should be considered in the species determination. For each of the criteria, the NMFS policy advocates a holistic approach that considers all types of available information as well as their strengths and limitations. Isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue in different population units. Important types of information to consider include natural rates of straying and recolonization, evaluations of the efficacy of natural barriers, and measurements of genetic differences between populations. Data from protein electrophoresis or DNA analyses can be particularly useful for this criterion because they reflect levels of gene flow that have occurred over evolutionary time scales.

The key question with respect to the second criterion is, if the population became extinct, would this represent a significant loss to the ecological/genetic diversity of the species? Again, a variety of types of information should be considered. Phenotypic and life history traits such as size, fecundity, migration patterns, and age and time of spawning may reflect local adaptations of evolutionary importance, but interpretation of these traits is complicated by their sensitivity to environmental conditions. Data from protein electrophoresis or DNA analyses provide valuable insight into the process of genetic differentiation among populations but little direct information regarding the extent of adaptive genetic differences. Habitat differences suggest the possibility for local adaptations but do not prove that such adaptations exist.

The Oregon Coast Coho Salmon ESU was identified as one of six west coast coho salmon ESUs in a coast-wide coho status review published by NMFS in 1995 (Weitkamp et al. 1995). The six ESUs identified in that status review were: Puget Sound/Strait of Georgia, Olympic Peninsula, Columbia River/Southwest Washington Coast, Oregon Coast, Northern California/Southern Oregon Coast, and Central California Coast (Weitkamp et al. 1995). Subsequently, the Columbia River/Southwest Washington coast ESU was divided into two ESUs (Columbia River and Southwest Washington Coast; (NMFS 2001)), resulting in seven coho salmon ESUs.

Weitkamp et al. (1995) considered a variety of factors in delineating ESU boundaries, including environmental and biogeographic features of the freshwater and marine habitats occupied by coho salmon, patterns of life-history variation and patterns of genetic variation, and differences in marine distribution among populations based on tag recoveries. Regarding the Oregon Coast Coho Salmon ESU, Weitkamp et al. (1995) concluded that Cape Blanco to the south and the Columbia River to the north constituted significant biogeographic and environmental transition zones that likely contributed to both reproductive isolation and evolutionary distinctiveness for coho salmon inhabiting opposite sides of these features. These findings were reinforced by discontinuities in the ocean tag recoveries at these same locations. Finally, the available genetic data also indicated that Oregon Coast coho salmon north of Cape Blanco formed a discrete, although quite variable, group compared to samples from south of Cape Blanco or the Columbia River and northward.

Based on these sources of information, Weitkamp et al. (1995) described the Oregon Coast Coho Salmon ESU as follows:

> This ESU covers much of the Oregon coast, from Cape Blanco to the mouth of the Columbia River, an area with considerable physical diversity ranging from extensive sand dunes to rocky outcrops. With the exception of the Umpqua River, which extends through the Coast Range to drain the Cascade Mountains, rivers in this ESU have their headwaters in the Coast Range. These rivers have a single peak of flow in December or January and relatively low flow in late summer. Upwelling north of Cape Blanco is much less consistent and weaker than in areas south of Cape Blanco. Sitka spruce is the dominant coastal vegetation and extends to Alaska. Precipitation in coastal Oregon is higher than in southern Oregon/northern California but lower than on the Olympic Peninsula. OC coho salmon are caught primarily in Oregon marine waters and have a slightly earlier adult run timing than populations farther south.

> Genetic data indicate that Oregon coast coho salmon north of Cape Blanco form a discrete group, although there is evidence of differentiation within this area. However, because there is no clear geographic pattern to the differentiation, the area is considered to be a single ESU with relatively high heterogeneity.

Status review updates in 2001 (NMFS 2001) and 2003 (Good et al. 2005) did not reconsider ESU boundaries, with the exception of the Columbia River/Southwest Washington Coast.

## Status Evaluation in 1994

For the first review in 1994 (Weitkamp et al. 1995), extensive survey data were available for coho salmon in the Oregon coast region and information on trends and abundance was better for the OC Coho Salmon ESU than for the more southerly ESUs. Overall, spawning escapements for OC coho salmon had declined substantially during the 20th century and natural production was at 5% to 10% of production in early 1900s. Productivity and abundance showed clear long-term downward trends. Average spawner abundance had been relatively constant since the late 1970s, but preharvest abundance was declining. Average recruits per spawner were also declining and average spawner:spawner ratios were below replacement levels in the worst recent years. OC coho salmon populations in most major rivers were found to be heavily influenced by hatchery stocks, although some tributaries may have maintained native stocks. Widespread habitat degradation was noted as a risk factor by the 1995 BRT and, along with low abundance, posed a risk to the ESU due to increased variability. Because of these risks, the 1994 BRT concluded that the ESU was likely to become endangered in the foreseeable future if present trends continued.

## Status Evaluation in 1996

Despite relatively good information on trends and abundance, the 1996 BRT (NMFS 1997a) faced some important uncertainties related to lack of information. Main uncertainties in the assessment included the extent of straying of hatchery fish, the influence of such straying on natural population trends and sustainability, the condition of freshwater habitat, and the influence of ocean conditions on population sustainability. For absolute abundance, the 1996, total average (5-year geometric mean) spawner abundance (44,500) and corresponding ocean run size (72,000) were less than one-tenth of ocean run sizes estimated in the late 1800s and early 1900s, and only about one-third of 1950s ocean run sizes (ODFW 1995). These abundances were well below estimated freshwater habitat production capacity for this ESU (run sizes of 141,000 under poor conditions ocean conditions and 924,000 under good ocean conditions (OCSRI Science Team 1997). Abundance was unevenly distributed within the ESU through the early to mid-1990s.

Long term trend estimates through 1996 showed that for escapement, run size, and recruits per spawner, trends were negative. While six years of stratified random survey population estimates showed an increase in escapement and decrease in recruitment.

Furthermore, in the 1990's recruitment remained only a small fraction of average levels in the 1970s. Although spawner:spawner ratios had remained above replacement since the 1990 brood year, recruit:spawner ratios for 1991–1993 brood years were among the lowest on record. Recruits per spawner continued to decline after OC Coho Salmon ESU was reviewed in 1994. And the new data, from 1994 to 1996, did not change the overall pattern of decline. This pattern was one of decline coupled with peaks in recruits per spawner every 4 to 5 years, with the height of the peaks declining over time. Risks that this decline in recruits per spawner posed to sustainability of natural populations, in combination with strong sensitivity to unpredictable ocean conditions, were the most serious concern the OC Coho Salmon BRT identified in 1996, including whether recent ocean and freshwater conditions would continue into the future.

Widespread spawning by hatchery fish, as indicated by scale data, continued to be a major concern to the 1996 BRT, even though Oregon had recently made some significant changes in its hatchery practices including reduced production levels in some basins, switching to on-station smolt releases, and minimizing fry releases. Uncertainty regarding the true extent of hatchery influence on natural populations, however, was a strong concern. Another concern the BRT discussed in 1996 was asymmetry in the distribution of natural spawning in this ESU; a large fraction of the naturally spawned fish occurred in the southern portion. Northern populations were also relatively worse off by almost every other measure: steeper declines in abundance and recruits per spawner, higher proportion of naturally spawning hatchery fish, and more extensive habitat degradation.

With respect to habitat, the 1996 BRT had two primary concerns: 1) that the habitat capacity for the OC Coho Salmon ESU had significantly decreased from historical levels; and 2) that the Nickelson and Lawson (1998) model predicted that, during poor ocean survival, only high-quality habitat is capable of sustaining coho populations, and subpopulations dependent on medium- and low-quality habitats would likely become extinct. Both of these concerns caused the 1996 BRT to consider risks from habitat loss and degradation to be relatively high for this ESU. The effects of the 1996 floods were not specifically discussed in this forum, but were included in factors for decline identified by NWR.

In addition to considering status based on recent conditions, the 1996 BRT was asked to consider ESU status if two sets of measures from the Oregon Coast Salmon Restoration Initiative (OCSRI) were implemented: 1) harvest management reforms and 2) hatchery management reforms.

Some 1996 BRT members felt that the harvest measures were the most encouraging part of the OCSRI plan, representing a major change from previous management. However, there was concern among some of the 1996 BRT members that the harvest plan might be seriously weakened when it was reevaluated in 2000 while the ability to monitor nontarget harvest mortality and to control overall harvest impacts were also seen as a source of uncertainty. Of the proposed hatchery measures, the 1996 BRT thought substantial reductions in smolt releases would have the most predictable benefit for natural populations and marking all hatchery fish was anticipated to resolve uncertainties about the magnitude of those interactions.

In 1996, the BRT concluded that, assuming that current conditions continued into the future (and that proposed harvest and hatchery reforms were **not** implemented), the OC Coho Salmon ESU was not at significant short-term risk of extinction, but it was likely to become endangered in the foreseeable future. A minority disagreed, and felt that the ESU was not likely to become endangered. The BRT generally agreed that implementation of the OCSRI's harvest and hatchery proposals would have a positive effect on the ESU's status, but they were about evenly split as to whether the effects would be substantial enough to move the ESU out of the "likely to become endangered" category.

## Status Evaluation in 2003

The OC Coho Salmon ESU continued to present challenges to those assessing extinction risk in 2003. The 2003 BRT (Good et al. 2005) found several positive features compared to the previous assessment in 1996. For example, adult spawners for the ESU in 2001 and 2002 exceeded the number observed for any year in the past several decades, and preharvest run size rivaled some of the high values seen in the 1970s (although well below historical levels), including increases in the formerly depressed northern part of the ESU. Hatchery reforms were increasingly being implemented, and the fraction of natural spawners that were first-generation hatchery fish were reduced in many areas, compared to highs in the early to mid-1990s.

On the other hand, the years of good returns just prior to 2003 were preceded by three years of low spawner escapements—the result of three consecutive years of recruitment failure, in which the natural spawners did not replace themselves, even in the absence of any directed harvest. These three years of recruitment failure were the only such instance observed in the entire time series Whereas the increases in spawner escapement just prior to 2003 resulted in long-term trends in spawners that were generally positive, the long-term trends in productivity as of 2003 were still strongly negative.

For the OC Coho Salmon ESU, the 2003 BRT received updated estimates of total natural spawner abundance based on stratified random survey techniques, broken down by ODFW's monitoring areas (MAs) (Fig. 29 in Lawson et al. 2007), for 10 major river basins and for the coastal lakes system.[3] In 2003, the total 3-year geometric mean spawner abundance was estimated at about 140,600 with spawners more evenly distributed than it had been previously.

The 2003 BRT used ODFW stratified random survey escapement data that indicated ESU-wide spawning escapement reached 30-year highs in 2001 and 2002. By contrast, in return years 1997–1999 (brood years 1994–1996), and for the first time on record (since 1950), recruits failed to replace the parental spawners: a recruitment failure occurred in all three brood cycles, even before accounting for harvest-related mortalities. Since 1999, until 2003, improving marine survival and higher rainfall were thought to be the factors contributing to an upswing in wild recruitment. However, it was far from certain that favorable marine conditions would continue

[3] ODFW's monitoring areas are similar, but not identical to, Gene Conservation Groups (Figs. 28 and 29 in Lawson et al. 2007) that were the population units in the 1997 update.

and, with the freshwater habitat conditions, whether OC Coho Salmon ESU could survive another prolonged period of poor marine survival remained in doubt.

In 2003, long-term (33-year) trends in spawner abundance for both the lakes and rivers were slightly upward. Lakes increased about 2% per year and rivers increased about 1% per year. In both the lakes and rivers, long-term trends in recruits declined about 5% per year since 1970. For the ESU as a whole, spawners and recruits declined at a 5% rate from 1970 to 2003.

There had been notable changes in harvest management since the 1996 status review. The Pacific Fishery Management Council adopted Amendment 13 (PFMC 1998) to its Salmon Fishery Management Plan in 1998 which was developed as part of the Oregon Plan for Salmon and Watersheds (Oregon Plan) (formerly OCSRI). It specified an exploitation rate harvest management regime with rates for OCN[4] dependent on marine survival and parental and grandparental spawning escapements. Allowable exploitation rates under the Amendment can range from 0-8% (poor marine survival) to a maximum of 45% (high survival and parent population).

Also, beginning in 1998 most adult hatchery-origin coho salmon in the Oregon Production Index area were marked with an adipose fin clip, allowing the implementation of mark-selective fisheries. Recreational mark-selective fisheries were conducted on the Oregon coast in each year between1998 and 2003, with quotas ranging from 13,000 to 24,000 marked fish. The 2003 BRT expressed concern that these incidental mortality rates estimated by PFMC were underestimates. Despite these uncertainties, there was no doubt that harvest-related mortalities were reduced substantially after 1994. This reduction was reflected in 2003 in positive short-term trends in spawner escapements despite continued downward trends in preharvest recruits. In summary, the higher returns in the early 2000's were tempered by the overall decline since 1970. When considered in the context of historical abundance and hatchery influence this trend indicated a continuing decline in abundance across the ESU. Therefore, the BRT considered that future remedies outside of harvest management were required until the decline in productivity reversed.

As of 2003, The Oregon Plan for Salmon and Watersheds (OCSRI Science Team 1997) was the most ambitious and far-reaching program to improve watersheds and recover salmon runs in the Pacific Northwest. The original Oregon Coastal Salmon Restoration Initiative was written in 1997, so the plan had been in operation for several years as of 2003.

Between 1991 and 2003 some Oregon coastal hatchery facilities were closed and numbers of smolts released from the remaining facilities were reduced from 6.2 million in 1992 to 0.93 million in 2001. Efforts to include more native brood stock were accomplished. The 2003 BRT considered that these changes would somewhat reduce risks to naturally spawning OC coho salmon. As of 1999 most adult coho salmon of hatchery origin were marked with an adipose fin clip for fishery management: an additional benefit was better accounting of hatchery fish spawning in the wild.

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[4] Oregon Coast coho salmon naturally produced fish, also includes SONCC populations in Oregon.

The 2003 BRT conclusions for the ESU as a whole reflected ongoing concerns for the long-term health of this ESU: a majority of BRT opinion was in the “likely to become endangered” category, with a substantial minority falling in the “not likely to become endangered” category. Although they considered the significantly higher returns in 2001 and 2002 to be encouraging, most members felt that the factor responsible for the increases was more likely to be unusually favorable marine productivity conditions than improvement in freshwater productivity. The majority of BRT members felt that to have a high degree of confidence that the ESU was healthy, high spawner escapements should be maintained for a number of years, and the freshwater habitat should demonstrate the capability of supporting high juvenile production from years of high spawner abundance. The 2003 BRT considered the long-term decline in productivity to be the most serious concern for this ESU. With all directed harvest for these populations already eliminated, harvest management (i.e., reducing harvest rates) could no longer compensate for declining productivity. The BRT was concerned that the long-term decline in productivity reflects deteriorating conditions in freshwater habitat and that the OC Coho Salmon ESU would likely experience very serious risks of local extinctions during the next cycle of poor ocean conditions. With the cushion provided by strong returns in 2001-2003, the 2003 BRT had much less concern about short-term risks associated with abundance than did earlier BRTs.

# New Contributions to Understanding and Assessing Status of Oregon Coast Coho Salmon

## ESU Delineation

The 2009 BRT evaluated new information related to ESU boundaries. The biogeographical and environmental information summarized by Weitkamp et al. (1995) remains unchanged, and the 2009 BRT did not reevaluate this information. The data on tag recoveries that Weitkamp et al. (1995) evaluated have subsequently been expanded, revised and published (Weitkamp and Neely 2002). The revised analysis continues to show a distinct pattern of ocean tag recoveries for the OC Coho Salmon ESU, consistent with Weitkamp et al.'s (1995) conclusions.

Several new genetic studies of west coast coho salmon that included samples from the Oregon coast have been published since the earlier status reviews. Ford et al. (2004) analyzed data at six microsatellite loci from 22 populations of OC coho salmon and several populations of Puget Sound coho salmon. Van Doornik et al. (2007) examined patterns of variation at 11 microsatellite loci from 84 coho salmon populations from northern California to southern British Columbia. Van Doornik et al. (2008) examined patterns of variation at 8 microsatellite loci from coho salmon sampled from central California to Alaska. Johnson and Banks (2008) analyzed 23 populations of OC coho salmon (included one population from the Rogue River, in the SONCC ESU) at 8 microsatellite loci.

The patterns of genetic variation in these newer studies are generally similar to those observed in the earlier studies summarized by Weitkamp et al. (1995). In particular, the new studies confirm that coho salmon are characterized by relatively low levels of population differentiation compared to other salmon species, particularly in the central part of their range. The new studies that include coast-wide samples (Van Doornik et al. 2007and 2008) are also consistent with the data cited by Weitkamp et al. (1995) indicating genetic discontinuities at or around Cape Blanco and the Columbia River mouth. In particular, in a neighbor-joining tree cluster analysis, Van Doornik et al. (2007 and 2008) found 100% bootstrap support for a cluster containing samples from the Rogue and Klamath Rivers distinct from Oregon coast samples north of Cape Blanco. The same result has been confirmed with a more recent analysis of 18 microsatellite loci from approximately 6000 coho salmon sampled coast wide.[5] These analyses indicate that the Oregon coast samples are distinct from the Columbia River and more northern populations, with moderate to high levels of bootstrap support.

[5] Carlos Garza, SWFSC, 110 Shaffer Rd. Santa Cruz, CA, pers comm. November, 2009.

After considering the new information, the 2009 BRT concluded that a reconsideration of the ESU boundaries for the OC Coho Salmon ESU is not necessary. The basis for this conclusion is that the environmental and biogeographical information considered by Weitkamp et al. (1995) remains unchanged, and new tagging and genetic analysis published subsequently to the original ESU boundary designation continue to support the current ESU boundaries.

## Artificial Propagation - Membership in the ESU

At the time of the 2004 proposed rule and January 2006 final determination not to list the OC Coho Salmon ESU, Cow Creek (ODFW stock #37), the North Umpqua River (ODFW stock #18), the Coos Basin (ODFW stock #37), the North Fork Nehalem stock, and the Coquille River (ODFW stock #44) hatchery coho programs were considered part of the OC Coho Salmon ESU. The Trask (Tillamook) and Salmon (Salmon, Siletz) stocks were excluded from the ESU due to observed or suspected divergence from natural populations (NMFS 2004b - http://www.nwr.noaa.gov/Publications/upload/SHIEER.pdf see Table 22.1 of referenced document). The North Umpqua, Coos, and Coquille programs have been discontinued since the 2006 final determination (NMFS, 2007a). The last year of returns for these programs was 2007. At the time of 2008 listing, only the Cow Creek stock was included in the ESU (the North Fork Nehalem was excluded from the ESU based upon comments from ODFW; NMFS 2008). As of 2009, only three coho hatchery stocks are released within the freshwater boundaries of the OC Coho Salmon ESU. These are the North Fork Nehalem, Trask (Tillamook basin) and Cow Creek (South Umpqua) stocks[6] . The BRT found no new information to suggest that current ESU membership status of these stocks (Cow Creek in the ESU, others out of ESU) should be changed.

## Population Delineation

Recently, the Oregon Coast Coho Salmon Workgroup (Workgroup), a subcommittee of the Oregon/Northern California Coast TRT, published two documents; "Identification of Historical Populations of Coho Salmon (*Oncorhynchus kisutch*)" (Lawson et al. 2007), and "Biological Recovery Criteria for Oregon Coast Coho Salmon" (Wainwright et al. 2008). These defined historical population structure and biological recovery criteria and are discussed below. Because of these analyses, the discussion of risk to the species can be focused at a finer scale than in previous status reviews.

The TRT's analysis of historical population structure of the ESU relies upon a simple conceptual model of the spatially dependent demographics of the 56 populations the Workgroup considered likely to have been present historically within the ESU. This model classifies populations on the basis of two key characteristics: persistence (their relative abilities to persist in isolation from one another), and isolation (the relative degree to which they might have been influenced by adult fish from other populations straying into their spawning areas). The 56

[6] Lance Kruzic, NMFS Habitat Conservation Division, Roseburg, OR. Pers. comm. December 2009.

populations are also used by ODFW and other resource agencies and have been incorporated into the State of Oregon's monitoring framework (ODFW 2007).

The TRT classified historical populations as dependent and functionally and potentially independent. For the purposes of this BRT, historical populations were reduced to two groups: independent, and dependent (Table 2; Fig. 3) Oregon coast drainage basins of intermediate to large size are thought to have each supported a coho salmon population capable of persisting in isolation. Some of them may have been demographically influenced by adult coho salmon straying into spawning areas from elsewhere in the ESU. Populations that appeared likely to have been capable of persisting in isolation were classified as independent (21 populations). Small coho salmon populations found in smaller coastal basins and may not have been able to maintain themselves continuously for periods as long as hundreds of years without strays from adjacent populations were classified as dependent populations (Lawson et al. 2007).

The TRT concluded that dependent populations relied at times upon the strength of adjacent larger populations for their continuous historical presence in the Oregon coast's smaller basins. As long as the larger persistent populations within the ESU remained strong, the smaller (dependent) populations would rarely if ever have disappeared from their basins. However, if some form of broad-scale environmental change triggered a substantial decline in one or more of the larger populations, the reduction in migrants would have increased the possibility that the same environmental change, perhaps coupled with local disturbances, would have resulted in the intermittent disappearances of the dependent populations found in some of the smaller basins. This may have occurred in the ESU in 1998 when no spawners were observed returning to Cummins Creek (Lawson et al. 2008.)

## Definition of Biogeographic Strata

Within the OC Coho Salmon ESU, there is substantial genetic and biogeographic structure, with populations clustering into a few larger geographic units that were identified by the Workgroup. These biogeographic strata represent both genetic and geographic similarities and assume that preserving sustainable populations in each of them will conserve major genetic diversity in the ESU as well as spread risks to the maintenance of genetic and geographic diversity due to catastrophes. The Workgroup considered that all strata must be secure for the entire ESU to be sustainable (Wainwright et al. 2008).

In defining the biogeographic strata, the Workgroup considered that the four ODFW monitoring areas (Fig. 29 in Lawson et al. 2007) in the ESU, for the most part, reflected the geography, ecology and genetics of the landscape. However, the lakes are very different from the other portions of the Mid-south Coast Monitoring Area ecologically and geographically as well as genetically. In order to reflect this diversity and to reduce the risks to genetic and geographical diversity due to catastrophes, they accepted the Ford et al. (2004) Lakes Complex as a fifth biogeographical stratum for use in defining areas of diversity important in conservation (Fig. 3).

Because these units represent both biological diversity (genetic and ecological) and geographic variation, the Workgroup considered that preserving all of them will accomplish two goals: preserving major genetic and life history variation in the ESU, and spreading risks due to catastrophes. The 2009 BRT used these strata in considering risks to genetic and life history diversity.

## Biological Recovery Criteria Used to Inform Risk Assessment

Wainwright et al. (2008) outlined biological recovery criteria (also called viability criteria) for the Oregon Coast Coho Salmon Evolutionarily Significant Unit (ESU), as identified in NMFS's status review for West Coast coho salmon (Weitkamp et al. 1995). The report was developed by the Oregon Coast Workgroup (Workgroup) of the Oregon and Northern California Coast Technical Recovery Team (ONCC TRT).

The BRT used the Wainwright et al. (2008) report as one important source of information to inform its risk assessment process. However, the BRT also considered other factors, such as environmental threats, not included in the Wainwright et al. (2008) criteria, in making its overall risk determination.

### Decision Support System

A complete assessment of the biological condition of the ESU is necessarily multifaceted, including a variety of interrelated criteria, with varying data quality. The recovery criteria developed by the TRT relate to biological processes at a variety of time and space scales, with processes varying from individual stream reaches to the entire range of the ESU. To track this large suite of data and criteria in a transparent and logically consistent framework, Wainwright et al. (2008) constructed a knowledge-based decision support system (DSS).

The DSS uses a network framework to link criteria at a variety of scales and aggregate them from fine-scale watershed-level criteria, through population-level criteria and biogeographic stratum-level criteria, to criteria for the entire ESU. The links take the form of logical operators that define specific relationships among the input values. In this knowledge-based system a type of "fuzzy" logic extends the ability to work with imprecise knowledge of attributes of the OC Coho Salmon ESU. The advantage of using this logic is that it allows evaluation and expression of certainty in an outcome, ranging from certainly false through uncertain to certainly true. The ability to work with a gradation of levels of certainty and uncertainty assisted the 2009 BRT in evaluating the degree of risk and uncertainty in its assessments. This analysis is further described in Current Biological Status below.

# New Comments

Below are brief summaries of comments NMFS received in response to the April 2009 Federal Register notice asking for new scientific information for consideration by the BRT. Full texts of the comments are available from NMFS Northwest Regional Office.[7] These comments were considered by the BRT in their deliberations.

**Trout Unlimited** comment that they favor maintaining the current status of listed as threatened. They asked the BRT to take a close look at hatchery practices, harvest, bycatch in estuary fisheries, and climate change during this status review. No specific information regarding these issues was provided (Trout Unlimited 2009).

**The U.S. Environmental Protection Agency (EPA)** comments focus on the inadequacy of state programs to protect water quality and other OC coho salmon habitat requirements. They present comments previously included in other OC coho salmon reviews that the Oregon Forest Practices Rules and Best Management Practices will not consistently meet water quality standards or protect riparian function. A letter they sent to the State of Oregon in 2005 regarding the inadequacy of the State's Oregon Coast Coho Conservation Plan was attached (USEPA 2009).

**The Pacific Rivers Council** (PRC) and **Center for Biological Diversity** support maintaining the current listing of threatened and assert that they have no knowledge of credible information available to support changing this ESU's status. They include by reference that the State of Oregon was unable to secure an ESA Section 10 Habitat Conservation Plan for the Elliot State Forest Management Plan. They cite a letter from NMFS/NWR Habitat Conservation Division stating that NMFS has unresolved concerns regarding the ability of the plan to protect OC coho salmon habitat. They also point out that other state forest plans throughout the range of OC coho salmon are similar to the Elliot State Forest situation and may be equally inadequate. The PRC also suggests that we use watershed road density as a measure of risk for OC coho salmon. They cite a new BLM analysis indicating that road densities are relatively high throughout almost all sub-watersheds occupied within OC coho salmon distribution. Their final point is about considering local extirpation and population homogenization due to the population dynamics driven by ocean conditions (Pacific Rivers Council 2009).

**The American Forest Resources Council** commented on measurable habitat improvements since adoption of the Oregon Plan in 1997. They cited several publications and reports indicating that recent improvements in OC coho salmon habitat demonstrate that the Oregon Plan is working. The Council is also supportive of a population viability assessment that

[7] NMFS Northwest Regional Office, 1202 NE Lloyd Blvd. Suite 1100, Portland, OR 97232.

is tailored to this particular ESU and its naturally wide swings in abundance. They caution against using the more simple population viability models relying primarily on abundance and productivity adopted by other west coast salmon TRTs (e.g., Puget Sound TRT 2002) (American Forest Resources Council 2009).

**ODFW** provided a significant amount of new information about the status of this ESU. Their comments highlight recent hatchery release reductions and changes to marine harvest. They point out that during times of low ocean survival, harvest will be managed under Amendment 13 of the Pacific Salmon Treaty, but state that at times of higher abundance, coho salmon harvest may occur at levels that limit progress toward recovery but does not represent a threat to viability. ODFW also provided new population data. New information on habitat conditions was also provided. ODFW generally concluded that range-wide stream and riparian habitat condition have remained relatively stable between 1998 and 2008. But, they also conclude that this habitat is in a condition suitable for producing enough smolts to maintain viability even during periods of low marine survival. ODFW reports that stream productivity seems to be improving slightly in all areas except the Umpqua Basin (Anlauf et al. 2009, ODFW 2009a).

**The Douglas County Commissioners** supplied a list of habitat improvement projects carried out in the Umpqua River Basin. They stated that the number of projects occurring in this basin was evidence that the Oregon Plan works as intended. The Commissioners also comment that significant harvest reform has been completed to ensure harvest no longer represents a threat to this ESU's viability. They assert that recent high abundance realized by Umpqua populations and the cancellation of the North Umpqua hatchery program further demonstrate that this ESU does not need to be listed. Finally, they point out what they believe are some problems with the BRT population models. The Commissioners are in favor of a not warranted finding for this ESU (Douglas County Commissioners 2009)

**The State of Oregon** (Governor's Office) commented that the State "through its natural resource agencies, continues to put substantial effort on the ground and in policy to improve conditions for and status of coastal coho salmon..." Their comments provide a summary of the Oregon Plan and the 2007 Oregon Coast Coho Conservation Plan. They also list the state agencies responsible for implementation of these plans and provide some of their recent accomplishments (Oregon 2009b).

**The Coquille Indian** Tribe comments mostly focused on coho salmon in the Coquille River Basin. They listed several habitat limiting factors and provided an update on recent restoration projects carried out by the Tribe and their partners. They also provided some information on recent abundance estimates and cited a study (Jacobs 2002) that concluded that recent surveys may have underestimated the abundance of returning coho spawners. The Tribe stated that predators (marine mammals, birds, and fish) may be having significant effects on OC coho salmon. The Tribe concluded their comments by suggesting that some basins like the Coquille, Coos, and Umpqua be examined differently in the status review because listing is not warranted (Coquille Indian Tribe 2009).

**Thad Springer** (a private citizen) was not in favor of a listing and comments that the presence of a listed species is a disincentive to private landowners to carrying out restoration projects on their land. Mr. Springer also provided a list of information sources the BRT should consider, mostly related to state programs (Springer 2009).

**Native Fish Society** (Paul Engelmeyer) commented that OC coho salmon should remain listed as threatened. He asserted that the Oregon Forest Practices Act and state programs for agricultural lands are insufficient to protect water quality in the ESU. He also pointed out several other threats including pesticide runoff into coho salmon streams, designation of the beaver as a nuisance species by State of Oregon, and ongoing floodplain development. He commented against terminal recreational harvest of OC coho salmon in TRT-identified independent populations (Umpqua, Coos, Yaquina, etc.) and was critical of Amendment 13 of the Pacific Salmon Treaty. Mr. Engelmeyer included numerous reports with his comments that have been made available to the BRT (Native Fish Society 2009).

# Oregon Coast Coho Salmon Symposium

In order to provide an opportunity for the State of Oregon and Oregon Department of Fish and Wildlife to present their information to the BRT, a one day symposium was organized. In addition to the State of Oregon, comanagers and interested parties were invited to make presentations of new scientific information and information on restoration activities. This section provides a short summary of the main topics presented at the symposium. The information presented was considered by the BRT in their deliberations.

**Oregon Coast Coho ESU: Population Status and Conservation Measures Update from Oregon Department of Fish and Wildlife**. Mr. Kelly Moore, ODFW presented an overview of fish metrics for the ESU. These were; wild or natural spawner, and hatchery spawner abundance time series from 1950 to 2008, spawner abundance by population, spawner distribution, spawner surveys from 2005-2008 occupancy, modeled parr capacity, juvenile occupancy rates, hatchery release history, trends in hatchery influence, lifecycle monitoring- egg to smolt and smolt to adult survival, habitat productivity HLFM modeled smolt capacity, population abundance patterns and spatial distribution variability and 2008-2009 returns. Oregon Plan and Oregon Coast Coho Conservation Plan information was also presented. This included additional factors for decline/issues of concern, the Oregon Plan habitat strategy, recognition of contributions to habitat by beaver and what ODFW is doing to encourage conservation of beavers and the contributions of Oregon watershed councils.

**The Status and Trends of Physical Habitat and Rearing Potential in Coho Bearing Streams in the Oregon Coastal Coho Evolutionary Significant Unit**. Mr. Kim Jones, ODFW, presented information on the Habitat Survey Program and included a discussion of factors for decline, Oregon Plan integrated monitoring, survey design, distribution of sites and balancing status and trends sampling requirements. He discussed the four monitoring strata and the status of stream habitat in the Oregon Coast Coho Salmon ESU. The monitored aspects of wadeable streams are pools, large wood volume, fine sediments and winter habitat. The Habitat Limiting Factor Lifecycle Model (Anlauf 2009) was discussed with a presentation of the capacity of differing kinds of pools, winter rearing and spawner abundance. Monitoring trends analysis done by Kara Anlauf concluded that the ESU's streams are generally pool rich, but structurally simple, mean values of the monitored attributes are all low, and that there are few off-channel habitats or beaver pools and most streams have low volumes of wood and high fine sediment.

**Oregon's Plan for Protecting Salmon and Watersheds.** Ms. Suzanne Knapp, of the Governor's Natural Resources Office, discussed the Oregon Plan framework and what agencies are addressing limiting factors such as water removal, water quality and stream complexity.

**BLM and USFS Land Management in Oregon Coast Coho ESU.** Mr. Joe Moreau, BLM State Office, presented information on the types of restoration activities and the costs that USFS and BLM have engaged in to help restore OC coho salmon habitat.

**Satellite-based Summaries of Yearly Timber Harvest Rates on all Lands Within the Coho ESU from 1985 to 2008.** Dr. Robert Kennedy, Department of Forest Ecosystems and Society, OSU, presented his work on a new application of his LANDSAT analytical method. He presented information that attempts to address the question "does terrestrial habitat condition matter for coho salmon with respect to temperature, sediment type and delivery?" His conclusions are that the yearly disturbance information is useful for interpretation of impacts of policy and economics, that disturbance magnitude shows variability across ownerships and time and that private lands dominate both the land base and disturbance impacts. He also suggested that variation in disturbance rates and timing across basins may provide leverage for useful inferences about land management actions.

**Maintaining Oregon's Forest Land Base: The Forest Practices Act Role in the Conservation of Forest Values on Non-federal Forest Lands.** Mr. Jim Paul, Oregon Department of Forestry, presented the Oregon Plan accomplishments of private timber land owners and discussed the threat of forest conversion to other land uses.

**Road Density, Watershed Condition, and Implications for Salmonid Conservation in the Range of the Oregon Coastal Coho Salmon**. Dr. Chris Frissell, Pacific Rivers Council, presented a summary of his and others' work on applicable science from studies in the Columbia Basin on Bull Trout (*Savelinus confluentus*). These centered around habitat response - more fine sediment, fewer pools, less wood, water quality decline (temperature and nutrients/toxics) and watershed degradation and salmon population response such as status, abundance and species diversity.

**Observations on Water Quality Improvement under SB1010 and other Lowland Issues.** Mr. Paul Engelmeyer, Native Fish Society, presented an overview of four issues that need significant change to improve the chances of coho population recovery at a landscape scale. These are: agricultural water quality management, State of Oregon beaver policy, policies to protect floodplain function, and improvement in forest practices.

**Recent Observations of Oregon Coast Coho Salmon in Smith River.** Dr. Joe Ebersole, EPA, presented some of his work that tries to help identify where habitat restoration activities should take place. His conclusions are that OC coho salmon utilize intermittent stream habitat for a significant amount of winter rearing. In addition, what should be very good habitat (high intrinsic potential) is presently poor habitat in the study area due to legacy stream effects such as splash damming. He suggests that habitat that should be improved and conserved is the existing habitat currently the center of coho salmon production. In other words, "fix the best first."

**Hinkle Creek Paired Watershed Study.** Mr. Daniel Newton, working with the Watershed Research Cooperative, presented preliminary results of the Hinkle Creek paired watershed study.  Their preliminary findings were that initial temperature response was small compared to original Alsea Watershed Study, downstream recovery of nutrient increases following timber harvest is typical of other studies, sediment increased following timber harvest, but was attenuated downstream, and that fish (coastal cutthroat trout and steelhead) survival and distributions were similar to pre-harvest patterns.

**Comments of Douglas County, Oregon, on Oregon Coast Coho Salmon ESU.** Mr. David Loomis, Douglas County Board of Commissioners and Public Works Department, presented information on the effects of unreported "habitat restoration projects" and the unreported decline of "likely to adversely affect" activities in freshwater habitat on the evaluation of habitat conditions.  He also discussed habitat restoration projects reflecting specific needs of OC coho salmon populations (instantaneous and long-term), spawner to spawner ratios and generational "health" of individual populations.  A discussion of recent ocean and in-river harvest history, the hatchery program level for North Umpqua and for Umpqua basin (strays) was also included.  He requested the BRT to use the North Umpqua Population Case Study as "truth value" of model sensitivity and risk of extinction status (Douglas County Commissioners 2009).

# New Data and Updated Analyses

## Current Biological Status

This section addresses new data and updated analyses for the VSP parameters of population size, population growth rate, spatial structure, and diversity (McElhany et al. 2000.) In addition, harvest impacts and artificial propagation sections are included here for consistency with previous BRT analyses. Finally, a new analysis utilizing the ONCC TRT's Biological Recovery Criteria is included.

### Population Size

In past status reviews (Weitkamp et al. 1995; NMFS 1997a; Good et al. 2005), the BRTs considered two measures of recent population abundance -- spawner abundance and pre-harvest recruits -- and also considered recent estimates in the context of published estimates of abundance in the late 1800s and early 1900s (Mullen 1981a[abundance]; Lichatowich 1989; ODFW 1995).

The 2009 BRT received updated estimates of total natural spawner abundance (and corresponding recruits) based on stratified random survey techniques broken down by historical populations for 10 major river basins and for the coastal lakes system.[8] These data are shown in Table 3 and in Figs. 4 and 5. Since the previous status review, natural spawner abundance was generally up relative to the late 1990s, and in all but 1 year (2007) has been well above the recent mean.

In the 1994 status review, Weitkamp et al. (1995, p. 113) considered historical estimates of abundance for this ESU, and concluded that "... these numbers suggest that current abundance ... may be less than 5% of that in the early part of the century." The current BRT re-examined that information, and re-analyzed some of the historic abundance information. The earlier review based this conclusion largely on estimates of "spawning escapement" published by ODFW (Mullen 1981a [abundance]). A re-examination of Mullen's tables found that he made a mis-calculation such that the spawning escapement estimates included in-river gill net harvest, and were thus inflated.

We made an independent estimate of spawners and recruits for the ESU for the period 1892 – 1956 using in-river gill-net harvest estimates from other ODFW reports (Cleaver 1951; Mullen 1981b [harvest]). Spawner escapement was estimated by expanding estimated gill-net

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8 River basins from Pacific Coast Salmon Plan Sept. 2003, data from Kelly Moore, Research and Monitoring Supervisor, Pers. Comm. ODFW Corvallis Research Lab, 28655 Hwy 34, Corvallis, Oregon 97333.

harvest, assuming a 40% harvest rate for 1892 - 1925 (Mullen 1981a [abundance]; Lichatowich 1989), which was reduced as rivers were closed to fishing (Table 7 in Mullen 1981b[harvest]; 12 rivers open in early years, 7 rivers remained open until 1956). Recruits were then calculated by adding in-river harvest and ocean troll catch. Ocean troll catch estimates are available for 1925 - 1927, and we assumed a 10% ocean harvest rate for 1912 - 1924 (Mullen 1981b). Results are shown in Fig. 6, compared with more recent estimates. From this historical perspective, recruits over the past few years have been close to the 1960-2009 average, but are only a fraction of abundance before 1940.

While these historical abundance estimates are very rough and based on an assumed gill-net harvest rate derived from expert opinion, they suggest that there has been a substantial decrease in ESU-wide abundance during the twentieth century. In fact, the decline was a concern to state biologists as early as the late 1940s (Cleaver 1951). Cleaver did not discuss causes of the decline other than to note that it was not caused by changes in harvest rates. However, Lichatowich (1989) related the overall decline to habitat loss, reporting a decline in production potential from about 1.4 million recruits ca. 1900 to only 770 thousand in the 1980s, likely resulting from habitat alterations related to timber harvest and agriculture which both expanded on the coast between 1910 and 1950.

## Population Growth Rate

Previous status reviews noted strong concerns regarding both long- and short-term trends in population productivity of the ESU. The BRT examined population growth rate (productivity) via two parameters: the ratio of recruits to spawners (R/S), and the natural return ratio (NRR). These measure different aspects of population dynamics. R/S indicates the basic productivity of populations in the absence of harvest, i.e., the intrinsic ability of spawners in one generation to produce adults in the next generation. NRR is defined as the ratio of naturally produced spawners in one generation to the total (natural + hatchery-produced) spawners in the previous generation. NRR indicates the realized ability of populations to replace themselves, given intrinsic production and the effects of harvest and hatchery production.

Recruits from the return years 1997–1999 failed to replace parental spawners: a recruitment failure occurred in all three brood cycles even before accounting for harvest-related mortalities (Fig. 4). This was the first time this had happened since data collection began in the 1950’s. In most years since 2000, improved marine survival and higher rainfall are thought to be factors that have contributed to an upswing in recruits. However, in the return years 2005, 2006, and 2007, recruits also failed to replace parental spawners (Fig. 4). There are several possible explanations for the more recent recruitment failure. It may reflect population dynamics that have not been allowed to occur since 1950; prior to 1994 harvest had consistently maintained spawner abundance near 50,000 fish (Fig. 5). With harvest sharply curtailed in 1994, most recruits have been able to return to spawn. Ocean conditions improved for the 1998 brood year, and recruits since 2001 have returned to spawn in numbers higher than we have previously observed. Harvest and hatchery reductions have changed the population dynamics of the ESU. Assuming these changes continue into the future, response of the system to fluctuations in environmental conditions and spawner escapements may show a different pattern than we have seen in the recent past. However, it is too soon to say with confidence the nature of these changes or the degree to which they may have improved the status of the ESU. In particular, it has not been demonstrated that productivity during periods of poor marine survival is now adequate to sustain the ESU.

Response of the system to higher escapements is essentially unknown: there are several possible interpretations of the recent patterns in productivity as measured by R/S and NRR. These productivity statistics are influenced by marine survival, freshwater survival, and freshwater carrying capacity (there is little evidence for an ocean carrying capacity). The current data set measures only the endpoints of spawners and ocean recruits so we cannot easily separate the effects of freshwater and marine survival, although the ODFW life cycle monitoring sites help address this concern for recent years. Several lines of evidence based on patterns in the marine environment (CalCOFI 2010) and patterns of survival and abundance of a variety of salmon stocks in the Pacific Northwest (PFMC 2011 [Review of Fisheries]) indicate that marine survival has been relatively good during the period from about 1998 to the present. Despite apparently high marine survival, OC coho salmon recruitment never exceeded 275,000, suggesting that current freshwater habitat capacity is substantially lower than it was up to the 1980s, when production potential was estimated at about 767,000 (Lichatowich 1989). The observation that recruits failed to replace spawners in 2005 – 2007 could be an indication that productive capacity had been reached or simply be a reflection of patterns in marine survival. Recent increases do not provide strong evidence that the century-long downward trend has changed. Abundance observations are consistent with the pattern of cyclical abundance overlying a downward trend as hypothesized by Lawson (1993).

While total spawners has been at its highest level since the 1950s total recruits has not (Figs. 5 and 6). This suggests that the overall productivity (Figs. 4, Fig. 8) and capacity (Figs. 5 and 6) of the system has, at best, been stable over the past half-century.

Given current habitat conditions, OC coho salmon are thought to require an overall marine survival rate of 0.03 to achieve a spawner:recruit ratio of 1:1 in high quality habitat (Nickelson and Lawson 1998). Less productive habitats require higher marine survivals to sustain populations. Based on Oregon Production Index (OPI) hatchery survival rates (Table 4), marine survival (Adults/Smolt) exceeded 0.03 only in 2001 and 2003. Assuming natural spawners survive at twice the hatchery rate (Wainwright et al. 2008, Lawson et al. 2004), in 11 out of 18 years since 1990 marine survivals were high enough to sustain the ESU. Increases in recruits (Fig. 6) reflect improved marine survival after 2000. Marine conditions will continue to cycle (Lawson 1993) and, with the current freshwater habitat conditions, the ability of the OC Coho Salmon ESU to survive another prolonged period of poor marine survival remains in question.

For the ESU as a whole, the 12 year Natural Return Ratio (NRR) is higher than the long term NRR mean, with an up-and-down trend over the recent 12 years (Fig. 8). The pattern is similar for the North Coast, Mid-Coast and Mid-South Coast strata. The Lakes and Umpqua River strata have recent mean NRR close to the long-term mean. The trend for the Umpqua

River stratum is similar to the other riverine strata, while the Lakes stratum has a flat trend in recent years.

## Population Spatial Structure

The 2009 BRT utilized historical populations defined and classified in Lawson et al. (2007). The TRT identified 56 populations; 21 independent and 35 dependent. The dependent populations were dependent on strays from other populations to maintain them over long time periods. The TRT also identified 5 biogeographic strata. This is a change from the 1996 status review, which partitioned OC coho salmon into ODFW’s 3 Gene Conservation Groups and from the 2003 status review which partitioned OC coho salmon into ODFW’s four Monitoring Areas (Figs. 28 and 29 in Lawson et al. 2007).

Spatial structure was identified as a problem in the 1980s and 1990s when it was observed that river systems on the North Coast had substantially lower spawner escapements than those on the South Coast. This problem persisted into the late 1990s (see Table 5). Causes of these disproportionately lower escapements were never clearly identified, but contributing factors may have included more intense fisheries north of Cape Falcon near the mouth of the Columbia River and high percentages of hatchery fish on the spawning grounds (Table 6). Stray hatchery spawners originated primarily from large hatcheries in the Nehalem and Trask Rivers, but also came from the Columbia River hatcheries. Harvest was generally reduced in 1994 (although not as severely north of Cape Falcon as south). Hatchery releases in the Nehalem and Trask Rivers have been reduced or eliminated so that the percentage of hatchery fish on the spawning grounds has declined from a high of 67% in 1996 to less than 5% in most recent years (Table 6). Since about 1999 the north coast basins have had escapements more on a par with the rest of the ESU. Reduced harvest, reduced hatchery influence, and improved ocean conditions are all likely contributors.

Current concerns for spatial structure focus on the Umpqua River. Of the four populations in the Umpqua stratum, two, the North Umpqua and South Umpqua, were of particular concern. The North Umpqua is controlled by Winchester Dam and has historically been dominated by hatchery fish (Table 6). Hatchery influence has recently been reduced, but the natural productivity of this population remains to be demonstrated. The South Umpqua is a large, warm system with degraded habitat. Spawner distribution appears to be seriously restricted in this population (Table 8), and it is probably the most vulnerable of any population in this ESU to increased temperatures.

The TRT's biological recovery criteria (Wainwright et al. 2008) describe a decision support system (DSS) to help evaluate the status of the ESU. One component of this DSS explicitly addresses diversity. Three of the diversity criteria are sensitive to abundance at the population (PD-1) and watershed (PD-3, PD-4) levels (see DSS section). The DSS is structured to provide high scores when spawner escapements are high and uniformly distributed among populations and strata. In addition, higher scores are generated when juveniles and spawners are widely distributed within each population.

## Population and Life History Diversity

In the spatially and temporally varying environment inhabited by OC coho salmon, diversity is important for species and population sustainability. Diversity allows OC coho salmon to use a wider array of environments than they could without it (see reviews in Groot and Margolis 1991) and protects against short-term spatial and temporal changes in the environment. Genetic diversity provides the raw material for surviving long-term environmental changes: fish with different characteristics have different likelihoods of persisting, depending on local environmental conditions. The more diverse a population is, the more likely it is that some individuals would survive and reproduce in the face of environmental variation (McElhany et al. 2000). As we see in this assessment of current status and future threats, OC coho salmon as a species, population, or as individuals, regularly face changes in their freshwater, estuarine, and ocean environments due to both natural and human causes.

Compared to other species of Pacific salmon, coho salmon exhibit moderate levels of life-history diversity (reviewed by Groot and Margolis 1991; Weitkamp et al. 1995). Coho salmon also tend to have somewhat lower levels of genetic diversity among populations compared to other Pacific salmon species, particularly in the central portion of their range (reviewed by Weitkamp et a. 1995 and Ford et al. 2004). These patterns have been interpreted as evidence for relatively high levels of gene flow among coho salmon populations (Ford et al. 2004, Johnson and Banks 2008). In the extremes of their range in California and Alaska, coho salmon tend to have higher levels of population differentiation than in their central range, probably due to genetic drift in relatively small populations (Bucklin et al. 2007; Olsen et al. 2003). Even within the OC Coho Salmon ESU, the geographically central populations had higher levels of genetic diversity compared to populations at the northern and southern boundaries of the ESU, apparently due to overlapping migration patterns from strong northern and southern populations (Johnson and Banks 2008).

Most of the studies of molecular genetic variation within and among Oregon coho salmon populations utilized either allozymes (reviewed by Weitkamp et al. 1995) or microsatellite loci (e.g., Ford et al. 2004; Johnson and Banks 2008). These types of genetic markers (particularly microsatellites) are typically interpreted under an assumption that the dominant forces driving their evolution are mutation, drift, and migration. In contrast, Johnson and Banks (2008) examined patterns of variation at several genes that play a role in olfaction, and are therefore potential candidates for evolution by natural selection. Their study focused on several of the Lakes populations and the Lower Umpqua River, and the authors found notably higher levels of among population differentiation at one of the olfactory loci than was observed at microsatellite loci, suggesting that natural selection is increasing patterns of genetic differentiation among these populations at some specific genes. This result suggests that despite the relatively high rates of genetic flow among OC coho salmon populations, there is potential for local adaptation among these populations.

Within the OC Coho Salmon ESU, there is substantial genetic and geographic variation and structure, with genetic similarities clustering into a few geographic units. In the Workgroup analyses, they designated these clusters as “biogeographic strata” which represent both genetic and geographic similarities, as well as identifiable diversity among them (Lawson et al. 2007). Biological Recovery Criteria (Wainwright et al. 2008) were based on the principle that preserving sustainable populations in each of these biogeographic strata would conserve major genetic diversity in the ESU as well as spread risks to the maintenance of genetic and geographic diversity due to catastrophes.

Providing access to a diversity of productive habitat types allows expression of phenotypes that may not otherwise occur. Although it is unknown which particular life history type will be successful in a given year, the expectation is for some life history types to be more successful than others. Consequently, by ensuring that a wide range of productive habitats are accessible to coho salmon, the opportunity is provided for greater expression of life history diversity, which, in turn, should increase the chances that at least some coho salmon life history types will be successful (Wainwright et al. 2008). In a more recent analysis, Greene et al. (2010) "…strongly suggest that life history diversity can both increase production and buffer population fluctuations, particularly over long time periods. Our findings provide new insights into the importance of biocomplexity beyond spatio-temporal aspects of populations, and suggest that maintaining diverse life history portfolios of populations may be crucial for their resilience to unfavorable conditions like habitat loss and climate change."

As an example, extensive losses of access to habitats in estuaries and tidal fresh water may have been an important factor in reducing population diversity in OC coho salmon. The Oregon coastal drainages supporting independent OC coho salmon populations all terminate in tidally influenced freshwater/brackish/saltwater wetland/estuarine habitats (e.g., Good 2000). Recent sampling in coastal rivers from northern California to Alaska indicates that coho salmon juveniles are often present in these lower river/tidal freshwater/estuarine habitats (e.g., Koski 2009). Migrant trapping studies indicate that a substantial number of coho salmon fry emigrate downstream from natal streams into tidal reaches and are therefore available to use lower river wetland/estuarine habitats (e.g., Chapman 1962, Miller and Sadro 2003, Koski 2009). In the past, observations of spring or early summer downstream migration of coho salmon fry were thought to represent a passive displacement in response to increased stream flows, competitive interactions, or capacity limitations. However, in recent studies summarized by Koski (2009) there is evidence that downstream migrations of coho salmon may be associated with specific life history strategies that contribute to resiliency in the face of fluctuating environmental conditions.

More recently, Bass (2010), working in the Coos River, has reported that "widespread estuarine wetland losses have likely reduced the rearing capacity of coastal basins and decreased resiliency by diminishing the expression of subyearling migrant life histories within and among coho salmon populations." They also reported 9 coho salmon jacks PIT tagged as subyearling reservoir residents in spring 2008 and detected in the fall of 2009. For the 2007 brood year, there were 33 returns from 1,191 coho tagged as presmolts (age 0) and 38 returns from 742 fish tagged as smolts.[9] This suggests that these "nomad" early downstream migrants can survive and contribute to the spawning population. Bass (2010) conclude: "By affecting coho salmon

[9] Katherine Nordholm, Oregon State University, Department of Fisheries and Wildlife, pers. comm. February, 2011.

nomads to a greater extent than other life history types, estuary loss may reduce the potential productivity boost and resilience component that this life history may contribute to its natal and neighboring populations."

In the recent past, the effect of hatchery releases had a significant effect on life history diversity in the OC coho salmon ESU. ODFW has significantly reduced hatchery releases of coho salmon, therefore the effect of hatchery fish on native population diversity should be abating, although there is little information about the duration of hatchery genetic effects on naturally spawning populations. Because of significant reduction in hatchery releases of coho, the hatchery fraction of spawners observed on the spawning grounds has been substantially reduced (ODFW 2009a). This should lead to improvement of diversity in naturally produced OC coho salmon in those populations once dominated by hatchery fish.

Since 1990 there have been years with extremely low escapements in some systems and many small systems have shown local extirpations, presumably reducing diversity due to loss of dependent populations. For example, Cummins Creek, on the central coast, had no spawners observed in 1998, indicating the potential loss of a brood cycle. These small systems are apt to be repopulated by stray spawners most likely from larger adjacent populations during periods of higher abundance (Lawson et al. 2007) and recent local extirpations may represent loss of genetic diversity in the context of normal metapopulation function.

Current status of diversity shows improvement through the waning effects of hatchery fish on populations of OC coho salmon. In addition, recent efforts in several coastal estuaries to restore lost wetlands should be beneficial. However the loss of diversity brought about by legacy effects of both freshwater and tidal habitat loss coupled with the restriction of diversity from very low returns over the past 20 years led us to conclude that diversity is lower than it was historically.

## Harvest Impacts

Historical harvest rates on Oregon Production Index area coho salmon were in the range of 60% to 90% from the 1960s into the 1980s (Table 3). Modest harvest reductions were achieved in the late 1980s, but rates remained high until a crisis was perceived, and most directed coho salmon harvest was prohibited in 1994. Subsequent fisheries have been severely restricted (ODFW 2005d, 2009a) and most reported mortalities are estimates of indirect (noncatch) mortality in Chinook fisheries and selective fisheries for marked (hatchery) coho. Estimates of these indirect mortalities are somewhat speculative, and there is a risk of underestimation (PFMC 2009, Lawson and Sampson 1996).

### Amendment 13

The Pacific Fishery Management Council adopted Amendment 13 (PFMC 1998) to its Salmon Fishery Management Plan in 1998. This amendment was developed as part of the Oregon Plan for Salmon and Watersheds. It specified an exploitation rate harvest management regime with rates for OC naturally produced coho salmon dependent on marine survival (as indexed by hatchery jack:smolt ratios) and parental and grandparental spawning escapements. Exploitation rates ranged from 13% to a maximum of 35%. In 2000, Amendment 13 was reviewed, and the harvest rate matrix was modified to include a 8% category under conditions of extremely poor marine survival, as was observed in the late 1990s. At the same time, the maximum exploitation rate was increased to 45% and the grandparental escapement criterion was dropped. Exploitation rates were calculated to allow a doubling of spawners under conditions of moderate-to-good ocean survival.

Risk assessment was conducted for Amendment 13 (PFMC 1998) and the 2000 Amendment 13 Review (PFMC 2000) using the Nickelson/Lawson coho salmon habitat-based life-cycle model (Nickelson and Lawson 1998). The models were augmented to include a management strategy evaluation that simulated the fishery management process, including errors in spawner assessment, prediction, and harvest management. In general, exploitation-rate management with a 35% cap showed a lower risk of pseudo-extinction than managing for an escapement goal of 200,000 spawners, but higher risk than a zero-harvest scenario. Starting from the very low escapements of 1994, basins on the north coast had higher extinction risks than those on the mid-north and mid-south coasts.

**Mark-selective fisheries**

Beginning in 1998 most adult hatchery-origin coho salmon in the Oregon Production Index area were marked with an adipose fin clip. This marking allowed the implementation of mark-selective fisheries, with legal retention only of marked fish. Unmarked fish were to be released unharmed. Recreational mark-selective fisheries have been conducted on the Oregon coast in each year since 1998, with quotas ranging from 9,000 to 88,000 marked fish.

Commercial troll fisheries targeting Chinook salmon were also operating. In 2007 a mark-selective commercial troll fishery targeting hatchery coho salmon was implemented with a quota of 10,000, and a similar fishery was implemented in 2008 with a quota of 21,240. Actual catch in these fisheries was about half of the quota in each year. A concern with these fisheries is the high ratio of unmarked to marked fish that was encountered.

Both the mark-selective coho and commercial troll Chinook salmon fisheries catch and release coho salmon, resulting in incidental mortalities. In addition, some coho encounter the gear, but escape or are eaten by predators; so-called drop-offs. Estimates of non-catch mortalities from hook and release and drop-off are difficult because they are, by their nature, unobserved. Field studies in the 1990s (NRC 1997) and a literature review and meta-analysis resulted in the adoption by the Pacific Fishery Management Council (PFMC), of hooking mortality rates of 13% for recreational fisheries and 26% for commercial fisheries. In addition, drop-off mortalities were assumed to equal 5% of the number of fish brought to the boat. These rates are used by the PFMC for a coho Fisheries Resource Allocation Model (FRAM) to estimate mortalities in Council-managed fisheries. Post-season estimates of OCN exploitation rates based on FRAM modeling have ranged from 0.07 to 0.15 since the curtailment of directed coho salmon fishing in 1994. The BRT considers that these rates may be underestimates, and that actual mortalities may have been greater (Lawson and Sampson 1996).

### Freshwater fisheries

A few small freshwater fisheries have been allowed in recent years based on the provision in Amendment 13 that terminal fisheries can be allowed on strong populations as long as the overall exploitation rate for the ESU does not exceed the Amendment 13 allowable rate, and population escapement is not reduced below full seeding of the best available habitat. The difference between these fisheries and the mark-selective fisheries in the ocean is that the freshwater fisheries are directed take on a listed species. NMFS has approved these fisheries with the condition that the methodologies used by ODFW to predict population abundances and estimate full seeding levels are presented to the PFMC for review and approval.

Despite these uncertainties, there is no doubt that harvest-related mortalities have been reduced substantially since harvest was curtailed in 1994. This reduction is reflected in positive short-term trends in spawner escapements (Figs. 5 and 6). Harvest management has succeeded in maintaining spawner abundance in the face of a continuing downward trend in productivity of these stocks. Further harvest reductions can have little effect on spawning escapements. Future remedies must be found outside of harvest management until the decline in productivity is reversed (Lawson 1993).

## Artificial Propagation

As of 2009, there are only three coho hatchery stocks in propagation within the OC Coho Salmon ESU. All other hatchery programs have been terminated. (For more discussion, see Artificial Propagation- ESU membership).

In previous OC coho salmon status reviews, coho salmon hatchery programs were a major concern throughout the ESU. High numbers of hatchery coho that could not be differentiated from naturally produced fish were released in most populations, hatchery brood stocks were intermixed among stocks of different populations, multiple life stages of juvenile hatchery coho were stocked into wild production areas, and hatchery origin (stray) coho were common in natural spawning areas throughout the ESU. However, since the early 1990's the State of Oregon has reformed hatchery practices due to a variety of genetic, ecological, and economic factors. This has lessened the risks of hatchery programs to wild coho populations in the ESU. These management changes have been described in detail in previous BRT assessments (i.e. Good et al. 2005) and are summarized below.

Releases of hatchery coho salmon in the ESU have declined from a peak of ~35 million fish in 1981 to ~260,000 smolts in 2009 (Fig. 9; Oregon 2005; ODFW 2009a, ODFW 2009b). In the early 1990's, hatchery coho were released in 17 of 19 ESU populations. In 2009, hatchery coho salmon were released in three of 19 ESU populations (Nehalem, Trask, and South Umpqua populations). In the early 1990's, ODFW managed 16 different brood stocks throughout the ESU. In 2009, there were only three brood stocks still in propagation (ODFW 2009a).

Since 1997 all hatchery coho released have been adipose fin clipped in order to differentiate between hatchery-origin and natural-origin fish in mark-selective fisheries and to evaluate straying of hatchery fish into natural spawning areas. External marking of all hatchery fish helped to resolve uncertainties about the magnitude of these interactions on the spawning grounds that had previously been assessed by evaluating fish scale data. In the 1990s many populations had proportions of hatchery fish in the natural spawning populations in excess of 40%, with the north coast populations having the highest proportion of hatchery spawners (Fig. 10; Table 6.) By the early 2000's, stray rates had decreased in most populations due to the elimination of hatchery programs and reductions in the number of fish released. Most populations are now below Oregon's stray rate standard of no more than 10% hatchery coho on the spawning grounds (Oregon 2007). The notable exceptions are the Salmon River and North Umpqua River populations, where stray rates were still greater than 50%. However, in brood year 2006, the Salmon and North Umpqua hatchery coho programs were eliminated entirely in order to decrease the straying problems. The percentage of hatchery fish spawning naturally in these two populations showed a substantial decrease beginning in the spawning season of 2009-10.

**New Data and Updated Analyses**

Since the previous status review assessments in 1997 and 2003, new information and analyses are available that help inform the BRT of the potential risks associated with hatchery programs and the conservation of the ESU. Interactions between hatchery and wild fish are generally considered to have negative outcomes for the wild fish. A large body of literature documents reduced spawning success, freshwater survival, and production of wild fish when hatchery fish are present (NRC 1997, Flagg and Nash 1999, Flagg et al. 2000, Independent Scientific Group [ISG] 2000, IMST 2001, Einum and Fleming 2001, Chilcote 2002, Hoekstra et al. 2007, Araki et al. 2008, Naish et al. 2008). Analyses of the specific effects of hatchery coho salmon on wild coho salmon on the Oregon coast have all concluded the existing hatchery programs were detrimental to the survival and productivity of this ESU (Nickelson 2003; Oosterhout et al. 2005; Buhle et al. 2009). The recent management changes by the State of Oregon are therefore expected to largely alleviate the detrimental effects of hatchery programs on wild coho salmon.

Overall, the reduction in hatchery activity is expected to benefit wild runs throughout the ESU. For example, Buhle et al. (2009) used data on natural spawning abundance, hatchery releases, and the proportion of hatchery fish in spawning populations to fit a model that allowed estimation of the impacts of hatchery releases on natural OC coho salmon productivity. Their model found a significant negative effect of both hatchery releases and naturally spawning hatchery fish, and they estimated the reductions in hatchery production since the mid-1990's accounted for ~27% of the increase in wild OC coho salmon seen in the 1997 to 2000 brood cycles. These results indicate that at least some of the benefits from reduced hatchery production have already been observed in the recent abundance trends. To the degree that past hatchery practices led to genetic deterioration of wild salmon stocks, additional benefits from the reduced levels of hatchery production may continue to accrue in the future as these populations adapt back to wild conditions. In addition, the two populations that have only recently seen reductions in hatchery releases (North Umpqua River and Salmon River) may also experience nearer-term gains in productivity due to the recent elimination of hatchery coho salmon released in those watersheds.

## TRT Biological Recovery Criteria Analysis

The biological recovery criteria developed by the TRT (Wainwright et al. 2008) are framed within the context of a Decision Support System (DSS). At the highest level, the DSS is structured to represent the hierarchical population structure of the ESU. Populations are grouped into biogeographic strata, which in combination make up the ESU. The DSS framework is organized into two categories; persistence and sustainability, which imply different levels of risk.

The persistence analysis assesses the ability of the ESU to persist (i.e., not go extinct) over a 100-year period without artificial support. This includes the ability to survive prolonged periods of adverse environmental conditions that may be expected to occur at least once during the 100-year time frame. This analysis has three population-level criteria that measure population productivity, probability of persistence, and abundance relative to critically low thresholds.

The sustainability analysis assesses the ability of the ESU to maintain its genetic legacy and long-term adaptive potential for the foreseeable future. Sustainability implies stability of habitat availability and other conditions necessary for the full expression of the population's (or ESU's) life history diversity into the foreseeable future. The criteria within the DSS (Table 7, Fig. 10) are used to evaluate population diversity using objective measures of spawner abundance, artificial influence, spawner and juvenile distribution, and habitat capacity. In addition, ESU-level diversity that includes genetic diversity (a function of genetic structure, effects of selection, effects of migration, and effects of introgression), phenotypic and habitat diversity, and small populations was evaluated. The BRT then used recent observations of these population metrics to inform their assessment of risk to the OC Coho Salmon ESU. In practice, application of the DSS began with evaluating a number of primary biological criteria that are defined in terms of logical (true/false) statements about biological processes essential to the persistence and/or sustainability of the ESU. Evaluating these primary criteria with respect to available observations results in a "truth value" in the range from –1 (false) to +1 (true). Intermediate values between these extremes reflect the degree of certainty of the statement given available knowledge, with a value of 0 indicating complete uncertainty about whether the statement is true or false. These primary criteria are then combined logically with other criteria at the same geographic scale, and then combined across geographic scales to result in an evaluation of ESU-wide criteria. Thus, the end result is an evaluation of the biological status of the ESU as a whole, with an indication of the degree of certainty of that evaluation.

Metrics for the DSS are derived from data provided by ODFW[10] from various survey and monitoring studies. Data include: Spawner survey data (peak counts and Area Under the Curve (AUC) estimates); estimates of wild and hatchery fish on the spawning grounds; distribution of spawners and summer juveniles; and estimates of habitat capacity. These

[10] Kelly Moore, ODFW, pers. comm. December 2010.

contribute to a set of objectively measurable criteria. ESU-level diversity was more difficult to evaluate because objectively measurable criteria were not available, so scores were produced using a formal process by an expert panel (Wainwright et al. 2008). ESU-level diversity was not reevaluated for this report.

**TRT Biological Recovery Criteria analysis results**

The DSS was run with data through the 2009 spawning run. In the process of compiling data for the four years since the TRT analysis, several inconsistencies were discovered and reconciled. For this reason the DSS results reported here (Figs. 11, 12 and Table 8, are not directly comparable to the results presented in Wainwright et al. (2008). Table 9 is presented for historical comparison but was not used by the BRT in their deliberations. Data used in the update were provided by ODFW. Table 10 summarizes VSP attributes (McElhany et al. 2000) related to DSS results.

Two criteria were not updated; Persistence probability, “PP-2”, based on four population viability (PVA) models, was not updated because sensitivity analysis presented in Wainwright et al. (2008) showed that DSS results were not very sensitive to small changes in individual model results. The main utility of the PVA model runs is to evaluate relative vulnerabilities of the populations. These relative vulnerabilities are unlikely to change with the addition of a few more years of data. Population functionality criterion “PF-1,” based on habitat quantity, was not updated because it would have required a major analysis of recent habitat data. The BRT considered that this criterion was not sensitive to small changes in habitat conditions and was also not particularly informative. Habitat issues were addressed with more rigor in new analyses outside the structure of the DSS. A ten-year time series of habitat survey data was analyzed for evidence of trends in habitat quality providing a much more informative metric than the habitat quantity measure currently used for PF-1 (see the Habitat Complexity discussion). In the future it may be possible to incorporate a habitat trend index in the DSS.

The Critical Abundance criterion, “PP-3”, in Wainwright et al. (2008), was discovered to have been evaluated using the wrong data set by the TRT (Wainwright et al. 2008). It was originally calculated using area-under-the-curve (AUC) spawner data rather than peak-count data as specified in the criterion. The updated Critical Abundance values are based on peak counts (Table 8). AUC estimates are always higher than peak counts because they include fish present on the spawning grounds over a longer period of time. Peak counts are simply the highest number observed at any one time. The object of the criterion was to evaluate the likelihood of depensation due to low spawner numbers. If too few fish are present on the spawning grounds at any one time then the probability that individuals will be able to locate mates is reduced. This effect, termed “depensation,” is thought to become a problem at spawner densities below four fish per mile (Wainwright et al. 2008). Therefore, peak counts are more suitable than AUC estimates for evaluating this effect. For comparison with results presented in Wainwright et al. (2008) DSS values based on AUC spawner estimates are also presented (Table 9).

The DSS result for ESU persistence was 0.34 (Table 8.). Recall that a value of 1 (Fig. 12) would indicate complete confidence that the ESU will persist for the next 100 years, a value of -1 would indicate complete certainty of failure to persist, and a value of 0 would indicate no certainty of either persistence or extinction. The BRT therefore interpreted a value of 0.34 as indicating a moderate certainty of ESU persistence over the next 100 years. The DSS result for ESU sustainability (ES) was 0.24, indicating a low-to-moderate certainty that the ESU is sustainable for the foreseeable future.

The overall ESU persistence and sustainability scores summarize a great deal of variability in population and stratum level information on viability. For example, although the overall persistence score was 0.34, the scores for individual populations ranged from -1 (Salmon River, Sixes River) to +0.98 (Tenmile Lakes), and approximately two thirds (13/21) of the populations had persistence scores >0.25 (Table 8). The stratum level persistence scores (SP) were calculated as the median of the population scores. Only the Lakes Stratum had a very high certainty of stratum persistence (0.88), followed by the Umpqua (0.40). The three remaining strata and persistence scores range narrowly from 0.24 to 0.27. Population sustainability scores (PS) ranged from -1.0 in two populations to a high of 0.85 in the Coquille River. The stratum scores for sustainability (SS) were less variable (Table 8), in the narrow range of 0.39 to 0.48.

The data set adjustment from AUC counts to peak counts for Critical Abundance lowered the persistence score substantially. Persistence is evaluated using three factors, while sustainability uses seven (including the three persistence factors). As a result, persistence is much more sensitive to changes in a single factor than is sustainability, so this score is considerably lower than was reported in Wainwright et al. (2008) while sustainability is slightly higher.

Spawning escapements in some recent years have been higher than has been seen in the past 60 years. This is attributable to a combination of management actions and environmental conditions. In particular, harvest has been strongly curtailed since 1994, allowing more fish to return to the spawning grounds (Fig. 5). Hatchery production has been reduced to a small fraction of the wild production (Fig. 10, ODFW 2005e). Nickelson (2003) found that reduced hatchery production led directly to higher survival of naturally produced fish. Ocean survival, as measured by smolt to adult survival of Oregon Production Index area hatchery fish, generally started improving for fish returning in 1999 (Table 4). In combination, these factors have resulted in the highest spawning escapements that have been seen since 1950, although total abundance before harvest peaked at the low end of what was observed in the 1970s (Fig. 6).

Higher spawner abundance in recent years has resulted in higher scores for population diversity (PD). Three of the Population Diversity factors are directly or indirectly related to abundance. The Spawner Abundance criterion is based on long-term harmonic mean abundance, so will increase in periods of high abundance. Spawner Distribution (PD-3) and Juvenile Distribution (PD-4) measures the distribution of coho salmon among watersheds within the populations. At higher spawner abundance coho salmon tend to spread out through a greater area of habitat. This leads to a similar expansion of the juvenile distribution. The criterion for evaluation of Juvenile Distribution was considered by some members of the BRT to be uninformative, so this criterion was given a lower weight in the BRT deliberations (but not in the computation of DSS results). In evaluating the DSS, both of the distribution criteria score higher during periods of high abundance unless all habitat is already occupied or unoccupied habitat is unsuitable or inaccessible.  With minor exceptions these scores increased from those in the TRT analysis, indicating that habitat was available for range expansions within most populations. Consequently, the peak in spawner abundance in the early 2000s, combined with the reduction in hatchery production, resulted in strong scores for population diversity (Table 8.)

# Factors for Decline, Threats

## Introduction

The BRT utilized the results of the DSS and information on population abundance, growth rates and productivity, spatial structure and diversity to inform their assessment of current biological status of the OC Coho Salmon ESU. Current information on harvest and hatcheries was included as well. In addition, the BRT also evaluated current and future threats to the ESU that may or may not be manifest in its current biological status. The BRT categorized these threats according to Section 4(a)1 of the Endangered Species Act:

- The present or threatened destruction , modification , or curtailment of its habitat or range;
- Overutilization for commercial, recreational, scientific, or educational purposes;
- Disease and Predation; and
- Other natural or manmade factors affecting its continued existence.

To the degree possible, the BRT attempted to characterize threats whose effects are likely to already be reflected in the current biological status of the ESU and those that are likely to become manifest in the future.

As a starting point for reviewing threats, the BRT reviewed the factors for decline, which had been identified as part of the original ESA status review process for the ESU. For example, Table 11 below lists freshwater habitat factors for decline that were identified in Oregon's OCSRI (1997) and subsequently discussed in NMFS (1997c). Other factors for decline were identified during the 1996 status review.

In the next step toward understanding not only what affected the ESU in the past, but to identify what affects the ESU now and may affect it in the future, NWR (NMFS 1997c) identified threats to the ESU as shown in Table 12. Threats were defined as:

> "human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future."

Limiting factors were defined as:

"physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) experienced by the fish at the population, intermediate (e.g., stratum or major population grouping), or ESU levels that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Key limiting factors are those with the greatest impacts on a population's ability to reach its desired status." (NMFS 1997c)

Because the list of threats has changed over the years, Table 13 compares the list of threats and limiting factors between those identified in 2003 (Good et al. 2005) and those considered by the BRT in this review. The BRT considered these factors for decline, limiting factors, and threats that had been previously identified, then reviewed additional information that has become available since 1997. The BRT utilized a "Threats Matrix" (see Appendix A Table A-1) to summarize the major human and natural threats facing the OC Coho Salmon ESU at this time and in the future.

## Other Natural and Manmade Factors

This portion of the BRT review started with the discussion of Other Natural and Manmade Factors for decline. These include the effects of ocean conditions and marine productivity, which have been recognized as significant issues for the OC Coho Salmon ESU since the 1993 status review (Weitkamp et al. 1995), and the effects of global climate change on freshwater and marine habitats.

### Past ocean conditions/marine productivity

Evidence has accumulated to demonstrate 1) recurring, decadal-scale patterns of ocean-atmosphere climate variability in the North Pacific Ocean (Mantua et al. 1997, Zhang et al. 1997, Overland et al. 2009, Schwing et al. 2009), and 2) correlations between these oceanic changes and salmon population abundance in the Pacific Northwest and Alaska (Hare et al. 1999, Mueter et al. 2002, Francis and Mantua 2003, Lawson et al. 2004). There seems to be little doubt that survival rates in the marine environment can be strong determinants of population abundance for Pacific salmon and steelhead. It is also generally accepted that for at least two decades, beginning about 1977, marine productivity conditions were unfavorable for the majority of salmon and steelhead populations in the Pacific Northwest (in contrast, many populations in Alaska attained record abundances during this period). Good et al. (2005) cited evidence that an important shift in ocean-atmosphere conditions occurred around 1998 that was expected to persist for several years. However, that change has not persisted. One indicator of the ocean-atmosphere variation for the North Pacific is the Pacific Decadal Oscillation (PDO) index. Since 1900, the PDO has shown a number of multi-decade periods of predominantly positive (1926-1947, 1977-1998) or negative (1948-1976) values (Fig. 13), which correspond roughly to periods of low (positive PDO) or high (negative PDO) West Coast salmon returns (Mantua et al. 1997). There was a sharp transition to negative values in 1999, followed closely by a positive transition in 2003 and a negative transition in 2007. Negative PDO values are associated with relatively cool ocean temperatures (and generally high salmon productivity) off the Pacific Northwest, and positive values are associated with warmer, less productive conditions. Wide fluctuations in many salmon populations in recent years may be largely a result of these shifts in ocean conditions.

Although these climate-related facts are relatively well established, much less certainty can be attached to predictions about what this means for the viability of listed salmon and steelhead. For several reasons, considerable caution is needed to project into the future. First, empirical evidence for "cycles" in PDO, marine productivity, and salmon abundance extends back only about a century, or about three periods of two to four decades in duration. These periods form a very short data record for inferring future behavior of a complex system. Thus, as with the stock market, the past record is no guarantee of future performance. Second, the past decade has seen particularly wide fluctuations not only in climatic indices (e.g., the 1997–1998 El Niño was in many ways the most extreme ever recorded, and the 2000 drought was one of the most severe on record) but also in abundance of salmon populations. In general, as the magnitude of climate fluctuations increases, population extinction risk also increases. Third, as anthropogenically caused global climate change occurs in the future, it will affect ocean productivity and will likely change the dynamics of ocean variation as well as ecosystem processes (Overland et al. 2009). Finally, changes in the pattern of ocean-atmosphere interactions do not affect all species (or even all populations of a given species) in the same way (Peterman et al. 1998).

**Ocean ecosystem conditions**

As ocean temperatures warm, empirical and theoretical studies show that marine fish and invertebrates tend to shift their distributions towards higher latitudes and deeper water, at observed and projected rates of 30 to 130 km/decade towards the pole and 3.5 m/decade to deeper waters (Cheung et al. 2009). Although this change may occur gradually, anomalously warm conditions may allow temporary range expansions. For example, during the 1997-98 El Niño, warm-water fishes invaded Oregon waters, including striped marlin (*Tetrapturus audux*), Dorado (*Coryphaena hippurus*), and Pacific barracuda (*Sphyraena argentea*) (Pearcy 2002). In Alaska, the summers of 2004 and 2005 were unusually warm and southern fish species including thresher (*Alopias vulpinus*) and blue sharks (*Prionace glauca*), opah (*Lampris guttatus*), and large numbers of Pacific sardines (*Sardinops sagax*) were recorded, often extending the northern limit of the known species' ranges (Wing 2006).

One species that is actively undergoing a substantial range expansion is the Humboldt or jumbo squid (*Dosidicus gigas*) (Field et al. 2007, Zeidberg and Robison 2007). Like most squids, Humboldt squid are ecological opportunists with a short life span (typically < 2 years) and high fecundity allowing their abundances to fluctuate greatly on short time scales: they have been likened to locusts of the marine realm, reaching plague proportions and creating famine (Rodhouse 2001). Even among squid species, Humboldt squid stand out: they have the highest growth rates (Mejia-Rebollo et al. 2008) and fecundity (up to 13 million eggs per female; Keyl et al. 2008) of any squid, are tolerant of water of a wide range of both temperatures and oxygen levels, including water typically considered hypoxic (Gilly et al. 2006, Zeidberg and Robison 2007), and can move horizontally nearly 200 km in a week (Gilly et al. 2006). Humboldt squid typically make diel migrations between surface waters (at night) and depths in excess of 250 m during the day, although large numbers of squid have been observed at the surface during the day, indicating considerable plasticity in their behavior (Olson et al. 2006).

The "normal" range of Humboldt squid is the eastern tropical Pacific Ocean, extending as far north as southern California (~30°N; Keyl et al. 2008), although they have been sporadically reported off the California coast throughout the last century (Field et al. 2007). In their current range expansion, they were first reported north of their normal distribution during the 1997 El Niño when they were observed in Monterey Bay (Zeidberg and Robison 2007) and off Oregon (Pearcy 2002). Reports of squid north of their typical range resumed in 2000 (Zeidberg and Robison 2007, Keyl et al. 2008) and Humboldt squid were reported from British Columbia and Alaska in 2004 (Cosgrove 2005) and again in Alaska in 2005 (Wing 2006).

Numerous long-term coastal sampling programs provide excellent documentation of this dramatic spread, in particular the apparent explosion of squid during summer 2009. For example, the joint Canada-U.S. Pacific hake *(Merluccius productus)* acoustic-trawl survey has documented a rapid increase in the number and frequency of Humboldt squid caught in trawls since the survey began in 1977 (Holmes et al. 2008). The first confirmed catch occurred in 2003 and by the 2007 survey the range and abundance of squid had greatly expanded (Holmes et al. 2008). In the 2009 survey, catches of Humboldt squid were extremely large and frequent: 44% of hauls in 2009 included at least one Humboldt squid.[11] Similarly, the NWFSC Predator (Emmett et al. 2006) and Stock Assessment Improvement Program (Auth 2008) research cruises, both of which sample with large trawls (mouth ~25 m wide x 20 m deep) at night, first caught Humboldt squid in 2006 and 2004, respectively. This summer (2009), these studies caught Humboldt squid in 14% ($n$ = 84 hauls) and 19% ($n$ = 85) of their hauls, respectively, with the highest catches in late summer.[12]

A recent analysis of factors contributing to the collapse of Sacramento fall Chinook salmon includes one section on Humboldt squid (Lindley et al. 2009). The authors conclude that Humboldt squid likely had limited impact on Sacramento Chinook salmon due to limited spatial overlap: most squid were beyond the continental shelf while most juvenile salmon were on the shelf. However, in 2005 and 2009 squid were caught off the Washington and Oregon coasts by research programs targeting juvenile salmon, suggesting overlap of squid and juvenile salmon within the range of OC coho salmon.

Humboldt squid are a “voracious, opportunistic predator” (Gilly and Markaida 2008), capable of feeding on a wide range of prey. Prey items identified in squid stomachs collected off the coasts of California and Oregon included both commercial (e.g., Pacific hake, northern anchovy [*Engraulis mordax*]), Pacific sardine, rockfishes [*Sebastes* spp.], flatfishes [Pleuronectiformes]) and noncommercial (e.g., northern [*Stenobrachius leucopsarus*] and blue [*Tarletonbeania crenularis*] lantern fishes) fish species (Field et al. 2006), with perhaps the biggest impact on hake populations (Holmes et al. 2008). Fishes found in squid stomachs were up to 42 cm in length, with a greater than 10% of the total biomass ingested consisting of prey at least 35 cm in length. Squid have also been observed attacking larger fish (up to 50 cm) when the prey are confined, such as skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) tunas caught together in with squid in purse seines (Olson et al. 2006). A Chinook salmon jack (262 mm FL) was caught in the lower Columbia River estuary in October 2009, with what appears to be a squid bite mark[13] , indicating that squid may attempt to take small salmon.

For OC coho salmon, the timing of Humboldt squid presence in our area is of particular concern because squid abundances typically peak during late summer (August, September), and are considerably lower in early summer (June, July; Field et al. 2007, Gilly and Markaida 2008; R. Emmett, NWFSC, unpublished data). The best predictor of Columbia River coho year class success is the number of juveniles caught off the Washington and Oregon coasts in September of the previous year (Wainwright and Weitkamp In prep., Van Doornik et al. 2007). This

[11] Dezhang Chu, NWFSC, National Marine Fisheries Service 2725 Montlake Blvd. E. Seattle, WA 98112-2097 Pers. comm. November, 2009.
[12] R. Emmett, NWFSC, Newport Research Station, 2032 SE OSU Drive, Newport, OR. Pers. comm., December, 2009
[13] L. Weitkamp, NWFSC, Newport Research Station, 2032 SE OSU Drive, Newport, OR. Pers. comm., December, 2009

relationship indicates that the individuals that reside in local waters throughout the summer are the ones that return as adults. Unfortunately, these individuals will likely overlap with the highest abundances of Humboldt squid and therefore face high predation risk. By contrast, spring Chinook originating from Pacific Northwest streams are present in local waters in early summer but then move northwards towards Alaska by mid-summer (Trudel et al. 2009). Because of their migratory patterns, these fish will likely experience much lower habitat overlap with Humboldt squid, unless squid densities are also high farther north.

It is not clear whether this most recent population explosion is long-lasting or transient, why it has occurred, or whether it includes a northern expansion of squid spawning areas (currently Gulf of California, the Costa Rica Dome; Gilly and Markaida 2008). There is also no direct data or information indicated that the presence of Humboldt squid will directly lead to reduced abundance of OC coho salmon, although the BRT was concerned that squid may potentially be a risk to the salmon or the ecosystem upon which they depend. Overall, the BRT concluded that the presence of this warm water species off the Oregon coast and further north beyond its previously known range is a sign that the coastal ocean ecosystem on which coho salmon depend is in an unpredictable state of flux.

**Effects of climate change on the Oregon Coast Coho Salmon ESU**

Recent climate change has had widespread ecological effects across the globe, including changes in phenology, changes in trophic interactions; range shifts (both in latitude and elevation and depth), extinctions, and genetic adaptations (reviewed by Parmesan 2006) and these changes have influenced salmon populations (ISAB 2007, Crozier et al. 2008a, and Mantua et al. 2009). Although these changes have undoubtedly influenced the observed VSP attributes for OC Coho Salmon ESU, we cannot partition past climate effects from other factors influencing the status of the ESU. Continuing climate change poses a threat to aquatic ecosystems (Poff et al. 2002) and more locally to Pacific salmon (Mote et al. 2003). Recently, Wainwright and Weitkamp (In prep.) reviewed the major potential physical effects of climate change in Western Oregon, presented an approach to integrating these effects across life-history stages, and applied that approach to evaluate potential effects on the OC Coho Salmon ESU. Here, we summarize their findings.

The coho salmon life cycle extends across three main habitat types: freshwater rivers and lakes, estuaries, and marine environments. In addition, terrestrial forest habitats are also essential to coho salmon because they determine the quality of freshwater habitats by influencing the types of sediments in spawning habitats and the abundance and structure of pools in juvenile rearing habitats (Cederholm and Reid 1987). Wainwright and Weitkamp (In prep.) begin by considering these four habitats, how physical climate change is expected to affect those habitats over the next 50 years, and how salmon will respond to those effects during specific life-history stages (Fig. 14). Climate conditions have effects on each of these habitats, thus affecting different portions of the life cycle through different pathways. This leads to a very complex set of potential effects to assess. Wainwright and Weitkamp (in prep.) recognized that, while we have quantitative estimates of likely trends for some of the physical climate changes, we do not have sufficient understanding of the biological response to these changes to reliably quantify the effects on salmon populations and extinction risk. For this reason, the analysis is qualitative: summarizing likely trends in climate, identifying the pathways by which those trends are likely to affect salmon, and assessing the likely direction and rough magnitude of coho salmon population response. Their assessment is summarized in Table 14, and discussed below.

Effects of change in terrestrial forest habitats on salmon are indirect through effects on hydrology, water quality, and physical habitat structure. While there is widespread agreement on the atmospheric changes likely to affect forests (warmer, drier summers and reduced snowpack), the effects of resulting changes in forests are uncertain, and the subsequent effects on salmon are of low certainty, and could range from slightly positive to strongly negative.

For freshwater habitats, climate change is expected to reduce summer flows and raise summer stream temperatures throughout western Oregon. These trends would reduce the amount of available summer rearing habitat for coho salmon, and increase thermal stress which would result in reduced growth and increased susceptibility to disease and parasites, and thus have a weak to strong negative effect on freshwater salmon production. Furthermore, increased water temperature will necessarily increase the consumptive demands of both juvenile coho and their predators (Petersen and Kitchell 2001). It remains to be seen how the food web as a whole would respond to these changes in energetics. In addition, reduced winter and spring snowpack is expected to result in earlier peak flows and increased flooding in snow-fed rivers. For this ESU, changes in snowpack are likely to have a significant effect on salmon only in the lower mainstem and upper portions of the Umpqua River basin (North and South Umpqua populations); the effect would be negative for those populations.

In estuaries, the main expected physical changes are rising sea level and warmer water temperatures. The effect of these changes on salmon is likely to be negative, due to losses of inter-tidal wetland habitats and increased thermal stress during migrations. As in freshwater, increased water temperature will also increase the metabolic demand of coho salmon and their predators (Petersen and Kitchell 2001). Changing temperatures may also lead to unpredictable changes in estuarine community composition, which might have either positive or negative effects on salmon.

In the ocean, there are a number of anticipated physical changes that could affect OC coho salmon. These include higher water temperature, intensified upwelling, delayed spring transition, intensified stratification, and increasing acidity in coastal waters. Of these, only intensified upwelling would be expected to benefit coastal-rearing salmon; all the other effects would likely be negative. Increasing temperature and acidity have high certainty of occurring, and both would likely have negative effects on coho salmon. Similar to freshwater and estuarine ecosystems, increased water temperature will also lead to increased metabolic demand for coho salmon and their predators (Petersen and Kitchell 2001). However, the local physical interactions of wind patterns and stratification on upwelling and the timing of the spring transition for our coast are difficult to predict with certainty, so the response of salmon to these other ocean factors is of low certainty. In combination, all of these physical effects are likely to result in changes in the species composition and structure of the coastal ecosystem, with unpredictable consequences for coho salmon.

While we have noted some expected positive effects, negative effects of climate change predominate for each habitat and life history stage (Table 14). While many of the individual effects of climate change on OC coho salmon are expected to be weak or are uncertain, we need to consider the cumulative impacts across the coho salmon life-cycle and across multiple generations. Because these effects are multiplicative across the life cycle and across generations, small effects at individual life stages can result in large changes in the overall dynamics of populations. This means the mostly negative effects predicted for individual life history stages will most likely result in a substantially negative overall effect of climate change on OC coho salmon over the next few decades. Despite large uncertainties surrounding specific effects at individual life stages, expectations for increasing air and water temperatures, drier summers, higher incidence of flooding, and altered estuarine and marine habitats, lead us to expect increasingly frequent years with low survival, resulting in an overall increase in risk to the ESU resulting from climate change over the next 50 years.

**Ecosystem impacts of non-indigenous species**

Oregon Coast coho salmon and other salmonids traverse large geographic areas from freshwater to estuarine and ocean habitats during their life cycle. During this time they encounter numerous non-indigenous (NIS) species (Sanderson et al. 2009). Boersma et al. (2006) documented many invertebrate and plant species introduced into the Pacific Northwest (and more specifically the OC Coho Salmon ESU) that have documented effects. In the OC Coho Salmon ESU, the majority of NIS are plants and fishes. The mechanisms of impact by these NIS are predation, competition, hybridization, infection (disease and parasites) and habitat alteration (Mack et al. 2000, Simberloff et al. 2005.)

The presence of NIS fishes poses one of the greatest threats to the persistence of healthy native fish populations (Rahel 2002). Sanderson et al. (2009) reports high to moderate densities of NIS fishes in the ESU. Effects of these fishes include predation by channel catfish (*Ictalurus punctatus)*, American shad (*Alosa sapidissima*), brook trout (*Salvelinus fontinalis)* and smallmouth (*Micropterus dolomieu)* and largemouth (*Micropterus salmoides)* bass. Other NIS fishes alter habitats and ecosystem function. For example, NIS warmwater fishes in Tenmile Lakes alter planktonic community structure. This affects the summer rearing and residency of OC coho salmon juveniles (ODEQ 2007). Additional discussion of NIS fishes is found in the Predation section.

Both plant and animal NIS invade and displace native plant species and communities when human disturbance such as timber harvest (NMFS 2006b) or change in climate occurs (Wainwright and Weitkamp In prep.). Brazilian elodea (*Egeria densa*), Eurasian water milfoil (*Myriophyllum spicatum*), Reed canarygrass (*Phalaris arundinacea*), Giant and Japanese knotweed (*Polygonum* spp.), [Reed canarygrass and Giant knotweed effects are discussed in the Stream Complexity section], cordgrasses (*Spartina anglica, S. densiflora,* and *S. patens* ), Japanese eelgrass (*Zostera japonica*), Evergreen and Himalayan blackberry ( *Rubus laciniatus, R. armeniacus*), Purple loosestrife (*Lythrum salicaria*), and New Zealand mudsnail (*Potomopygyrus antipodarum*) are already found in the ESU (Boersma et al. 2006). These plants and invertebrates alter habitats and ecosystem function. For example, Purple loosestrife displaces sedges and cattails. This causes shifts in local nutrient availability and affects detrital foodwebs (Blossey et al. 2001). New Zealand mud snails blanket streambeds, can consume a majority of gross primary production, and out-compete other macroinvertebrates such as larval mayflies, stoneflies, and caddisflies, which are important freshwater salmon prey (Kerans et al. 2005, Hall et al. 2003).

Potential new invasions that have been identified include Zebra mussel(*Dreissena polymorpha)*, Chinese mitten crab (*Eriocheir sinensis)*, and hydrilla (*Hydrilla verticillata)*. A list of potential invasive species is identified in the Oregon Conservation Strategy's discussion of the Coast Range Ecoregion (ODFW 2011) and in US Forest Service Invasive Plant Program documents (USDA Forest Service 2005). Some of these have already caused significant damage to aquatic and terrestrial ecosystems in other parts of the U.S. Of present concern, however, is the collapse of a major food source of OC coho salmon in some estuaries. During outmigration of OC coho salmon smolts in the Mid-Coast stratum, one of their major food sources is mudshrimp (*Upogebia pugettensis*) (These intertidal benthic invertebrate are among the most dramatically affected by recent introduced species invasions and associated hydrological and geochemical alterations of the estuaries (Dumbauld et al. 2010).

Some members of the BRT were concerned that invasions by NIS present a risk to the salmon or the ecosystem upon which they depend. Though some NIS species already established in the ESU may be reflected in current biological status, invasions by NIS and the subsequent ecosystem changes brought about by their establishment may constitute a future threat to the species.

## The Present or Threatened Destruction, Modification, or Curtailment of its Range

### Fish passage

The foundation of ESU viability is built upon the ability of populations to function in an integrated manner and persist across the landscape. This integration includes dispersal within and among populations (i.e., connectivity) and a diversity and distribution of habitat types and conditions that allow for the expression of a range of life-history types (Williams and Reeves 2003). Dams are not the only barrier to migration; barriers can include smaller scale features such as road culverts that block seasonal passage to and from mainstem rivers and also inter- and intra-tributary movement.

Any habitat modification that prevents annual or seasonal movement across the landscape can affect coho salmon populations. Ebersole et al. (2006) described within-basin movement of juvenile coho salmon in a coastal Oregon basin (West Fork Smith River, Douglas County, Oregon). Although the focus of their work was on winter movement and overwinter use of tributaries, Ebersole et al. (2006) suggested that during wetter years, small tributaries could also provide improved summer survival and subsequently higher densities of juvenile salmonids prior to the overwinter period. Culverts, tide gates and temperature blockages can affect access of juveniles to these small systems.

The BRT utilized the original factors for decline summarized by NMFS in 1997 (NMFS 1997c) as a starting point for their assessment. A discussion of fish passage was included in this assessment because it was part of the original factors for decline discussion and some members of the BRT felt that it may be an important source of risk to the OC coho salmon ESU. Fish passage was not identified in the State of Oregon's Oregon Coastal Coho Assessment (Oregon 2005) as either a primary or secondary limiting factor for any population of OC coho salmon.

There are wholesale blockages of fish passage by hydropower projects, which is considered a major factor for decline, in many salmonid ESUs. The effect of hydropower development in the ESU was reviewed in the Oregon Coast Coho Assessment (Oregon 2005)[14]. Oregon's conclusion was;

> "Generally, within the majority of the ESU, impacts from hydroelectric projects are insignificant or non-existent. Specifically, within the Umpqua basin, Oregon Coastal coho have been prevented from reaching 36 miles of spawning and rearing habitat by hydroelectric projects. Impacts to downstream reaches include; alteration of flows and interruption of natural sediment and large woody debris regimes." (ODFW 2005f)

As discussed above, fish passage problems are not just related to blockage by hydropower projects. As part of the Oregon Coastal Coho Assessment, Dent et al. (2005) gathered data on stream crossings from private industrial land owners (60% of data captured), federal (Forest Service 100% of data captured) and state (90% of data captured) agencies and data sets with a complete census of state and county roads (100% of data captured). Fish passage status was provided by the landowners and crossing status was not verified. These crossings were binned in three categories: high intrinsic potential for coho salmon, low intrinsic potential and non-coho. Their results show that for the entire ESU, 11% of low IP streams, 10% of high IP streams (These are probably minimal estimates because ODF did not have complete coverage of IP streams for this analysis[15]), and 16% of non-coho streams have limited access. They estimated that of all the stream miles with limited access, approximately 18% were high IP streams. The percent of stream crossings in high IP areas are: 60% of the total number of stream crossings pass fish, 14% limits fish passage and 26% are unknown.

Dent et al. 2005 concluded:

> "Our analysis suggests that a relatively small percent of coho habitat remains inaccessible (10-11%) and that Oregon Plan fish passage restoration projects have improved access to 6-11% of coho habitat. However, our analysis also suggest that a significant proportion of the coho habitat has unknown access status (28-31%). With unknown access to approximately 1/3 of the habitat, fish passage cannot be eliminated as a risk to coho at this point in time."

As part of the review of the Oregon Coastal Coho Assessment, NMFS NWR commented that fish passage through culverts, tide gates and bridges presented a higher risk to OC coho salmon than the State's assessment (Oregon 2005).

> "The technical document (Oregon 2005) concludes that nearly a third of the area has an unknown passage status, that fish passage restoration projects have not

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[14] Reviewer 2 reports that future hydropower projects may occur in this ESU on the Siletz River at the old town site of Valsetz (W.H. Pacific 2009)

[15] Gordon Reeves, USDA Forest Service, Pers. comm. February 2011.

> been tested at high flows, and that fish passage projects have rarely been monitored to test whether they are actually passable and that fish passage cannot be eliminated as a risk to coho at this point in time." (NMFS 2005a).

Since 2005, a concerted effort was made to improve the fish passage barrier geographic information systems (GIS) layer, which was released in late 2009 (Oregon Fish Passage Barrier Data Set (OFPBDS) ODFW 2009d). This layer includes bridges, cascades, culverts, dams, debris jams, fords, natural falls, tide gates, and weirs. The OFPBDS dataset, however, does not include dikes, levees or berms. Barriers in the dataset may have information on their passability to salmonids. This information may designate complete or partial blockage to fish passage, complete passability, or an unknown passage status. The dataset comes mainly from ODFW, Oregon Department of Transportation (ODOT), and US Bureau of Land Management (BLM). The database does not include barrier data from the Oregon Department of Forestry (ODF), Oregon Water Resources (OWRD), soil and water conservation districts, watershed councils, tribes and other originators, so the barriers shown in Fig. 15 do not include barriers from private timber or agricultural lands, which contains 81% of the high IP habitat in the ESU (Burnett et al. 2007). In addition, it reflects only a handful of the tide gates in the ESU: a newly available dataset (Mattison 2010) documents approximately 350 tide gates, which we know from Bass (2010), are at least partial barriers to fish passage.

An aspect of fish passage that has been ignored until recently is the blockage of fish access to tidal stream, marsh and swamp habitat by dikes and levees in estuarine and freshwater tidal areas. It is possible however, to utilize the presence of a tide gate as a proxy for blockage of habitat. Giannico and Sauder (2005) reviewed the topic of the effect of tide gates on migratory behavior of salmonids and found that tide gates had direct effects on salmonid movements through abrupt changes in salinity, elevated water velocities and turbulence, and a total physical barrier to fish passage during the time the gate is completely closed. Bass (2010) found in Coos Bay, Oregon, that tide gates have the potential to restrict movement of OC coho salmon subyearlings and smolts when compared to a non-gated channel. At a minimum, tide gates in the OC Coho Salmon ESU act as partial barriers to fish passage and were, for the most part, previously unaccounted for in past analyses. Few tide gate locations are included in the 2009 OFPDS, so are not shown in Fig. 15. A database of tide gates in the OC Coho Salmon ESU is presently under development by Oregon Conservation and Development Commission (OCDC).

Fish passage barriers have not been identified as a major limiting factor for OC coho salmon by ODFW, however, within the OC Coho Salmon ESU, of barriers that are in the dataset, nearly half (49%) are of unknown status. The incompleteness of the information that is included in the 2009 barriers database and new information regarding the effect of tide gates on fish passage for OC coho salmon led some members of the BRT to consider that because information is unavailable on a large portion of important OC coho salmon habitat (low gradient agricultural lands, low elevation private timber lands) – and where information is available, 49% of crossings are of unknown status, fish passage may continue to be a significant information gap in identification of habitat problems in the ESU. In the absence of information regarding blockages due to dikes and levees and from Oregon Department of Forestry, Oregon Water Resources, soil and water conservation districts, watershed councils, and tribes, it is clear that there is a substantial uncertainty as to the true effect that fish passage barriers present to OC coho salmon.

For the purposes of this risk assessment, the current biological status probably reflects, for the most part, the status of fish passage in the ESU. Improved passage status information in the data base would allow a better assessment of the effect of fish passage on OC coho salmon and therefore on the potential effects of any future increase in road building (culverts) or protection of low lying areas from higher flood elevations and sea level rise (tide gates). Future effects of fish passage barriers depend on the success of Oregon Plan programs to address fish passage problems, the anticipated effects of land use changes in the ESU and the response to anticipated sea level rise.

**Water availability**

In their discussion of water availability as a threat, the BRT noted that the State of Oregon in the Conservation plan (Oregon 2007), identified water availability as a primary limiting factor for the Middle Umpqua and South Umpqua OC coho salmon populations. The Mid-South Coast stratum was identified as an area where water availability and water withdrawal is a problem as well, but was not identified as a primary limiting factor (Oregon 2007). Instream water availability problems can present limitations to OC coho salmon through several mechanisms. May and Lee (2004) found that juvenile coho salmon abundance in pools decreased by 59% during the summer, with significantly higher losses occurring in gravel-bed versus bedrock pools. This means that gravel-bedded streams that have water withdrawals would likely have a higher potential impact on summer juvenile coho abundance than those in bedrock dominated reaches. In addition, if connectivity is reduced due to the removal of water, then growth rates can be altered, which in turn has an effect on survivorship. For example Kahler et al. (2001) found that juvenile coho salmon moved out of smaller and shallower habitat units, and fish that moved among habitat units grew faster than fish that remained in the same habitat unit (Kahler et al. 2001).

Ebersole et al. (2006) found that tributary streams that were naturally nearly dry in midsummer, supported high densities of spawning coho salmon in the fall, and juveniles rearing there exhibited relatively high growth rates and emigrated as larger smolts. They also reported that improved winter growth and survival of juvenile coho salmon utilizing tributary habitats underscore the importance of maintaining connectivity between seasonal habitats and providing a diversity of sheltering and foraging opportunities, particularly where main-stem habitats have been simplified by human land uses.

What this means for water withdrawals is that where and when they occur in the landscape is critical to coho salmon. So water withdrawals that affect tributaries, particular those that are gravel-bedded, are most sensitive to changes in flow. If future water withdrawals are concentrated in tributaries of main river systems, and are in gravel bedded systems this could lead to a decline in the summer abundance and overall survivorship of coho smolts. Another less investigated aspect of water availability is the effect of surface erosion on surface runoff. If climate change contributes to an increase in flooding, this flooding is often accompanied by mass wasting. As small valleys fill with coarse alluvium from this mass wasting, this could result in less surface flow and more subsurface flow.[16]

[16] Peer reviewer 7, pers. comm. September 2010.

For most subbasins in the Umpqua stratum, water withdrawal for irrigation is a major consumptive user of water, and during the summer months from August to October, there is no natural stream flow available for new water rights (Partnership for Umpqua Rivers [PUR] 2007) except in the lowermost reaches of the mainstem of the Umpqua River (INR 2005). At times, in the South Umpqua population, the flow is below one cfs in systems as large as Days Creek due to other consumptive uses (PUR 2007). EPA has placed all of the subbasins in the South Umpqua on the 303(d) list for flow modification, the North Umpqua and Lower Umpqua River are on the list as well (PUR 2007).

The Oregon Water Resources Department has initiated instream water rights and leasing to mitigate loss of instream flow. The OWEB 2007-2009 Oregon Plan update (Oregon 2009a) reports that OWRD places a high priority on monitoring and protecting instream water rights statewide. Fifty-six percent of those streams regulated by OWRD during the 2007 water year, were regulated on behalf of instream rights. Leases provide a mechanism for temporarily changing the type and place of use for a certificated water right to an instream use. The leased water remains in-channel and benefits stream flows and aquatic species and while leased and the instream use counts as use under the right for purposes of avoiding forfeiture (PUR 2007). However, the effectiveness of instream water rights protection does not provide certain instream flow for fish and wildlife because virtually all of these existing rights for instream flow have priority dates after 1955, they are fairly junior to other water rights in most basins and therefore do not often affect water deliveries (INR 2005).

In a landscape already significantly affected by instream water availability issues, increased demand (Kline et al. 2003), temperature rise and the anticipated changes in precipitation patterns (see discussion of global climate change below) could have substantial effects on the OC Coho Salmon ESU. In the Umpqua River Stratum, the South Umpqua and Middle Umpqua populations are the most likely to be significantly affected by global climate change and temperature rise due to their interior position on the landscape. The Middle and Lower Umpqua populations are also the most subject in the ESU to downstream flow effects from the anticipated shift from a snow melt hydrology to rain hydrology that will affect stream flow timing and temperature due to shifts in precipitation in the cascades. They are also the most likely to be affected by increased demand due to population growth (Kline et al. 2003).

Some water availability problems such as the effect of summer rearing limitations experienced in the Umpqua River Stratum are probably already reflected to a large degree in current biological status. However, future impacts to water availability from the effects of population growth, global climate change, or even shifts in shorter term climate variability are not reflected in current biological status and may constitute a future threat.

**Land use management- stream habitat complexity**

Freshwater habitat complexity has been defined as; the number of habitat units per length of stream (Quinn and Petersen, 1996), the number of pools per channel width (Montgomery et al. 1995, and the amount of wood and other obstructions that control specific channel features such as the amount of instream cover juvenile salmonids have during specific times of the year (Quinn and Petersen 1996). Habitat complexity of freshwater habitat is identified as a key limiting factor to the recovery of OC coho salmon by ODFW (OCSRI 1997, Anlauf et al. 2009). Stream complexity has been identified as a factor for decline since 1997 (OCSRI 1997, NMFS 1997c). The State of Oregon also specifically identified it as a primary limiting factor for the purposes of the Oregon Coastal Coho Conservation Plan (Oregon 2007). Table 15 shows which populations are considered by ODFW to be limited by stream complexity. Thirteen of the twenty one independent populations are considered stream complexity limited. The BRT's habitat subcommittee decided that stream complexity was such an important component to any risk assessment of habitat, that they would pursue analyses based on techniques and data sets utilized by ODFW.

**Legacy splash damming/stream cleaning-** From an historical view, the stream complexity narrative begins with activities associated with the impacts of timber harvest. Three of these that have been identified are splash damming, log driving and stream cleaning.

Splash damming and log driving is no longer practiced on Oregon coastal streams and rivers, but was utilized extensively during the "deforestation" phase of timber harvest. (Maser and Sedell 1994). Splash dams were used to hold back enough water so that the logs that had been harvested and yarded to the pool behind the dam would sluice down the stream channel carrying the logs. This practice was well documented by Benner (1992) in the Coquille basin. Often, before the release took place, the downstream channel would be cleared as much as possible of impediments- these included instream boulder fields and debris jams. Figure 16 shows sites identified by Maser and Sedell (1994) and Miller (2010) for splash dams and log drives in the OC Coho Salmon ESU. Legacy effects from these activities may still be affecting geomorphic processes and landscape and local scale stream complexity in OC Coho Salmon ESU (Montgomery et al. 2003). These activities have contributed to the loss of wood or boulders that acted to hold back gravel in the channel, the loss of large trees that act as key constituents of log jams, and to incision of stream channels and loss of floodplain connectivity (Montgomery et al. 2003).

Another aspect to the simplification of the complexity of streams in the OC Coho Salmon ESU is that of stream cleaning activities formerly practiced by ODFW. Information presented in The Elliott Forest Watershed Analysis (ODF 2003) presents a picture of the effect of stream cleaning in Oregon coastal streams.

> Damage caused to streams and rivers by early logging operations (splash dams, slash disposal in streams, log drives, etc.) often resulted in substantial logjams. In some cases, these jams could be a mile or more in length, and undoubtedly prevented or impeded anadromous fish passage. Largely as a result of these spectacular cases, in the 1930s the Oregon Game Commission began to require loggers to prevent woody debris from entering streams. …
>
> While the early stream surveys often called for clearing debris, its removal was effected in two ways. First, the Oregon Game Commission employed a "stream improvement" crew that drove throughout the region identifying "obstructions" and contacting land managers about their removal. This program lasted for 20 years, from about 1956-1976 according to ODFW files. The second tactic was to include stream cleaning, and specifically logging

> debris removal, in timber sale contracts. [I]t appears to have continued until at least the mid-1980s…
>
> Both kinds of stream cleaning were often done by running bulldozers up and down the stream (this technique also applied to log yarding from the 1950s into the 1970s). Notations … often identified the number of Cat D6 or D8 hours required for each job (although this also included winching logs out of streams). Without a doubt, stream cleaning had a widespread impact on aquatic habitat and the effects are still seen today in the amounts and distribution of wood in stream channels.

ODFW ended this practice, but legacy effects from the loss of large amounts of wood in the stream system endure. It is not surprising, therefore, that despite the number of instream complexity projects undertaken by watershed councils, ODFW, USFS, BLM and private landowners (OWEB 2009), that according to ODFW (Anlauf et al. 2009) "All monitoring areas are low in key pieces of wood relative to reference conditions."

**Beaver in Oregon Coast coho salmon habitat-** Beavers (*Castor canadensis*) are an important species to proper watershed functioning in coastal Oregon streams. They are considered a "keystone species" (Naiman et al. 1988) that provides significant coho salmon rearing habitat, primary productivity, nutrient retention/cycling, floodplain connectivity and stream flow moderation (Reeves et al. 1989). Beavers and associated ponded habitats occur throughout the OC Coho Salmon ESU and can be found from the headwaters to the estuarine environment. Beavers are found in estuarine and freshwater tidal marshes and can build dams in the upper portions of sloughs and provide physical habitat for juvenile coho (Miller and Sadro 2003). Beavers are well known for damming smaller, lower gradient (less than 3%) streams with unconfined valleys (valley widths greater than four channels widths) (Retzer et al. 1956, Suzuki and McComb, 1998, Pollock et al. 2003) as well as the floodplains of larger river systems (Murphy and Koski 1989, Pess et al. 2005). The potential benefits of beavers and their associated habitats to juvenile coho salmon thus may be dependent upon their location within the landscape.

Historically, beaver were abundant throughout North America, with estimates ranging between 55 million to 400 million (Seton 1929, Pollock et al. 2003). Their pelt and castoreum was considered of great value and they were thus overexploited for centuries (Rosell et al. 2005). To reverse the effects of this overexploitation, beavers were protected and, in the 1920s, reintroduction programs were initiated. In North America, today the population in USA is currently estimated to be 6 to 12 million (Naiman et al. 1986). While populations have increased, their abundance levels are typically 3 to 10% of their historic levels and have been so for some time (Pollock et al. 2003).

Several lines of evidence point to the importance of beaver ponds and side channels as principal habitat features for coho salmon (e.g., Naiman et al. 2000, Pollock et al. 2003). When evaluating habitat for OC coho salmon using the habitat limiting factors model (HLFM) version 7 (Nickelson 1998), reaches with beaver ponds have rearing capacities an order of magnitude higher than reaches without beaver ponds (Beechie et al. 1994). As Pollock et al. (2004) report:

> Watershed scale restoration activities designed to increase coho salmon production should emphasize the creation of pond and other slow-water environments; increasing beaver populations may be a simple and effective means of creating slow-water habitat.

The Pollock et al. (2004) study focused, for the most part, on sites in the Puget Sound Region; however, the BRT noted that areas where beaver pond density is highest typically has the same physical characteristics regardless of the ecological region - lower gradient (less than 2%), unconfined valley bottoms, in smaller watersheds (drainage areas typically less than 10km2). Smaller, lowland, rain-dominated Puget Sound watersheds have the same basic physical and hydrological characteristics as the smaller Oregon coast watersheds, thus the relationships we see with respect to beaver pond densities in Puget Sound should also hold true for the Oregon coast.

Beavers have been recognized as important to OC coho salmon recovery by the State of Oregon in the Oregon Plan (OCSRI 1997) and the Oregon Coast Coho Conservation Plan (Oregon 2007). Notably, the Fisheries Section of ODFW has long recognized the importance of beaver to recovery of OC coho salmon (ODFW 2005a), and is actively working to stress their importance to other sections of their agency as well as other state agencies (ODFW 2009a).

The BRT discussed the importance of beavers to coho salmon on the landscape and considered whether there have there been changes that would lead BRT members to consider that loss of beavers would be expected over the next few decades. Two studies were discussed in regard to the present and future status of beavers in the OC Coho Salmon ESU.

The first was a MidCoast Watersheds Council study (MCWC 2010), that attempts to address anecdotal evidence for major declines in large winter-persistent beaver ponds over the past 2-3 decades. In order to examine the issue, the Mid-Coast Watersheds Council engaged in a study to quantify trends, not on beaver populations, but the presence and habitat metrics of beaver dams and ponds. This study covered streams in the Upper Five Rivers (Alsea River), Tillamook Basin, Upper Yaquina River, and the rest of the Yaquina Basin. The results show that the Mid-Coast region included in the study has experienced widespread declines in numbers of beaver dams and ponds. Currently, the majority of dams are low and ponds are small and ephemeral. Only five of 40 streams surveyed in the Yaquina survey had “healthy” reaches of beaver habitat, with large, stair-stepped ponds. All five of these streams have difficult public access, with gated roads or no roads.

Another study was pursued in the Tillamook population (Biosurveys 2009); the entire basin was snorkeled with 320 miles of stream, from head of tide to end of coho salmon distribution in 5 river basins: Miami, Kilchis, Wilson, Trask, and Tillamook. These surveys also recorded beaver dams. The same 360 miles snorkeled in 2006 was repeated in 2007 (Table 16). The inter-annual comparison shows a decline in beaver ponds, most importantly in the Tillamook River. The Tillamook River has the proper morphology for extensive beaver colonization and a historical legacy of their presence (Coulton et al. 1996) in many reaches where they are currently absent. Because of limited stream morphology, the remaining Tillamook Basin rivers (Wilson, Kilchis, Miami and Trask) have limited potential for broad colonization of beaver except for the Devils Lake Fork of the Wilson River. As expected, most beaver activity was found in the low stream gradients and sedimentary geologies. No active beaver dams were found in the Kilchis basin which is generally high gradient or highly disturbed.

In the past, ODFW has been able to track the harvest of beaver populations because all trapping required a permit and a harvest report. However, because of a change in the application of state regulations, no permit or harvest report is presently needed for trapping of nuisance animals on private land, making assessment of beaver harvest difficult (ODFW 2005a). As of 2005 an analysis of the data collected in aquatic habitat surveys showed no significant trend in beaver dams in the entire ESU from 1998 to 2003 (ODFW 2005a). Some Monitoring Areas such as the Umpqua River showed a very low percent of habitat that contains beaver pools.

Based on these limited sources of information, the BRT concluded that there is some evidence for continued concern in regard to beaver abundance, but of very uncertain extent or scope. Due to the limited dataset we cannot conclude that there is an overall trend and would recommend a more extensive monitoring effort be pursued to identify short and long-term trends throughout the OC Coho Salmon ESU. If beaver abundance has in fact declined, or does not trend upward in the form of beaver dam density throughout the ESU, the BRT would consider this to be a significant threat to the availability of high quality habitat for OC coho salmon.

The BRT did not have any information on beaver population trends over time in the ESU, therefore the habitat subcommittee examined the ODFW stream monitoring habitat data for the Oregon coast to gain a better understanding of the overall trends in beaver dam density in the different strata from 1998 to 2009. The habitat subcommittee found that the densities of beaver dams in the surveyed streams for each strata averaged less than 1 (0.53 dams/km ±0.33) beaver dam per kilometer in each of the strata, with the exception of the North Coast (1.31 ±1.4) (Fig. 17). The trend in beaver dam density over this time period is relatively flat (Fig. 17). In addition, the density of beaver dams throughout this time period is considerably less than what typically occurs in protected or remote areas throughout North America (Pollock et al 2003). There are also some strata-specific trends that relate to overall habitat condition. For example, the occurrence of beaver dams in the Umpqua strata was 36% for the streams surveyed between 1998 and 2009, while the occurrence level was 82% for all other strata with the exception of the Lakes strata (18%). Thus not only were beaver dam densities the lowest (0.09 dams/km ±0.16) in the Umpqua of any strata, they typically were non-existent in many of the streams surveyed. Possible causes for the consistently low numbers of beaver dams across the ESU could be due to natural population fluctuations, forest succession, disease (Tularemia), trapping, increased cougar predation, reduced food supply, and reduced supply of building materials or a combination of all.

Pollock et al. (2003) summarized beaver dam density from pristine, remote, and protected areas in the North America and found the average to be 24.9 dams/km (±21.9). A low level of beaver dam density is typically correlated with lower abundance levels of beaver (Pollock et al. 2003). Managed and recovering beaver dam density also has a considerable range typically between 2 and 6 dams/km, and an average of approximately 3 dams/km (Pollock et al. 2004). Assuming habitat preference (i.e. the types of stream characteristics that beaver prefer – less than 4% stream channel gradient, unconfined valleys [greater than 4 channel widths] [Suzuki and McComb 1998, Pollock et al. 2004]), then the density of beaver ponds will vary as a function of the number of beaver colonies and beavers in those areas.

Because the number of empirical studies that assess beaver abundance on the Oregon coast is limited, a brief analysis was pursued based on the published literature. Pollock et al. (2003) identified that remote or protected beaver populations[17] have a density that ranges between 0.4 and 0.9 colonies/$km^2$, while recovering or managed populations have a range between 0.1 to 0.4 colonies/$km^2$. The number of beavers per colony ranges between 4 to 8 beavers/colony (Jenkins 1979, Pollock et al. 2007). This means the range of the number of beaver is 1.6 to 6.4 per $km^2$. Assuming a watershed size of 500 $km^2$ then the estimate for a beaver population in a pristine or protected area would be between 800 to 3200 beaver, while in a managed or recovering area the same watershed would be 200 to 1600. Pollock et al. (2004) estimated the number of beavers in a pristine environment in a west Cascade watershed to be 236 to 473 colonies and a population estimate that ranged between 946 and 3782 beavers in any given year.

As of 2004, nuisance beavers may be removed by landowners or their agents without permits from ODFW (ODFW 2009a), and trapping is open in its entirety in all the coastal counties, including BLM and Forest Service Lands, with the exception of Curry County (ODFW 2008). The regulations state the following regarding the Coast Range:

> "Attention Coastal Beaver Trappers. ODFW requests your continued cooperation in protecting beaver dams in coastal areas important to coho salmon rearing. If you are not familiar with this program, which was initiated in 1998, please contact your local ODFW biologist." (ODFW Furbearer Regulations 2008b, page 2)

Thus while trapping is not promoted and beavers are acknowledged as an important part of the coastal area, only beaver dams are "protected" in some manner and not the population of beavers that create and maintain their existence (ODFW 2008b). Therefore the range of beaver colonies and the number of beaver in the OC coho salmon ESU would likely fall into the category of managed, not recovering and not protected category. This is also evident in the low density of beaver dams per kilometer from 1998 to 2009.

The effect of past declines in beaver dams in the OC Coho Salmon ESU are probably manifest in the current biological status of the species, because beaver-created habitat degrades rapidly in the absence of active beaver populations (Naiman et al.1988). The combination of one agency promoting the importance of beaver, with the lack of any protection for beaver on private lands and minimal or no requirements for monitoring the take of beaver makes it extremely difficult to predict the abundance of beaver in the future compared to current levels. Despite this uncertainty, the BRT was concerned that lack of protection for beaver could result in a potential decline of this important habitat forming species, with continued low levels of beaver dams and potentially resultant declines in the abundance of high quality habitat for OC coho salmon. The BRT concluded that a lack of protection of beavers and degraded beaver dam density levels is an ongoing threat to OC coho salmon that is not fully manifest in the current biological status of the species.

[17] where no trapping is occurring and they are either protected with regulations or due to their remoteness

There is an important point to consider; that even if beaver populations and beaver ponds increase in the Oregon coast other ecological constraints need to be incorporated into the management actions of beaver ponds. One particular concern is the invasion of Reed canarygrass (*Phalaris*) in ponded areas. The cycle of beaver impoundment and abandonment both disrupts the native community and provides an ideal environment for Reed canarygrass, which once established tends to exclude development of herbaceous communities and limits vegetation species richness (Perkins and Wilson 2005). Strong management actions to control Reed canarygrass are most likely needed to re-establish native flora that is considered beaver food which may be relatively expensive and a slow process (Healy and Zedler 2010, Hoffman 2010).

**Roads-** A number of studies have found negative correlations between road density and coho salmon productivity. Bradford and Irvine (2000) found that the rate at which individual coho populations declined between 1988 and 1998 in the Thompson River, British Columbia was related to the extent of agricultural and urban land use, and the density of roads in the watershed. An increase in road density was correlated to an increase in coho salmon population decline. The road densities in the Bradford study ranged from 0-2 $km/km^2$ compared to 1.5-4 $km/km^2$ in the OC Coho Salmon ESU (Fig. 18). The road densities for the OC Coho Salmon ESU in Figure 18 are an under-representation of actual road densities in the ESU because industrial forest land roads are not included in the dataset.

Sharma and Hilborn (2001) found that lower valley slopes, lower road densities, and lower stream gradients were correlated with higher smolt density in 14 western Washington streams between 1975 and 1984. The results suggest a decrease of 500 smolts/km for each 1 $km/km^2$ increase in road density. If road densities affect Oregon streams similarly, they could have a significant effect on OC coho salmon smolt production in much of the ESU (Fig. 18).

Pess et al. (2002b) also found a negative relationship between road density and the number of fish-days[18] for coho salmon over time in the Snohomish River Basin, Washington. Most of the negative correlation was the result of urbanization and impervious surface. Urbanization can lead to an increase in impervious surface area and increase stream-flooding frequency and magnitude (Hollis 1975). The pre-urbanized 10-year recurrence interval flow event can occur every 2–5 years in urbanized areas of the Puget Sound region (Booth 1990), which can lead to declines in adult coho salmon(Moscrip and Montgomery 1997).

In a study of the tributaries of Elk River, Oregon, Burnett et al. (2006) found that density of large wood in pools was negatively correlated with road density. Road density was also negatively correlated with forest cover, and at the scale they examined, may integrate the impacts of timber harvest associated with the road network.

Dr. Chris Frissell, of Pacific Rivers Council presented information at the Oregon Coast Coho Salmon Symposium presenting known road densities throughout the OC Coho Salmon ESU and related those to the properly functioning condition defined for bull trout in the Columbia Basin (see New Comments section). His hypothesis is that with the high road densities

[18] Fish-days were calculated by multiplying the live fish observed on each survey date by the number of days between surveys. These values were then summed for the entire observation period to generate a relative index of spawner abundance at a reach for any given year (Pess et al. 2002b.)

that are known and included in the BLM roads GIS layer, and the probable road densities that are not known,[19] road density in the OC Coho Salmon ESU is probably very high and constitutes risk to OC coho salmon as he has shown road densities to affect bull trout.

The effects of current road densities may not yet be reflected in the current biological status as existing and legacy roads can contribute to continued stream degradation over time through restriction of debris flows, sedimentation, restriction of fish passage and loss of riparian function. Future land management actions in forest, agriculture and urban settings with their resultant additions to the roads network, have the potential to contribute to future reductions in OC coho salmon populations and could constitute a future threat.

**Non- indigenous plant species-** Another aspect of human disturbance that can affect stream habitat complexity has been identified in the Oregon Conservation Strategy (ODFW 2011) and in the U.S. Forest Service's Pacific Northwest Region Invasive Plant Program (USDAFS 2005, NMFS 2005b). Invasive non-native species can be powerful disrupters of native plant and animal communities. Two examples of how exotic plants can affect stream complexity are those of Giant knotweed (*Polygonum sachlinense*) and Reed canarygrass (*Phalaris arundinacea*). Giant knotweed displaces regenerating alder and conifer trees in riparian areas (Urgenson et al. 2009), and reed canary grass prevents regeneration of willow, and alder, species that may affect physical stream complexity, but are also species that are food items for beaver use (Perkins and Wilson 2005, Healy and Zedler 2010).

**Human landscape disturbance-** The condition of aquatic ecosystems and associated fish populations are a function, at least in part, of the characteristics of the surrounding landscape (Frissell et al. 1986, Naiman et al. 2000, Gregory et al. 2008). Timber harvest and associated roads have extensively altered aquatic ecosystems throughout the Pacific Northwest (Everest and Reeves 2007). A consequence of these effects of timber harvest activities is that the behavior of ecosystems is altered, which in turn has consequences for fish populations and their habitat (Reeves et al. 1993). There is a negative association between the amount of in-channel large wood and percent of area (in a watershed) intensively logged (Murphy and Koski 1989, Bilby and Ward 1991, Montgomery et al. 1995). Burnett et al. (2006) found that that the mean density of large wood in Elk River (on the southern Oregon coast) was positively related to the area in larger trees in the catchment. Reeves et al. (1993) examined watersheds in the Oregon Coast Range and found that the diversity of the fish assemblage and the amount of large wood was significantly greater in streams in which less than 25% of the watershed was clear-cut compared to watersheds in which more than 25% of the area was clear-cut.

The condition of aquatic habitat and fish populations is also directly correlated with the density of roads in a watershed, which in turn is generally directly related to the amount and intensity of land management activities (Lee et al. 1997). Roads are sources of sediment either as surface erosion or as mass erosion (Furniss et al. 1991). They also can alter water delivery by increasing the drainage network, particularly in the upper portions of the network. Sharma and Hilborn (2001) examined 14 streams in Washington and found that smolt density was inversely correlated with the density of roads. Logging activities involve the creation and maintenance of

[19] Industrial forest land road density data sets are not generally available and therefore not included in the GIS layer.

roads, and logging has been linked directly to increased sediment levels in streams (Platts et al. 1989).

Despite the connection between human disturbance and fish habitat and population performance, the ONCC TRT (Wainwright et al. 2008) was unable to include habitat condition directly in their biological recovery criteria (and is therefore not included on the results of the DSS analysis because there was, at the time, no uniform measure of habitat quality over the entire ESU. Habitat surveys by ODFW were available but the density and distribution of on the ground surveys made them unsuitable for fine-scale analysis needed for biological recovery criteria.

Recent public availability of Landsat imagery and the development of tools for analysis now make it possible to analyze human disturbance patterns on a fine temporal and spatial scale. Satellite images have the potential for measuring properties of large landscapes at a relatively fine scale. In an analysis conducted for the BRT, satellite annual vegetation maps of the OC Coho Salmon ESU were updated through 2008 and analyzed for patterns of disturbance for the time period 1986 to 2008. The scale of resolution of these analyses is approximately 100m, so disturbances as small as 1 ha can theoretically be detected. This made it possible to detect individual disturbance events from the satellite images and to map new disturbances on an annual basis. Intensity of disturbance can also be measured, so low-intensity (i.e., thinning) can be distinguished from high-intensity (i.e., clear cut) disturbances. Fires were also mapped, but fire has had a small role in shaping habitat in the OC Coho Salmon ESU over the past 23 years (for more information on methods, see Appendix B and Kennedy et al. 2010).

Human disturbance was widespread over the ESU, and predominantly of high intensity (Fig.19). Disturbance patterns varied over space, time, and land ownership. Some river systems have experienced higher disturbance than others (Fig. 20). The time series of disturbance, as derived from the Landsat images is shown for four major river systems in the Mid-Coast stratum in Fig. 21. The cumulative disturbance ranges from twenty percent (Alsea) to fifty percent (Siletz). The Siletz, Necanicum, and Tahkenitch basins have had up to fifty percent of the basin area disturbed in the analysis period, while North Umpqua has had less than ten percent disturbance. Most disturbance is in the high category, while a lesser amount is low intensity. The proportion of low intensity disturbance appears to be relatively constant over the time period. The rate of disturbance has been relatively constant over the time series, with indication of a slight increase in the most recent few years.

The pattern of human disturbance by land ownership has shown a dramatic shift (Fig. 22.) Prior to 1991 most disturbance was on U.S. Forest Service land. With the implementation of the Northwest Forest Plan, disturbance on federal lands fell sharply. Disturbance in privately owned industrial timber lands started increasing rapidly in 1997, reaching a broad peak around 2002 before moderating. The dip in 2007 is probably related to the recent economic crisis, which brought demand for building materials to a low level.

Caution is needed in the interpretation of the implications of the vegetative disturbance on OC coho salmon and their freshwater habitat. Other researchers have found relationships between landscape characteristics and the condition of habitat of coho salmon (Pess et al. 2002a) and other species of Pacific salmon (e.g., Steel et al. 2004). Hicks and Hall (2003) noted that discerning the effects of timber harvest on fish and fish habitat in the Oregon Coast Range was particularly difficult because of the inherent variability in rock types and associated stream features. The use of Landsat imagery to assess the rate of vegetative change and the extent of disturbance does not assess the impacts of timber harvest on populations and habitat of coho salmon. However, it can provide insights into the potential effects and the extent of the impacts across the ESU, which in turn has implications for the assessment of the status of the ESU.

The BRT was unable to conduct an analysis to determine if there is a relationship between the rates of disturbance of the vegetation and changes in the abundance of coho salmon and habitat conditions because of limits on time and resources. However, this information on rates of disturbance can be a potential indicator of current and, at least in part, future habitat conditions. The diversity of the salmonid assemblage and the amount of large wood in the channel is related to amount of timber harvest in watersheds in the Oregon Coast Range. Reeves et al. (1993) found that the diversity and amount of large wood was greater in watersheds where <25% of the area was subjected to timber harvest compared to those where >25% was harvested. This pattern was observed in other areas for other land-uses including agriculture (Berkman and Rabini 1987) and urbanization (Scott et al. 1986).

There is recognition in the scientific literature about the importance of periodic disturbances for creating and maintain fish habitat (Naiman et al. 1992, Reeves et al. 1995, Rieman et al. 2006). Timber harvest can alter the disturbance process and ultimately have negative rather than positive consequences to fish populations and habitat (Reeves et al. 1995, Bisson et al. 2009, Cover et al. 2010). Naturally occurring disturbance events were important sources of sediment and large wood, the basic structural components of habitat. This is particularly true in the Oregon Coast Range (Reeves et al. 1995, Reeves et al. 2003, May and Gresswell 2003, Bigelow et al. 2007). Disturbances associated with timber harvest, primarily landslides and debris flows, have less large wood associated with them than those that occurred naturally (Hicks et al. 1991, Lancaster et al. 2003). The loss of wood results in decreased habitat quantity and quality (Reeves et al. 1995, Cederholm et al. 1997).

Burnett et al. (2007) suggested that widespread recovery of coho salmon in the OC Coho Salmon ESU is unlikely unless habitat improved in areas of high intrinsic potential on private lands. The effects of timber harvest on fish and habitat is likely most pronounced on private and state lands. Requirements for management of riparian zones on these lands are less than on federal lands. Current forest practice regulations reduce the size of the streamside riparian area to less than that needed to maintain the full suite of ecological processes provide by riparian areas and allows for the removal of trees from within this zone, which further reduces ecological effectiveness. Additionally, there is no requirement for protection on small intermittent streams, which are important sources of wood (Reeves et al. 2003, May and Gresswell 2003, Bigelow et al. 2007), on private lands. These streams are given consideration on a portion of each stream on state lands. Botkin et al. (1995) and the IMST (1999) found these regulations to be insufficient to improve or recover habitat that is currently degraded.

The recent availability of Landsat images, along with the development of tools for analysis, allowed a comprehensive, uniform picture of human disturbance patterns that was previously unavailable. This analysis showed that disturbance has been widespread in the ESU, that some basins experienced much higher disturbance than others, that rates of disturbance are relatively constant, and that the most intense disturbance has moved from federal to private lands, presumably in response to policy changes.

The BRT felt that human landscape disturbance is captured somewhat in the current biological status, but that the effects of human landscape disturbance constitutes an ongoing threat to OC coho salmon.

**Loss/gain of large wood /future habitat conditions-** Large wood is a key component of habitat complexity for coho salmon in the OC Coho Salmon ESU. This wood is recruited from riparian areas immediately adjacent to the stream and from upslope sources, primarily along smaller, non-fish bearing streams (Reeves et al. 2003). Currently, wood is lacking in many streams in the OC Coho Salmon ESU because of past management activities.

Burnett et al. (2007) examined the current and future condition of riparian areas along streams with coho salmon within the entire ESU. Thirty-six percent of the stream length available to coho salmon was classified as high intrinsic potential (IP; see Glossary). The vast majority of that (81%) was primarily on non-industrial private lands. Forty four percent of the riparian areas along streams with high IP are currently either non-forested or recently logged; 10% has stands that are dominated by large (50-75 cm Quadratic Mean Diameter (QMD)) or very large (>75 cm QMD) trees. The large and very large trees are the size of tree that creates more complex habitat conditions (Abbe and Montgomery 1996). These large and very large trees are found almost entirely on federal lands, which have a relatively small proportion of the high coho salmon IP streams (Burnett 2007).

The percentage of buffers with large and very large trees is projected to increase to at least 75% on federal lands and 60% on state lands in 100 years under current policies. Less than 25% of the buffers in private ownership will have vegetation in these size classes at the end of that time. As a result, Burnett et al. (2007) concluded that widespread recovery of habitat in high IP streams, a key element of future OC coho salmon habitat recovery, is unlikely unless there are greater improvements on private lands.

The likelihood of recovery of complex stream habitat for coho salmon in the ESU is potentially further limited because of the lack of or limited requirements to consider non-fish bearing streams on private and state lands, respectively, in current management policies. Reeves et al. (2003) found that 65% of the number of pieces of large wood in Cummins Creek, a small watershed in a federally designated wilderness area on the central Oregon coast, originated in areas outside of the stream-adjacent riparian zone. Bigelow et al. (2007) found that wood delivered in debris torrents in non-fish bearing streams was a key component of habitat in a sandstone watershed on the central Oregon coast. Thus, the potential of landscape and local scale stream complexity in habitat for coho salmon in the ESU to improve is likely to be less than what Burnett et al. (2003) concluded because current policies guiding the management of riparian areas on state and private lands have limited or no management requirements for this important potential source of wood.

The BRT felt that the loss of large wood from streams in the OC Coho Salmon ESU is captured to some degree in the current biological status, but that the effects of continued loss and lack of replacement of large wood in areas that can contribute to stream complexity constitutes an ongoing threat to OC coho salmon.

**In-channel habitat complexity**-Since the original status review, the ESU has experienced an increase in abundance and productivity that largely reflects improved marine survival conditions; this increase may have reduced short-term risks to the ESU; however, the BRT was also concerned that freshwater habitat may not be sufficient to maintain the ESU at times when marine conditions are poor. The BRT also noted that the criteria in the decision support system do not take advantage of some important habitat monitoring data. To address the latter deficiency and to generally evaluate trends in freshwater habitat, the BRT, in collaboration with Oregon Department of Fish and Wildlife (ODFW), conducted some additional analyses of trends in the freshwater habitat attributes of this ESU.

Over the past decade (1998 to present), ODFW has monitored wadeable streams (streams shallow enough to wade across during survey efforts) to assess freshwater rearing habitat for the OC Coho Salmon ESU during the summer low flow period (Anlauf et al., 2009). The goal of this program is to measure the status and trend of habitat conditions throughout the range of the ESU through variables related to the quality and quantity of aquatic habitat for coho salmon: stream morphology, substrate composition, instream roughness, riparian structure, and winter rearing capacity (Moore et al. 2008). In 2009, scientists from ODFW and from NMFS independently analyzed these data to ask the question "Has juvenile coho habitat changed over the past 11 years?" These analyses reached somewhat different conclusions. In particular, the Anlauf et al. (2009) analysis generally indicated that there were no significant trends in habitat attributes (either positive or negative) across the ESU, while the 2009 NMFS analysis indicated declining trends in some measures of habitat quality across several regions of the ESU.

To better understand and resolve the discrepancies between these analyses, NMFS and ODFW formed a joint Habitat Trends Working Group (HTWG). The working group determined that the differences in results were caused primarily by the use of two different data sets and the use of slightly different statistical models of data analysis. In particular, the Anlauf et al. (2009) analysis focused on data only from within the spawning and rearing distribution of OC coho salmon, while the NMFS team used a dataset that also included habitat sites upstream from these areas. In addition, the Anlauf et al. (2009) analysis used a statistical model with some parameters that were supported by the survey design but that the NMFS analysis found as currently unsupported by the data.

The HTWG (Appendix C) used three models to estimate trends for 5 habitat metrics – Aquatic and Riparian Effectiveness Monitoring Program (AREMP) ( Reeves et al. 2004, Reeves et al. 2006) channel score, summer parr capacity, winter parr capacity, % of riffle that is sand/silt/organics, and volume of large woody debris (LWD) per 100m (Table 17). The first three metrics are multi-variate measure of habitat complexity/capacity, and the latter two are single metrics with reasonably well understood relationships to coho habitat quality. The three models were the NMFS and ODFW versions of maximum likelihood analysis and a separate Bayesian analysis (see Appendix C for details). Analyses were conducted separately on two non-overlapping datasets: one limited to coho rearing habitat and the other to upstream areas inaccessible to coho but potentially important for downstream habitat forming processes (e.g., contribution of wood). For the upstream areas, only the two 'single metrics (LWD, % sand) were assessed. Overall, the results were very similar using all three statistical models (Appendix C); here we focus on the results from the Bayesian modeling framework since these provide more explicit information about the relative certainty/uncertainty of declining or increasing trends.

The results from the coho rearing areas are summarized in Table 18. Trend estimates are mixed, and vary both among metrics and regions. Positive indications of habitat condition change include trends of decreasing fine sediment levels in the North Coast and Mid-Coast, increasing wood volume in the Mid-Coast and Mid-South-Coast, increasing habitat complexity (Channel score) in the North Coast and Mid-Coast, and increasing Summer Parr capacity in the North Coast, Mid-Coast and Mid-South Coast. Habitat complexity and specific habitat metrics also showed declining habitat conditions. Fine sediment levels are increasing in the Mid-South Coast, and wood volume is decreasing in the North Coast and Umpqua. Habitat complexity, both the Channel Score and estimated Summer and Winter parr capacity showed declines in the Mid-South Coast (Winter Parr capacity and Channel score) and the Umpqua (Winter and Summer Parr capacity). Both positive and negative trends varied in their magnitude (estimate) and the degree to which the trends were supported by the data ($Pr < 0$), and the analysis does not reveal a consistent pattern of habitat improvement or degradation across the habitat metrics or monitoring areas. In contrast to the coho rearing areas, trends in upstream areas were more pronounced. In particular, Large Woody Debris (LWD) declined substantially in all regions. Trends in sediment were mixed, with increases in the Mid-Coast and Mid-South, and declines in the North Coast and Umpqua strata (Table 19).

The BRT was impressed with the ODFW habitat monitoring program, and believes it is an invaluable source of information on freshwater habitat trends on the Oregon coast. The results from the HTWG were encouraging in that they resolved some clear discrepancies between earlier analyses. The BRT concluded that the results paint a complex picture of habitat trends along the Oregon coast. Some trends, such as the increase in habitat complexity and summer parr capacity in 3 of the 4 regions were clearly encouraging. Other trends, such as the declines in LWD in the North Coast and Umpqua strata and in upstream areas in all strata appear more troubling. The North Coast trend in LWD may be a result of large debris dams that formed during the 1996 floods that have been actively redistributed over the past several years, reducing overall LWD densities. While the North Coast stratum experienced a large decline, it also had the largest amount of LWD relative to the other strata. The declining trends in winter parr capacity (believed to be a limiting life-stage for coho production) in two strata also concerned the BRT.

**Stream habitat complexity summary-** Stream habitat complexity, both at landscape and local scales, has been identified as a factor for decline (OCSRI 1997, NMFS 1997c), a key limiting factor (OCSRI 1997, Anlauf et al. 2009), and a primary limiting factor (Oregon 2007) for OC coho salmon. Complex stream habitats are diverse and dynamic. Complexity is maintained through connection to the surrounding landscape and it has been well established that a century and a half of land use activities have simplified Oregon coastal streams (Reeves et al. 1993 & 1995, Burnett et al. 2007). Because of its importance to the status and recovery of the species, the BRT considered multiple aspects of this issue. These included legacy effects of splash dams, log drives and stream cleaning, beaver status and management, road densities and their effects on coho smolt densities, disturbance, large wood in riparian zones, and trends in both landscape and local stream complexity across the ESU (Naiman et al.1988, Maser and Sedell 1994, Bradford and Irvine 2000.)

The BRT habitat subcommittee analyzed the complexity of available freshwater habitat using multidimensional stream complexity metrics developed by ODFW's Oregon Plan coho salmon monitoring program (HLFM winter and summer parr capacity). The subcommittee analyzed channel score and parr capacity metrics that were constructed from the ODFW stream habitat monitoring data sets. Newly available Landsat data were also analyzed to examine anthropogenic disturbance to the landscape of the OC Coho Salmon ESU. Other impacts, such as roads, were discussed with reference to their effects on coho smolt densities from Washington and British Columbia (Bradford and Irvine 2000). Legacy effects of splash dams and stream cleaning, and current and future condition of large wood in riparian areas were discussed with respect to the availability of wood for stream complexity. Indications as to the present and future status of beaver were examined through beaver studies that occurred in the ESU and an analysis based on published literature.

Even though splash damming, log drives and stream cleaning is no longer practiced or endorsed by ODFW, legacy effects of these activities still affect the amount and type of wood and gravel substrate available and, therefore, stream complexity across the ESU (Miller 2010, Montgomery et al. 2003). Increasing complexity would indicate that these legacy effects are being mitigated as wood and gravel move into the stream channel. The resulting channel would be more hydraulically diverse, with pools, side-channels and backwater units that support higher summer and winter capacity for spawning and rearing. Eleven-year trends of stream complexity metrics were analyzed at the level of the stream, population, and stratum (HLFM version 7). Similar to the ODFW/ Anlauf et al. (2009) trend analysis of individual habitat attributes, the subcommittee's analyses found that habitat complexity across the ESU exhibited no consistent trends over the period of consideration (1998--2008). There are exceptions, such as summer parr capacity in the Mid-South or Mid-Coast strata. But for any metric, or any stratum, no trends were identified.

To help understand these patterns the BRT examined several other lines of evidence. Clear-cut logging removes wood from upslope and disturbs the riparian zone (Montgomery et al. 2003) and reduces the amount of large wood available to the streams and interferes with processes that generate complexity (Reeves et al. 2003, Burnett et al. 2007). Use of Landsat images allowed the BRT to look at patterns of clear-cutting and thinning from 1986 to 2009. Timber harvest and other land-use activities were widespread throughout the ESU, with about 40% of the total forest area experiencing anthropogenic disturbance in the 23-year period. Timber harvest rates varied by basin, but there was no evidence of a general reduction in the pace of logging. The cumulative percentage of forest clearing by basin was highest in the Siletz basin, followed by the Necanicum to the north, and Coos, Coquille, and mid-Umpqua to the south. The most striking change was a shift in impacts from National Forest land to private industrial land.

The patterns of simplification of stream habitat and reductions in salmon habitat capacity caused by forestry activities are consistent with other information (ODFW 2005c, 2009a) that indicate low levels of large wood (Burnett et al. 2006) and high levels of sediment (Lee et al. 1997) in streams of the Oregon Coast Range. The BRT considered the long-term (multiple decades) effects of logging activities and associated road building on stream conditions, the wide-spread occurrence of these activities, and lack of any sign that logging activities are abating, as indications that these threats to habitat are pervasive and ongoing in the OC Coho Salmon ESU.

Beavers are an important species to proper watershed functioning in coastal Oregon streams, and the loss of beaver and their dams has been identified by ODFW (OCSRI 1997, ODFW 2007) and many other authors as an important loss to stream complexity that significantly affects OC coho salmon. Because ODFW has only aquatic habitat survey data from which to infer beaver populations and structures, knowledge of what could be a significant contributor to OC coho salmon recovery is severely limited; however, continued loss of this important keystone species constitutes a continuing risk to stream complexity and impediment to habitat improvement.

In summary, habitat complexity across the ESU did not improve over the period of consideration (1998--2008). Road densities are high and affect stream quality through hydrologic effects like runoff and siltation and by providing access for human activities. Beaver activities, which are thought to produce highly productive coho salmon rearing habitat, appear to be reduced, and recovery of beaver populations could be impaired by their classification as a nuisance species. Stream habitat restoration activities may be having a short-term positive effect in some areas and passive efforts to restore landscape condition may be effective on much longer time periods than is considered here, but the quantity of impaired habitat and the rate of continued disturbance appears at this time to be outstripping the efforts to restore complex instream habitat[20].

Some stream complexity problems such as the legacy effects of splash damming and stream cleaning are probably already reflected to a large degree in current biological status. However, future impacts to stream complexity from large wood availability, disturbance from road building, logging and other land use practices and reduction of beaver populations are not reflected in current biological status and may constitute a future threat.

**Land management- forest and agriculture conversion**

> The pressures of urban and rural residential land use affect aquatic ecosystems and salmonids through alterations of, and interactions among, hydrology, physical habitat structure, water quality, and fish passage. These alterations occur at local and, especially, watershed scales, and thus require study and management at multiple scales. Urban and rural-residential development causes profound changes to the pathways, volume, timing, and chemical composition of stormwater runoff. These changes alter stream physical, chemical, and biological structure and potential, as well as the connectivity of streams with their watersheds. (IMST 2010)

[20] The effect of restoration projects not reflected in the ODFW data set is not discussed in this document, but is discussed in the Federal Register Notice as "conservation measures."

The BRT discussed several modeling studies undertaken to understand the potential for conversion of lower density land uses to higher density ones. These were modeling studies by Kline et al. (2003) (see Table 20) and Lettman et al. (2009) that looked at the potential for land use conversion based on land use regulations existing at the time of the study. Kline et al. (2003) as part of the CLAMS Project modeled the potential expansion of urban and suburban areas in most of the OC Coho Salmon ESU (Fig. 23). Land use is projected to change in the ESU-primary changes are expected to be from agriculture, forest and rural residential to urban (Table 21). Figure 23 shows a possible scenario between 1994 and 2044 based on existing land use zoning and property ownership as of 1994 (Kline et al. 2003). This model allows building densities to increase on any private lands, with some lands or ownerships (e.g. non industrial private) having greater likelihood of increases. By 2044, in this analysis, some change is anticipated in certain areas; particularly the area of the ESU near the urban centers along the Oregon coast. The Lakes stratum is anticipated for urban densities to nearly double, the Mid-coast stratum to increase by a factor of 4, the North Coast to increase by a factor of 5, the Mid-south coast by a factor of 1.5 and the Umpqua stratum increase by 2.5. This analysis did not include the entire Umpqua Basin, however. While these increases are relatively large, they are still below the potential threshold effects of fundamentally altering the magnitude and frequency of flood events (Booth 1990, 1991). However, if urbanization is concentrated in distinct areas, as is typically the case, then watersheds with those areas could have increases that result in urbanized drainage areas of greater than 10-15% where the 1 to 4-year flood event has a magnitude that is more similar to a 10-year flood recurrence interval (Moscrip and Montgomery 1997). This change in the hydrology of the streams could then result in decreases in coho salmon abundance levels from 2.5 to 4 times the levels typically seen in forested environments, particularly if urbanization also included alteration to wetland habitats directly associated with the stream network (Pess et al. 2003).

The Oregon Department of Forestry (ODF) has also developed a model that predicts potential future land use changes in the ESU due to increased conversion of forest land to agriculture and urban/suburban uses (Fig. 24, Table 21 ) (Lettman et al. 2009). The results of these projections show that under each of these scenarios, the most likely effects will be in the Mid-Coast, Mid-South Coast and Umpqua River strata.

Human disturbances, such as agriculture and urbanization, can lead to a decrease in coho salmon habitat availability and quality (Beechie et al. 1994; Bradford and Irvine 2000, Berkman and Rabeni 1987). Beechie et al. (1994) found a decrease in tributary and off-channel habitats (e.g., wetlands, sloughs, and ponds) of up to 75%, almost all of which was due to deliberate modifications of the channel and floodplain. The vast majority of these impacts are related to the conversion of forested areas to agricultural and subsequently to residential use. Maintained channelization can increase channel incision to the point where the streambed is disconnected from its floodplain (Booth 1990). Floodplain isolation reduces the amount of off-channel habitat available for adult salmonid spawning and juvenile rearing, which can lead to the downstream displacement of newly emerged salmonids to less-desirable habitats (Seegrist and Gard 1972; Erman et al. 1988). Stream cleaning and riparian vegetation removal reduces the amount of in-channel wood, leading to a loss of pool habitat quantity (Montgomery et al. 1995; Collins et al. 2002), which can substantially reduce coho redd density (Montgomery et al. 1999).

Urbanization can lead to an increase in impervious surface area and increase stream-flooding frequency and magnitude (Hollis 1975). The pre-urbanized 10-year recurrence interval flow event can occur every 2–5 years in urbanized areas of the Puget Sound region (Booth 1990), which can lead to declines in adult coho (Moscrip and Montgomery 1997). Urban watersheds also generate high concentrations of compounds that are toxic to salmon or alter their behavior in ways that could reduce survival (Scholz et al. 2000).

Conversion of lower intensity land use to higher intensity land use with a greater amount of impervious surface was identified as a factor for decline in portions of the OC Coho Salmon ESU by NMFS (NMFS1997c). If urbanization, rural residential development and loss of forest cover is concentrated in distinct areas, as is often the case due to land use zoning, then those watersheds would experience a change in the hydrology of the streams that would result in decreases in coho salmon abundance levels. The IMST (2010) found that:

> In the Pacific Northwest, there is a growing understanding that aquatic habitat affected by existing development is important for salmonids (e.g., Pess *et al.* 2002b; Regetz 2003; Mac Coy & Blew 2005; Sheer & Steel 2006; Burnett *et al.* 2007; Bilby & Mollot 2008). Projections of future land use and land cover in Oregon's coastal mountains show increasing rural-residential and urban development within 328-foot (100-meter) buffers surrounding high quality coho and steelhead habitat, with more rapid development projected for coho habitat (Burnett *et al.* 2007).

The BRT considered that the existing land use in the ESU was reflected in the current biological status of OC coho salmon. Future conversions of lands to urban, suburban, and agriculture are dependent on many factors including economic conditions and land use planning and are therefore uncertain. Some of the BRT members felt that urbanization presented a smaller problem to OC coho salmon compared to salmon in the Willamette Valley. Other BRT members, however, felt that urbanization and rural residential development retards advances in recovering important OC coho salmon habitat in locations like Tillamook Bay and Coos Bay. They also considered that conversion of agriculture and forests to urban and rural residential land uses results in a disproportional impact to high potential coho salmon habitat and the effects of conversion of land to uses with levels of impervious surface above 15% within a watershed were therefore considered a potential future threat with uncertain magnitude to OC coho salmon populations.

**Land management- loss/gain of estuarine/freshwater intertidal habitat**

The Oregon coastal drainages supporting independent OC coho salmon populations terminate in tidally influenced freshwater wetland/estuarine habitats (Fig. 25) (e.g., Good 2000). In declaring critical habitat for OC coho salmon, NMFS (2008) recognized that Oregon's estuaries/tidal freshwater wetlands provide habitat important to the migratory and rearing life stages of this ESU. The IMST (2002) also highlighted the importance of estuaries for the "productive foraging environments for juvenile salmonids before they enter the ocean, refuges from predation, refuge from strong tidal and river currents, habitats of intermediate salinity for juvenile salmonids transitioning from fresh water to the ocean, migration corridors for adult salmonids returning from the sea, and at times, cooler water temperatures than [occur in] mainstem lowland rivers."  ODFW has also cited the role of estuaries in providing foraging and growth opportunities for out-migrating coho smolts and the importance of stream/estuary ecotones for rearing coho juveniles[21] (Miller and Sadro 2003).

**OC coho salmon use of estuarine/freshwater intertidal habitats-** The predominant life history pattern for coho salmon originating south of the central BC coast is a three year cycle, including freshwater rearing for approximately 18 months followed by an equivalent period of ocean residence (Weitkamp et al. 1995).  Several studies (Schreck 2002, Chapman In prep., Power Unpublished manuscript) have focused on the use of estuaries and tidal freshwater habitats by yearling smolts emigrating to the ocean from natal rearing reaches.   Koski (2009) reviewed results from several studies of downstream coho migration and rearing and discussed the importance of the stream/estuary ecotone as a rearing area.  The stream/estuary ecotone, defined as the transition zone from tidal fresh to tidal brackish waters, can serve as a transition area for smolts adapting to salt water.  This zone is characterized by low salinity, warm temperatures in the summer, and an abundance of food for juvenile salmonids and can serve as acclimation areas allowing coho salmon juveniles to adapt to the higher salinity levels associated with downstream subtidal reaches.  Smolts outmigrating from upstream freshwater reaches may feed and grow in lower mainstem or estuarine habitats for a period of days or weeks prior to entering the nearshore ocean environment[22],[23] (Chapman et al. In prep., Miller and Sadro 2003 ). Chapman et al. (In prep.) found that wild juvenile coho smolts rearing in several Mid-Coast Oregon estuaries prey almost exclusively on intertidal benthic invertebrates found on mudflats that are available only during high tides.  In addition to serving as transition areas for outmigrating smolts, estuarine (both brackish and freshwater) areas may provide more extended rearing opportunities for young of the year (age 0) coho juveniles (Miller and Sadro 2003).

Juvenile sampling studies in coastal rivers from northern California to Alaska indicate that coho salmon (age 0) juveniles are often present in these lower river/estuarine habitats, particularly in freshwater tidally influenced habitats (e.g., Jones et al. Unpublished Manuscript). Koski (2009) summarized information from recent studies indicating that downstream migrations of coho salmon may be associated with specific life history strategies that contribute to resiliency in the face of fluctuating environmental conditions.   The relative contribution to adult returns from variations on an early downstream emigration pattern is not known for OC coho salmon populations (Jones et al. Unpublished Manuscript).  Migrant trapping studies have shown that substantial numbers of coho salmon fry may emigrate downstream from natal streams into tidally influenced lower river wetland/estuarine habitats (e.g., Chapman 1962, Koski 2009, Bass 2010). Observations of spring or early summer downstream migration of coho salmon fry were originally thought to represent a passive displacement in response to increased stream flows, competitive interactions, or capacity limitations.  Chapman (1962) used the term 'nomads' to characterize coho salmon juveniles moving downstream between emergence and early fall, which is well before typical smolt migration in the spring.   However, little direct quantitative

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[21] Robert Buckman, District Biologist, ODFW Newport Field Office 2040 SE Marine Science Drive Newport, OR 97365, Pers. comm. January 2011.

[22] Robert Buckman, District Biologist, ODFW Newport Field Office 2040 SE Marine Science Drive Newport, OR 97365, Pers. comm. January 2011.

[23] J. Power, USEPA U.S. Environmental Protection Agency Hatfield Marine Science Center 2111 SE Marine Science Drive Newport, Oregon  97365-5260, Pers. Comm. May 2011.

information exists on the relative proportions of coho salmon juveniles that use this life history pathway, the survival rates and capacity relationships involved, and the relative contribution to adult returns.

At least three discrete life history strategies involving downstream coho fry/presmolt migrations into lower river habitats have been identified in the literature (e.g., Koski 2009, Sandercock 1991):

- Late fall migration into side channel or pond habitats connected to lower mainstem reaches from mainstem summer rearing habitats. For example, juveniles following this pattern had relatively high growth and overwinter survival rates in the freshwater side channel habitats in lower Clearwater River, a major tributary to the Queets River on the Washington coast (Peterson 1982). In Winchester Creek (a relatively short tributary draining into the South Slough of Coos Bay, Oregon), some of the coho salmon juveniles that had emigrated downstream and reared over the summer in the brackish portion of the creek migrated into off-channel beaver pond habitats to overwinter (Miller and Sadro 2003). Similarly, Wallace and Allen (2009) determined that coho salmon juveniles rear through the summer in the tidal freshwater portions of Humboldt Bay tributaries. A portion of those juveniles emigrate into side channel habitats for overwintering.

- Lower mainstem/estuarine summer rearing followed by upstream migration for overwintering. Skeesick (1970) documents upstream movements of coho salmon juveniles into overwintering habitats in three Oregon coastal streams including Munsell Creek in the tidal portion of the Siuslaw River. Koski (2009) also cites a number of studies that demonstrate fall movement of coho salmon juveniles into habitats with conditions conducive to overwintering survival.

- Lower mainstem/estuarine rearing followed by subyearling outmigration to ocean. A substantial number of subyearling coho in the Salmon River (Oregon coast) migrate downstream through the summer and early fall and rear in estuarine and freshwater tidal marsh habitats. Some of these juveniles may enter the ocean as subyearlings. Scale analyses conducted in one system, the Salmon River, indicated that the annual proportions of adult coho returning to the Salmon River that entered the ocean as subyearlings varied from 1% to 18% between 1993 and 2003 (Jones et al. Unpublished Manuscript). Future otolith analyses may provide estimates of relative adult return contributions from subyearlings that migrate directly to sea from upstream natal habitats vs. those that may rear for an extended period in intertidal habitats prior to entering the ocean.

The relative contributions of these alternative life history pathways to either current or historical adult coho returns to Oregon coastal populations is not known. For example, numerous historic studies reporting age structure of adult coho salmon from scales very rarely find individuals that did not spend at least one year in freshwater prior to ocean entry (reviewed in Weitkamp et al., 1995). Few systematic surveys exist of the relative density and timing of juvenile coho rearing in upper and lower estuarine habitats for Oregon coastal drainages. Examples of Oregon coast stream/estuary ecotones cited by Koski (2009) include: the upper 3km of Winchester Arm of South Slough of Coos Bay (Miller and Sadro 2003); Lint Slough (Garrison 1965); and the Salmon River (Cornwell et al. 2001). More recent work not reported in Koski has been done in the Salmon, Alsea, Siuslaw, Nestucca, and Yaquina Rivers (Jones et al. Unpublished Manuscript) as well as Coos Bay (Bass 2010). ODFW has also sampled juveniles and smolts in these habitats in the Siletz, Yaquina, and Alsea river basins.[24]

**Losses of intertidal habitat.** Historical losses of tidal habitat is documented in two reports that summarize estimates of current and historical tidal wetland habitats within Oregon coastal drainages with independent coho salmon populations (Good 2000, Adamus et al. 2005). Because the two assessments used different techniques to determine losses, the estimated quantities of wetland habitat loss was also different, although the two analyses yield similar trends among coastal basins (Table 22 and Fig. 26).

Both assessments indicate that the historical ratio of estuarine/tidally influenced wetlands to total drainage area for the Coquille, Coos, and Tillamook basins were relatively high in comparison with other Oregon coastal drainages. The Umpqua River represents the largest single drainage on the Oregon coast and includes four independent populations. Adamus et al. (2005) estimated the highest proportion of historical lower river wetlands habitat in the Umpqua River, while the Umpqua River ranked fourth among Oregon coastal drainages in total estuarine habitat in the Good (2000) analysis.

The amount of tidal wetland habitat available to support coho salmon migration, foraging and rearing has declined substantially relative to historical estimates across all of the biogeographic strata (Table 22, Fig. 26). The greatest historical losses (total area and proportional reduction) have occurred across populations in the North Coast and Mid-South Coast strata, driven by the relatively high proportional reductions in the largest estuaries. The time frame for contemporary estimates of tidal wetland areas differ between the two sources: Good (2000) reported values as of 1970, whereas Adamus et al. (2005) summarized wetland totals for the early 2000's. In addition to the direct losses, restriction of access to sections of tidal habitat and stream/estuary ecotone through the installation of tide gates (Bass 2010) has severely changed habitats available to out-migrating smolts relative to historical conditions. Overall, the results of recent coho salmon surveys imply that beyond the potential effects on the smolt rearing capacity of coastal basins, widespread estuarine/tidal freshwater wetland losses have also likely diminished the expression of subyearling migrant life histories within and among coho salmon populations.

**Restoration and protection intertidal habitat.** Estuarine/tidal freshwater restoration projects have been carried out in several drainages in more recent years. Additional wetland habitat that has become potentially available to juvenile salmon through these OWEB, USFWS, and USFS projects are incorporated into Table 23. If aggregated across OC coho salmon independent populations, recent restoration efforts have targeted a total area equivalent to 14-20% of current baseline of tidal habitat (Table 23). The largest increase has been in the Mid-South Coast stratum (Coos Bay and Coquille Bay), with a 28-32% aggregate increase in potential intertidal rearing habitat. The North Coast (11-14%) and Mid-Coast strata (11-19%) also had relatively large proportional increases. Intertidal habitat gains in a small basin, the

[24] Robert Buckman, ODFW, pers. comm. January 2011.

Nestucca River, accounted for the change in the aggregate North Coast area total. Likewise, the Mid-Coast Stratum increase was accounted for largely by changes in the Salmon River. These gains notwithstanding, the proportional change in the total amount of available intertidal habitat after adding in gains through recent restoration efforts is small relative to historical conditions (Table 23). In addition to the restoration actions, approximately 2,900 acres of existing high quality intertidal or adjacent riparian habitat has been afforded protection through OWEB fee title and conservation easement programs in recent years[25]

The OC coho salmon biological recovery criteria directly considers the status of tidally influenced habitats at the population and ESU levels as an indication of remaining diversity (Wainwright et al. 2008). Two of the component criteria in the DSS are informed by measures of the relative status of tidally influenced habitats. The Workgroup noted that while it was clear that estuarine habitat conditions have changed relative to historical, it is difficult to determine the degree to which those changes have affected fish.

Future threats to OC coho salmon from loss of estuarine and freshwater tidal habitat may also come in the form of sea level rise in Oregon's estuaries (OCCRI 2010, National Wildlife Federation 2007). Although recent restoration efforts have increased the amount of estuarine habitats suitable for coho rearing, it is uncertain whether gains can continue to be realized in light of the potential impact of sea level rise. If the human response to sea level rise is to raise the protection level of dikes and levees, then there would likely be widespread loss of tidal habitat because the opportunity for tidal marshes, swamps and mudflats to move to higher ground will be blocked by protection structures and basin topography. Tidal marshes and mudflats are substantial contributors to the estuarine food chain in direct and indirect ways (Gray 2005, Chapman In prep.). Loss of more tidal habitats through sea level rise could have a negative effect on feeding and rearing of OC coho salmon in estuarine/tidal freshwater habitats.

The current biological status of Oregon coastal coho populations reflects the effects of estuarine tidal habitat loss relative to historical conditions, including the potential impacts of the associated diminished life history diversities. With an increasingly variable marine ecosystem, this loss of life history diversity may constitute a future threat, particularly for production from smaller tributaries associated with relatively large estuaries. It is difficult to quantify the potential impact of those losses given the current uncertainty regarding the historical contributions from the various life history patterns.

**Land management loss/gain of freshwater wetland habitat**

Determining the freshwater wetland losses outside estuaries in each population of the OC Coho Salmon ESU is not possible with the data sets available at present. There have been estimates of estuarine wetland losses in several studies (Good 2000, Adamus et al. 2005, and Christy 2004). All have differing estimates, probably from the use of differing data and methodologies. As an example of the severity of the losses, Christy (2004) found that the estimated total acres of wetlands in estuaries in the OC Coho Salmon ESU that were converted to

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[25] Miriam Hulst, Acquisitions Specialist, Oregon Watershed Enhancement Board, 775 Summer Street NE Suite 360, Salem, Oregon 97301-1290. Pers. Comm. 10/15/2010.

other uses, from 1850-2000, was estimated at 43,672 acres. Of these losses freshwater wetland were highest with-34,276 acres; salt marsh losses were next with 9,383l acres, lake associated wetlands were reduced by only 13 acres and subtidal habitat suffered zero acres of loss. Of course, these numbers do not reflect any losses upstream of the estuaries.

For somewhat recent losses/gains to wetlands in the OC Coho Salmon ESU, Table 24, which is Table 1 of the Department of State Lands Wetlands and Estuaries Report, part of the Oregon Coast Coho Assessment (ODSL 2005) details the information available at the time. This analysis is not restricted to just estuarine wetlands, so is not comparable to Christy (2004), but shows that there was continued wetland loss to filling activities as well as restoration of wetlands in counties occupied by the OC Coho Salmon ESU.

More recent requests for information (2007-2008) from the Department of State Lands permit tracking system reported 12.5 acres of both freshwater and estuarine wetlands lost, 9.6 acres gained, and 46.21 acres enhanced in the counties of the ESU.[26] There are still wetland losses occurring, and some wetland gains being made, but probably not at the scale that historic freshwater wetlands (just in estuaries) were lost. Substantial development of data and historical reconstructions are necessary before the true magnitude of wetland losses throughout the OC Coho Salmon ESU are understood.

The results of coho salmon surveys (ODFW 2009a), however, imply that loss of wetlands throughout the ESU has had a significant effect on rearing capacities of coastal basins, not just in estuaries. These losses may originate from, to name a few, stream incision and loss of connection with the floodplain, filling and diking of wetlands for agriculture and urban development, and loss of wetlands engineered by beavers due to trapping and disease. This, in addition to estuarine losses may also have diminished the “nomad” life history in OC coho salmon populations due to loss of slow water rearing areas.

Although it is apparent that wetland losses in estuaries have slowed, and in some basins, reversed, losses in freshwater wetlands upstream of the estuaries in the ESU are difficult to quantify. Some information about recent losses is available through the Department of State Lands Permit Tracking system, but studies of historic freshwater wetland losses are either too large scale for usefulness, or are restricted to the Willamette and Klamath Basins (Morlan 2000). Many of the freshwater wetlands important to coho salmon are not inventoried because they are outside the “wadeable stream” restriction for the ODFW aquatic habitat surveys. Because wetlands are so important to coho rearing (Nickelson 1998, Burnett et al. 2003), lack of information regarding these off-channel and slow water areas constitutes a risk in making future management decisions without a robust understanding of OC coho salmon lifecycle and utilization of these habitats.

The BRT considered that freshwater wetland losses were probably reflected in the current biological status of the species. Because the potential magnitude of future freshwater wetland losses are poorly understood, the scale of the future threat to the OC Coho Salmon ESU is uncertain.

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[26] Joy Vaughn, ODSL. Pers. Comm. Dec. 2009.

**Land management-mining**

Mining in general and gravel mining in particular was identified as a factor for decline in NMFS (1997c). Until recently, gravel mining, particularly in the Umpqua and Tillamook River Basins has been a serious concern in the past to fishery managers and remains a concern in the Coquille River. Providing for fisheries in gravel mining operations has been the subject of substantial effort for protection of all anadromous salmonids in the Umpqua stratum. At this point in time, there are no active instream gravel mining operations in the Umpqua; however, there are continuing operations in the Tillamook and Nehalem Basins, both in the North coast stratum. There is a concern that if ESA protections are removed, instream gravel mining operations could become a serious threat to The OC Coho Salmon ESU in the future.

The BRT considered that the effects of mining were probably reflected in the current biological status of the species. However, because the potential for future gravel mining activities are poorly understood, the scale of the future threat to the OC Coho Salmon ESU is uncertain.

**Land management- water quality degradation**

Water Quality has long been identified both as a factor for decline (NMFS 1997c) and as a limiting factor for recovery (Oregon 2005) for OC coho salmon. Water quality is made up of many facets that were presented in NMFS (1997c), ODEQ (2005) and Oregon (2005). Table 15 lists the 15 populations where water quality is an important limiting factor.

In 2005 Oregon Department of Environmental Quality assessed the situation in the OC Coho Salmon ESU:

> Water quality improvements in an area like the coastal coho ESU – where the problems largely relate to nonpoint source pollution and flow and channel modification – take time. At this time, we are not able to demonstrate an improving trend in water quality, but there are some indications that improvements will occur. One sign of progress is reflected in the on-the-ground efforts of landowners and others and the partnerships being forged to conduct TMDL implementation activities (ODEQ 2005).

For the purposes of this status review, the focus is on temperature limitations within the ESU because of temperature's important effect on coho salmon success in fresh water. For an overview of water quality status of the OC Coho Salmon ESU streams, Fig. 27 shows a substantial amount of the streams and rivers in the ESU as water quality limited. Category 5 shows impairment by one or more pollutants and Category 4 shows that the reach is impaired but has an approved Total Maximum Daily Loads (TMDL) management plan. The mileage of impairments in OC Coho Salmon ESU is difficult to assess because impairments of stream reaches may be different and overlap. However, as illustrated in Fig. 28 (ODEQ 2007) the temperature impairments in the OC Coho Salmon ESU are 40% of OC coho salmon distribution stream miles.

It can be argued that water temperature is the primary source of water quality impairment in the OC coho salmon Critical Habitat. Welsh et al. (2001) found in the Mattole River, California, that juvenile coho were not found in streams with mean weekly average temperatures (MWAT) greater than 18 degrees C, and that all streams in their study area with MWAT below 14.5 degrees C held juvenile coho. Temperatures above about 15 degrees C stress salmon in a variety of ways. At higher temperatures metabolic rates are higher so fish must forage more actively to maintain growth rates. This adds stress of the food supply is limiting and forces fish to be more exposed to predators. Dissolved oxygen is lower at higher temperatures, further stressing the fish. Many of the diseases that salmon are susceptible to occur at higher rates as temperatures increase (Marcogliese 2001, 2008). These include fungal infections such as *Columnaris*, which can cause mortality in both juveniles and returning adults. Life cycle timing can be disrupted at higher temperatures, potentially leading to a mismatch between smolt outmigration timing and onset of upwelling in spring (Crozier et al. 2008b). Higher temperatures in the summer limit the quantity of stream habitat that is available for juvenile salmon rearing, while high temperatures in the fall can block adult migrants from reaching spawning grounds (Ebersole et al. 2006.)

Temperature has been negatively correlated with coho salmon survival and abundance in freshwater (Lawson et al. 2004, Crozier et al. 2008b). Temperature effects operate through a wide variety of mechanisms; beaver pond wetlands tend to moderate water temperatures, parasites are more virulent at higher temperatures (Lawson 2009), life cycle timing can be disrupted at higher temperatures potentially leading to a mismatch between smolt outmigration timing and onset of upwelling in spring (Crozier et al. 2008b) The broad conclusion is that rising temperatures that are anticipated with global climate change, will have an overall negative effect on the status of the ESU. If 40% of the OC Coho Salmon ESU is already temperature impaired (ODEQ 2007), just the effects of climate change in the absence of threats from other human activities like forestry and agriculture, pose a significant risk to those systems already impaired, and increase the likelihood of temperature impairment in the rest of the aquatic systems in the ESU.

The BRT considered that the effects of current water quality impairment were probably reflected in the current biological status of the species. Because of the expected effects of global climate change on OC coho salmon habitat, water quality was considered a significant future threat to the OC Coho Salmon ESU.

## Disease or Predation

### Disease and parasitism

In its assessment of OC coho salmon ODFW (ODFW 2005b) asserted that disease is not an important consideration in the recovery of OC coho salmon. Jacobson et al. (2003, 2008) identified *Nanophyetus salmincola* as a potentially important source of early marine mortality. Cairns et al. (2005) has also shown that “the direct effects of temperature associated with increased metabolic demand can be exacerbated by other factors, including decreased resistance to disease and increased susceptibility to parasites”

Jacobson (2008) reports that annual prevalences of *N. salmincola* in yearling coho salmon caught in ocean tows off the coast of Oregon were 62-78%. Yearling coho had significantly higher intensities of infection and higher infection in wild versus hatchery juveniles, presumably due to the greater exposure to metacercaria in natal streams. Prevalences and intensities of yearling coho salmon caught in September were significantly lower (21%) than those caught in May or June in 3 of 4 years of data. This suggests parasite-associated host mortality during early ocean residence for yearling coho salmon. Pearcy (1992) hypothesized that ocean conditions (food and predators) are very important to marine mortality, especially soon after the juveniles enter the ocean. This is the time period that Jacobson et al. (2008) observed the loss of highly infected juveniles. Jacobson hypothesizes that high levels of infection may lead to behavioral changes in the fish and thus make the juveniles more susceptible to predation.

The issue that Cairns et al. (2005) investigated is the influence of summer stream temperatures on black spot infestation of juvenile coho salmon in the West Fork of the Smith River (WFSR), Oregon in the OC Coho Salmon ESU. Their studies show that "although other environmental factors may affect the incidence of black spot, elevated water temperature is clearly associated with higher infestation rates in the WFSR stream network." This may be an important issue for coho salmon juveniles as many of the streams they inhabit are already very close to lethal temperatures during the summer months (see Fig. 28) and with the expectation of rising stream temperatures due to global climate change, changes in metabolic rates may act as a stressor that may result in higher infection rates in coho salmon.[27] Changes in infection rates of juvenile coho by parasites as well as new parasites associated with invasive species may become an increasingly important stressor both for freshwater and marine survival.

Parasitism and disease was not considered an important factor for decline in early status reviews for OC coho salmon. However, some of the studies discussed above suggest that it may become more important as temperatures rise due to global climate change and may become a very important risk for juveniles in the early ocean-entry stage of the lifecycle.

The BRT considered that the effects of disease and parasitism were probably reflected in the current biological status of the species. However, because of the expected temperature effects of global climate change on OC coho salmon freshwater habitat, disease and parasitism was considered a potential future threat to the OC Coho Salmon ESU.

## Predation

Due to the visibility of predators and their interactions with resource users in both fresh and salt water, predators are often mentioned by stakeholder groups as a serious threat to OC coho salmon populations (ODFW 2005h). Fresh (1997) concluded that predation was probably not a primary factor in OC coho salmon population declines. The IMST (1998) examined the question of predation and concluded that salmon have evolved with predators and that despite the presence of many kinds and large numbers of predators, coho salmon have persisted over many millennia. They note that there is variability in predators over time depending on ocean

[27] Although Bisson and Davis (1976) found that elevated temperatures reduced infestation rates by *Nanophyetus* on juvenile Chinook.

conditions, the size of the predator and availability of salmon juveniles. They also concluded that when populations are low, however, predation can have a significant effect on extinction risk.

**Birds and marine mammals-** Cormorants (*Phalacocrorax* spp.), terns (*Sterna* spp.), brown pelicans (*Pelecanus occidentalis*), sooty shearwaters (*Puffinus griseus*), common murre (*Uria aalge*), mergansers (*Mergus* spp.), gulls (*Larus* spp.), belted kingfisher (*Megaceyle alcyon*) grebes and loons ( *Gavia* spp.), herons (Family Ardeidae) osprey (*Pandion haleaetus*) and bald eagles (*Haliaeetus leucocephalus*) all prey on juvenile salmonids in the OC Coho Salmon ESU to one degree or another (IMST 1998). In the Columbia River estuary just adjacent to the OC Coho Salmon ESU, terns and double-crested cormorants have been shown to affect juvenile salmonid survival significantly, (Collis et al. 2002, Roby et al. 2003, Antolos et al. 2005). However, river basins in the OC Coho Salmon ESU do not have dredge spoil islands to attract large tern and double-crested cormorant colonies. Neither do they have an extended time period of juvenile salmonid outmigration similar to the Columbia River system.

Predation by avian predators may however be important in the loss of salmonid juveniles in some populations in the ESU. In a study of steelhead outmigrants in the Nehalem River, Schreck et al. (2002) observed substantial mortality of juvenile steelhead trout in the estuary, presumably from predation by double-crested cormorants, Caspian terns and harbor seals. More recently, Johnson et al. (2010), in the Alsea River observed mortality rates on naturally reared steelhead juveniles as high as 53%- mainly in the lower estuary, presumably from avian predation and harbor seals. Neither study, however, demonstrated direct evidence of predation by any particular predator. Bass (2010), in Coos Bay was able to demonstrate predation on OC coho salmon juveniles by double- crested cormorants by utilizing PIT tag detections of deposits below the rookery. These were smolts that he had tagged for a study on the effect of tide gates on juvenile coho salmon movement.

The common murre is the most abundant seabird in the OC Coho Salmon ESU, but does not appear to have a significant impact on juvenile salmonids in the nearshore at present. The common murre breeding population on the north coast of Oregon has been severely affected by bald eagle predation. They have abandoned their nesting sites on the north coast rocks. Murres therefore are not feeding on juveniles from those coho populations in the large concentrations that they would if they were breeding on the nearshore rocks.[28] Other species have shown substantial increases in population levels- particularly Caspian terns and double -crested cormorants in the lower estuary of the Columbia River (Collis et al. 2002). However, outside of the Columbia River system, Adkins and Roby (2009) report that there were 2384 breeding pairs of double crested cormorants nesting at 22 colony sites along the Oregon coast. This is similar to the 1992 estimate of 1,850 breeding pairs in 13 colonies (Carter et al. 1995) so there is no reason to believe that substantially higher abundance in double-crested cormorant populations has contributed significantly to OC coho salmon population declines in recent years.

Because of the increasing abundance and visibility of marine mammal predators since the passage of the Marine Mammals Protection Act, there is a perception among users of the estuarine and marine environment that reducing predation by harbor seals (*Phoca vitulina)* and California sea lions (*Zalophus californianus)* is important for the restoration of OC coho salmon

[28] Roy Lowe, USFWS. Oregon Coastal Refuges Newport, Oregon 97365. Pers comm. September 2010.

(Smith et al. 1997). Botkin et al. (1995) concluded that marine mammal predation on anadromous fish stocks in Northern California and southern Oregon was only a minor factor for their decline. NMFS (1997d) also examined the issue and determined that marine mammal predation in some northwest fisheries have increased on the Pacific Coast. This predation may significantly affect salmonid abundance in some local populations when other prey are absent and physical habitat conditions lead to the concentration of adults and juveniles in restricted areas or stocks. The IMST (1998) concluded "that the California sea lion, Pacific harbor seal, Caspian tern and cormorant populations along the Oregon coast have all increased in recent years, coinciding with historic lows in salmon abundance. Predation by these species may be a factor in the lack of recoveries of some depressed stocks but there is no compelling scientific evidence that predation has been a primary cause for decline of salmonids." In the 2005 Oregon State Coho Assessment, ODFW (ODFW 2005h) reports that there is little new evidence that allows analysis beyond the summary statements made by NMFS (1997d) and the IMST (1998). The result of future investigations is "not likely to change the general conclusion that, while negative effects can occur in specific situations where other prey is in unusually low abundance, local predator numbers are high and restrictions in passage or reduction in habitat quality have all increased predation success, natural predation by pinnipeds or seabirds has not been a significant cause in the decline of salmonid stocks at the ESU scale."

A recent study by Brown et al. (2005) reports that though the abundance of harbor seals has increased since the passage of the MMPA, the Oregon/Washington harbor seal population grew rapidly until the 1990's but appears to be stable around an equilibrium with variability due to ocean conditions. Whether or not the harbor seal population in growing, Schreck et al. (2002) (Nehalem River) and Johnson et al. (2010) (Alsea River) implicate harbor seals as well as birds in significant (29%-66%) loss of juvenile steelhead. Avian and mammalian predation may not have been a significant factor for decline when compared with other factors, but this more recent work shows that it may be important to recovery actions in certain populations and specific situations within the OC coho salmon ESU.

**Non-indigenous fish-** In contrast to mammalian and avian predators, OC coho salmon have not evolved with Non-indigenous Fish (NIS) fish species. Fish predation can be a significant source of mortality of coho salmon juveniles particularly in lake and slow water systems. Largemouth bass and smallmouth bass are a particularly efficient predators of juvenile coho salmon[29] (Bonar et al. 2004

Lake rearing coho salmon represents life history diversity that is essential to the resilience of OC coho salmon (Lawson et al. 2007). While river populations exhibited wild swings in abundance during the low return years of the 1990's, the lakes produced consistent returns during that time period. However, the change in productivity of the Tenmile lakes system in the 1970s shows the effect of NIS fish on OC coho salmon. High abundance was observed from 1955 to 1973 when adult spawners ranged from about 5,700 to 42,000 adults. The Tenmile Lakes escapement from 1974 to 1999 after introduction of NIS warmwater fishes and treatment with rotenone to rid the lake of them fell to adult an average of only 3,453 (777 to 7,581) (Zhou 2000). Current returns in the Tenmile Lakes system remain substantially lower than returns prior to the introduction of the NIS fish. For Siltcoos and Tahkenitch Lakes, which had introductions

[29] Lance Kruzic, NMFS Habitat Conservation Division, Roseburg, OR. Pers. comm. December 2009.

of these warm water game fish in the 1930's it is impossible to discern changes due to lack of data. The effects of these NIS fish are not consistent across the landscape of the OC Coho Salmon ESU; the North coast and Mid- coast monitoring areas have some introduced fish species, but they do not have much in the way of lakes and slow water like the Lakes, Umpqua and Mid-South coast strata. Also, higher summer temperatures in these more southerly systems favor NIS fish. (ODFW 2005g). This effect is expected to increase with rising temperatures in the lakes and slow water areas of the Oregon coast.

EPA (USEPA 2009) commented that NIS fish are capable of ecosystem changing effects as well of those of predation. NIS warmwater fishes pose a future threat to coho rearing due ecosystem change as well as predation if anticipated temperature rise associated with global climate change occurs. Peer reviewer #2 commented that predation and competition, particularly in light of the warming water temperatures from global climate change, could significantly affect the lakes and slow-water rearing life history of OC coho salmon, not only by NIS fish but by "native" invasions as well (Reeves et al. 1998). As water temperatures increase, NIS warm water and other native fish will be at an even greater advantage over OC coho salmon in lake and slow water situations due to predation, competition and ecosystem alterations.

For this analysis on the current status of the effect of predation, effects of current populations of NIS warmwater fish are probably reflected in OC coho salmon current biological status of these populations. However, in anticipating future conditions, as water temperatures increase, there is greater risk to OC coho salmon in lake and slow water situations due to predation, competition and ecosystem alterations. This effect on the slow water and lake life histories of OC coho salmon may present a significant threat to diversity of the species.

## Factors for Decline and Threats Summary

As was described above, the BRT analysis started with the list of major threats previously identified by the NWR and revised the list to include discussion of emerging issues such as global climate change. Some threats, in particular hatchery production and harvest, have been greatly reduced over the last decade and appear to have been largely eliminated as significant sources of risk. Other factors, such as habitat degradation and water quality, were evaluated to be ongoing threats that appear to have changed little over the last decade. Changes to freshwater and marine habitat due to global climate change were considered to be threats likely to become manifest in the future. A summary of the threats considered by the BRT is found in Table 25.

# Overall Risk Assessments

The BRT's determination of overall risk to the OC Coho Salmon ESU used the categories of at "high risk" of extinction; at "moderate risk" of extinction; or "neither at high risk or moderate risk" of extinction. The high and moderate risk levels were defined by the NMFS Northwest Regional Office in their status review request as follows:

> Moderate risk: a species or ESU is at moderate risk of extinction if it exhibits a trajectory indicating that it is more likely than not to be at a high level of extinction risk. A species/DPS may be at moderate risk of extinction due to projected threats and or declining trends in abundance, productivity, spatial structure or diversity. The appropriate time horizon for evaluating whether a species or DPS is more likely than not to be at high risk depends on the various case- and species-specific factors. For example, the time horizon may reflect certain life-history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect the timeframe or rate over which identified threats are likely to impact the biological status of the species or DPS (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence.
>
> High Risk: a species or ESU with a high risk of extinction it is at or near a level of abundance, productivity, and or spatial structure that place its persistence in question. The demographics of a species/DPS at such a high level of risk may be highly uncertain and strongly influenced by stochastic and/or depensatory processes. Similarly, a species/DPS may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification or curtailment of its habitat, or disease epidemic) that are likely to create such imminent demographic risks.

Quantitative and qualitative conservation assessments for other species have often used a 100-year time frame in their extinction risk evaluations (Morris et al. 1999, McElhany et al. 2000) and the BRT adopted this time scale as the period over which it had confidence in evaluating risk. In particular, the BRT interpreted the high risk category as a greater than ~5% risk of extinction within ~100 years, and the moderate risk category as a greater than 50% risk of moving into the high risk category within 30 – 80 years. Beyond the 30 to 80 year time horizon, the projected effects on OC coho salmon viability from climate change, ocean conditions, and trends in freshwater habitat become very difficult to predict with any certainty. The overall extinction risk determination reflected informed professional judgment by each BRT member, based on both the quantitative and qualitative information reviewed in this report. This assessment was guided by the results of the risk matrix analysis (see below), supplemented by results from the decision support system (Table 7), and integrating information about demographic risks with expectations about likely interactions with threats and other factors.

## Risk Matrix Approach

In previous NMFS status reviews, BRTs have used a "risk matrix" as a method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainwright and Kope (1999) and has been used for over 10 years in Pacific salmonid status reviews (e.g., Good et al. 2005, Hard et al. 2007), as well as in reviews of Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), Puget Sound rockfishes (Stout et al. 2001a; Drake et al. 2010), Pacific herring (Stout et al. 2001b; Gustafson et al. 2006), eulachon (Gustafson et al. 2010) and black abalone (VanBlaricom et al. 2009). In this risk matrix approach, the collective condition of individual populations is summarized at the ESU level according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity (Table 26). These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well founded in conservation biology and are generally applicable to a wide variety of species. The criteria describe demographic risks that individually and collectively provide strong indicators of extinction risk. The summary of demographic risks and other pertinent information obtained by this approach is then considered by the BRT in determining the species' overall level of extinction risk.

After reviewing all relevant biological information for the species, including the threats currently impacting the ESU or reasonably certain to impact the ESU in the future, each BRT member assigned a risk score (Table 26) to each of the four demographic criteria. The scores were tallied (means, modes, and range of scores), reviewed, and the range of perspectives discussed by the BRT before making its overall risk determination. Although this process helped to integrate and summarize a large amount of diverse information, there was no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. For example, an ESU with a single extant population might be at a high level of extinction risk because of high risk to spatial structure/connectivity, even if it exhibited low risk for the other demographic criteria. Another species might be at risk of extinction because of moderate risks to several criteria.

To allow individuals to express uncertainty in determining the overall level of extinction risk facing the species, the BRT adopted the "likelihood point" method, often referred to as the "FEMAT" method because it is a variation of a method used by scientific teams evaluating options under the Northwest Forest Plan (FEMAT 1993). In this approach, each BRT member distributes ten likelihood points among the three extinction risk categories, reflecting their opinion of how likely that category correctly reflects the true species status (Table 27). Thus, if a member were certain that the species was in the "not at risk" category, he or she could assign all ten points to that category. A reviewer with less certainty about the species' status could split the points among two or even three categories. This method has been used in all status reviews for anadromous Pacific salmonids since 1999, as well as in reviews of Puget Sound rockfishes (Stout et al. 2001b, Drake et al. 2010), Pacific herring (Stout et al. 2001a; Gustafson et al. 2006), Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), eulachon (Gustafson et al. 2010) and black abalone (VanBlaricom et al. 2009.)

In its May 2010 draft report, the BRT conducted both the risk assessment matrix analysis and the overall extinction risk assessment under two different sets of assumptions. First, the BRT evaluated extinction risk based on the demographic risk criteria (abundance, growth rate, spatial structure and diversity) recently exhibited by the ESU, assuming that the threats influencing ESU status would continue unchanged into the future. This case in effect assumed that all of the threats evaluated in the previous section of the report were already fully manifest in the current ESU status and would in aggregate neither worsen nor improve in the future. In the 2010 draft report, the BRT also evaluated extinction risk based on the demographic risk criteria currently exhibited by the ESU, taking into account consideration of predicted changes to threats that the BRT evaluated to be not yet manifest in the current demographic status of the ESU. In effect, this scenario asked the BRT to evaluate whether threats to the ESU would lessen, worsen, or remain constant compared to current conditions.

In the time since the completion of the last risk assessment in 2010, the BRT considered additional information on the potential magnitude and trajectory of threats including climate change, changes in ocean conditions, and trends in freshwater habitat. The BRT also further refined the time horizon used to evaluate whether the OC Coho Salmon ESU was at moderate risk of extinction. Considering this new information, the BRT felt it unnecessary and potentially confusing to conduct the risk assessment under multiple sets of assumptions. For the final risk assessment reported here, therefore, each BRT member evaluated all the available information on both current demographic status and threats to come to a single overall conclusion on the degree of extinction risk.

## Summary of Risk Conclusions

The mean risk matrix scores for each demographic risk factor fell between the low risk (2) and moderate risk (3) categories (Table 28), indicating that the BRT as a whole did not consider any of the demographic risk factors as likely to contribute substantially to a high risk of short-term extinction when considered on its own. The overall assessment of extinction risk of the OC coho salmon ESU indicated considerable uncertainty about its status, with most likelihood points split between “moderate risk” and “not at risk”, and a small minority of points indicating “high risk” (Table 29).

The large range in the demographic risk scores (Table 28) and the lack of a strong mode in the overall assessment of risk (Table 29) were indicative of considerable uncertainty both within and among BRT members about the current level of risk facing the ESU. This uncertainty was largely due to the difficulty in balancing the clear improvements in some aspects of the ESU’s status over the last ~15 years against persistent threats driving the longer term status of the ESU, which probably have not changed over the same time frame and are predicted to degrade in the future. Both of these issues are discussed in more detail below. In addition, the BRT noted that accurately predicting the long-term trend of a complex system is inherently difficult, and this also led to some uncertainty in the overall risk assessment.

The BRT concluded that some aspects of the ESU's status have clearly improved since the initial status review in the mid-1990's (Weitkamp et al. 1995). In particular, the BRT assigned a relatively low mean risk score to the abundance factor, noting that spawning escapements were higher in some recent years than they had been since 1970 (Figure 5). Recent total returns (pre-harvest recruits) were also substantially higher than the low extremes of the 1990s, but still mostly below levels of the 1960s and 1970s (Figure 5). The BRT attributed the increased spawner escapements largely to a combination of greatly reduced harvest rates, reduced hatchery production, and improved ocean conditions (see New data and updated analysis section). Even with the recent increases, however, abundance remains at ~10% of estimated historical abundance (~150,000 current compared to ~1.5M historical – see discussion in the Current Biological Status' section). The BRT also noted that compared to the mid-1990's, the ESU contained relatively abundant wild populations throughout its range, leading to a relatively low risk associated with spatial structure (Table 28). The BRT also discussed the observation that the recent natural origin spawning abundance of the OC coho salmon ESU was higher than that observed for other listed salmon ESUs, although some members noted that the 15-fold variability in abundance since the mid-1990s brings into question how heavily to weigh abundance as an indicator of status. Finally, the BRT noted that hundreds of individual habitat improvement projects over the last ~15 years had likely benefited the ESU, although quantifying these benefits is difficult.

The BRT also discussed some ongoing positive changes that are likely to become manifest in abundance trends for the ESU in the future. In particular, hatchery production continues to be reduced with the cessation of releases in the North Umpqua River and Salmon River populations, and the BRT expects that the near-term ecological benefits from these reductions would result in improved natural production for these populations in future. In addition, the BRT expected that reductions in hatchery releases that have occurred over the past decade may continue to produce some positive effects on the survival of the ESU in the future, due to the time it may take for past genetic impacts to become attenuated.

Despite these positive factors, the BRT also had considerable concerns about the long-term viability of the ESU. The BRT continued to be concerned that there had been a long-term decline in the productivity of the ESU from the 1930's through the 1990's (Figure 5). Despite some improvements in productivity in the early 2000's, the BRT was concerned that the overall productivity of the ESU remains low compared to what was observed as recently as the 1960's and 1970's (Figs. 5 and 6). The BRT was also concerned that the majority of the improvement in productivity in the early 2000's was likely due to improved ocean conditions, with a relatively smaller component due to reduced hatchery production (Buhle et al. 2009).

The BRT noted that the legacy of past forest management practices combined with lowland agriculture and urban development has resulted in a situation in which the areas of highest habitat capacity (intrinsic potential) are now severely degraded (see Land Use Management – Stream Complexity). The BRT also noted that the combined ODFW/NMFS analysis of freshwater habitat trends for the Oregon coast found little evidence for an overall improving trend in freshwater habitat conditions since the mid-1990s, and evidence of negative trends in some strata (Appendix C). The BRT was also concerned that recent changes in the protection status of beaver, which through their dam building activities create coho habitat, could result in further negative trends in habitat quality. The BRT was therefore concerned that when ocean conditions cycle back to a period of poor survival for coho salmon, the ESU may rapidly decline to the low abundance seen in the mid-1990’s. Some members of the BRT observed that the reduction in risks from hatchery and harvest are expected to help buffer the ESU when marine survival returns to a lower level, likely resulting in improved status compared to the situation in the mid-1990’s. Others noted that potential declines in beaver, observed negative trends in some habitat features, and the potential for more severe declines in marine productivity could result in even lower abundance levels than during the last period of poor ocean conditions. On balance, the BRT was, as a whole, uncertain about whether the long-term downward trajectory of the ESU's status has been arrested and uncertain about the ESU’s ability to survive another prolonged period of low ocean survivals.

Finally, the BRT was also concerned that global climate change will lead to a long-term downward trend in both freshwater and marine coho salmon habitat compared to current conditions (see Climate section and Wainwright and Weitkamp, in prep.). There was considerable uncertainty about the magnitude of most of the specific effects climate change will have on salmon habitat, but the BRT was concerned that most changes associated with climate change are expected to result in poorer and more variable habitat conditions for OC coho salmon than exist currently (Table 14). Some members of the BRT noted that changes in freshwater flow patterns as a result of climate change may not be as severe in the Oregon coast as in other parts of the Pacific Northwest, while others were concerned by recent observations of extremely poor marine survival rates for several West Coast salmon populations. The distribution of overall risk scores reflects some of this uncertainty.

## Significant Portion of its Range Question

The BRT concluded that, when future conditions are taken into account, the Oregon Coast Coho Salmon ESU as a whole is at moderate risk of extinction. The BRT therefore did not explicitly address whether the ESU was at risk in only a significant portion of its range.

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# Glossary

**Abundance.** The number of fish in a *population*.

**Artificial propagation.** *Hatchery* spawning and rearing of salmon, usually to the *smolt* stage.

**AUC (Area Under the Curve).** A statistical technique for estimating an annual total number of *spawners* from periodic spawner counts.

**Barrier.** A blockage such as a waterfall, culvert, or rapid that impedes the movement of fish in a stream system.

**Biological Review Team (BRT).** The team of scientists who evaluate scientific information for the National Marine Fisheries Service (NMFS) status reviews.

**Bootstrap support.** A measure of the confidence in a particular branch in a genetic tree. Specifically a large number of trees are created using randomly drawn sets of loci sampled from the data with replacement. The bootstrap value for a node is the proportion of the trees that have that all the samples contained on that node.

**Catastrophic events.** Sudden events that disastrously alter large areas of landscape. These can include floods, landslides, forest fires, and volcanic eruptions.

**Channel gradient.** The slope of a stream reach.

**CLAMS (Coastal Landscape Analysis and Modeling Study).** A cooperative project between the Oregon State University Department of Forestry and the U.S. Forest Service Pacific Northwest Forest Science Laboratory.

**Coded-wire tag (CWT).** A small piece (0.25 × 0.5 or 1.0 mm) of stainless steel wire that is injected into the snouts of juvenile salmon and steelhead. Each tag is etched with a binary code that identifies its release group.

**Comanagers.** Federal, state, and tribal agencies that cooperatively manage salmon in the Pacific Northwest.

**Critical Habitat.** (1) specific areas within the geographical area occupied by the species at the time of listing, on which are found those physical or biological features that are essential to the conservation of the listed species and that may require special management considerations or protection, and (2) specific areas outside the geographical area occupied by the species at the time of listing that are essential for the conservation of a listed species… If a species is listed or critical habitat is designated, ESA section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of such a species or to destroy or adversely modify its critical habitat (NMFS 2008)."

**Delisting.** Taking a species off of the endangered species list.

**Demographic risk.** Risks to a small population resulting from population processes such as depensation or chance events in survival or reproductive success.

**Density effects.** Survival of juvenile salmon may be influenced by their density. Survival is usually higher when density is low.

**Dependent populations.** Populations that rely upon immigration from surrounding populations to persist. Without these inputs, dependent populations would have a lower likelihood of *persisting* over 100 years.

**Depensation.** The effect where a decrease in spawning stock leads to reduced survival or production of eggs through either 1) increased predation per egg given constant predator pressure, or 2) the "Allee effect" (the positive relationship between population density and the reproduction and survival of individuals) with reduced likelihood of finding a mate.

**Distinct population segment (DPS).** A *population*, or group of populations of a vertebrate species that is "discrete" from other populations and *significant* to the biological species as a whole.

**DNA (deoxyribonucleic acid).** A complex molecule that carries an organism's heritable information. The two types of DNA commonly used to examine genetic variation are *mitochondrial DNA* (mtDNA), a circular molecule that is maternally inherited, and *nuclear DNA*, which is organized into a set of chromosomes (see also *allele* and *electrophoresis*).

**Ecoregion.** An integration of physical and biological factors such as geologic history, climate, and vegetation.

**Electrophoresis.** The movement of charged particles in an electric field. This process has been developed as an analytical tool to detect genetic variation revealed by charge differences on proteins or molecular weight in DNA.

**Endangered species.** A species in danger of extinction throughout all or a significant portion of its range.

**ESA.** U.S. Endangered Species Act.

**Escapement.** Usually refers to adult fish that "escape" from both fisheries and natural *mortality* to reach the spawning grounds.

**Estuarine habitat.** Areas available for feeding, rearing, and smolting in tidally influenced lower reaches of rivers. These include marshes, sloughs and other backwater areas, tidal swamps, and tide channels.

**Evolutionarily Significant Unit (ESU).** An ESU represents a *distinct population segment* of Pacific salmon under the *Endangered Species Act* that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component of the evolutionary legacy of the species. See also *Distinct population segment*.

**Exploitation rate.** The proportion of adult fish from a *population* that die as a result of fisheries.

**Extinction.** The loss of a species or ESU. May also be used for the extirpation of local populations.

**Factors for decline.** These are factors identified that caused a species to decrease in *abundance* and *distribution* and become threatened or endangered.

**Fecundity.** The number of offspring produced per female.

**FEMAT.** Forest Ecosystem Management Assessment Team.

**Fish-day.** Fish-days were calculated by multiplying the live fish observed on each survey date by the number of days between surveys. These values were then summed for the entire observation period to generate a relative index of spawner abundance at a reach for any given year (Pess et al. 2002b).

**Fourth-field and fifth-field hydrologic units.** In the United States Geological Survey (USGS), hydrologic units have been divided at different scales. The area of a fourth-field hydrologic unit is 440,000 acres and a fifth-field hydrologic unit is between 40,000 and 250,000 acres.

**Freshwater habitat.** Areas available for spawning, feeding, and rearing in freshwater.

**Fry.** Young salmon that have emerged from the gravel and no longer have an egg sack.

**Functionally independent population.** A high-*persistence population* whose dynamics or extinction risk over a 100-year time frame is not substantially altered by exchanges of individuals with other populations (*migration*). Functionally independent populations are net "donor" populations that may provide *migrants* for other types of populations. This category is analogous to the "independent populations" of McElhany et al. (2000).

**Fuzzy Logic.** " A system of logic in which a statement can be true, false, or any of a continuum of values (Merriam-Webster 2010).

**Gene Conservation Groups.** Management areas defined by Kostow (1995) to conserve genetic diversity in Oregon Coast coho salmon. Shown in Figure 28 in Lawson et al. (2007).

**Gradient.** The slope of a stream system.

**Habitat quality.** The suitability of physical and biological features of an aquatic system to support salmon in the freshwater and estuarine system.

**Hatchery.** A facility where *artificial propagation* of fish takes place.

**Historical abundance.** The number of fish that were produced before the influence of European settlement.

**Hydrology.** The distribution and flow of water in an aquatic system.

**Independent Multidisciplinary Science Team (IMST).** A scientific advisory body to the Oregon legislature and governor on watershed, forestry, agriculture, and fisheries science issues.

**Independence**. Reflects the interaction between *isolation* and *persistence*. A persistent population that is highly isolated is highly independent.

**Integrated hatchery.** Integrated Hatchery means in this case for Cow Creek hatchery program that wild coho are regularly taken into the hatchery program's broodstock.  Typically greater than 10% of the broodstock annually is of wild fish origin.  In some years, 100% of the broodstock is wild fish.

**Intensity (of infection).** Intensity (of infection) is the number of individuals of a particular parasite species in a single infected host.

**Intrinsic potential.** A modeled attribute of streams that includes the channel gradient, valley constraint, and mean annual discharge of water. Intrinsic potential in this report refers to a measure of potential coho salmon habitat quality (Burnett et al. 2003).

**Isolation.** The degree to which a population is unaffected by migration to and from other populations. As the influence of migration decreases, a population's isolation increases.

**Jack.** A male coho salmon that matures at age 2 and returns from the ocean to spawn a year earlier than normal.

**Juvenile.** A fish that has not matured sexually.

**Keystone species.** A keystone species is a species that plays a pivotal role in establishing and maintaining the structure of an ecological community. The impact of a keystone species on the ecological community is more important than would be expected based on its biomass or relative abundance.

**Life history.** The specific life cycle of a fish from egg to adult. Life history includes changes experienced from birth through death and includes variation in traits such as the size and age at maturity, and fecundity.  Traits such as juvenile growth rate and age at ocean emigration are aspects of coho salmon life history.

**Limiting factors.** Factors that limit survival or *abundance*. They are usually related to habitat quantity or quality at different stages of the life cycle. Harvest and predation may also be limiting factors.

**Listed species.** Species included on the "List of Endangered and Threatened Species" authorized under the Endangered Species Act and maintained by the U.S. Fish and Wildlife Service and NOAA Fisheries Service.

**Lowland habitat.** Low-gradient stream habitat with slow currents, pools, and backwaters used by fish. This habitat is often converted to agricultural or urban use.

**Marine survival rate.** The proportion of smolts entering the ocean that return as adults.

**Metacercaria.** Tiny cases that contain the intermediate stages of parasites.

**Metric.** A unit of measure.

**Microsatellite.** A class of repetitive DNA used for estimating genetic distances.

**Migrant.** A fish that is born in one population but returns to another population to spawn.

**Migration.** Movement of fish from one population to another.

**Migration rate.** The proportion of spawners that migrate from one population to another. See also Effective migration rate.

**Monitoring Areas.** Map found in Figure in Figure 29, Lawson et al. 2007, also at http://nrimp.dfw.state.or.us/crl/default.aspx?pn=AIProjOrPlnSalWtrshd.

**Natural Return Ratio.** The ratio N/T, where N is naturally produced spawners in one generation and T is total (hatchery produced + naturally produced) spawners in the previous generation.

**NMFS.** National Marine Fisheries Service, also known as NOAA Fisheries Service.

**NOAA.** National Oceanic and Atmospheric Administration.

**NOAA Fisheries Service.** NOAA's National Marine Fisheries Service, also known as NMFS.

**NWFSC.** NMFS Northwest Fisheries Science Center.

**NWR.** NMFS Northwest Regional Office.

**OC coho salmon.** Oregon Coast Coho Salmon.

**OCN.** Naturally produced Oregon Coast coho salmon. Often used by ODFW to distinguish from hatchery-raised fish and includes fish from the SONCC ESU in Oregon.

**ODFW.** Oregon Department of Fish and Wildlife.

**ONCC TRT.** Oregon and Northern California Coast Technical Recovery Team.

**OPI.** Oregon Production Index.

**OWEB.** Oregon Watershed Enhancement Board.

**PDO.** Pacific Decadal Oscillation.

**PVA.** Population Viability Analysis.

**Parr.** The life stage of salmonids that occurs after *fry* and is generally recognizable by dark vertical bars (parr marks) on the sides of the fish.

**Population.** A group of fish of the same species that spawns in a particular locality at a particular season and does not interbreed substantially with fish from any other group.

**Population classification.** The grouping of *populations* into *functionally independent*, *potentially independent*, and *dependent* classes.

**Population dynamics.** Changes in the number, age, and sex of individuals in a *population* over time, and the factors that influence those changes. Five components of populations that are the basis of population dynamics are birth, death, sex ratio, age structure, and dispersal.

**Population identification.** Delineating the boundaries of *historical populations*.

**Population structure.** This includes measures of age, density, and growth of fish populations.

**Potentially independent populations.** *High-persistence populations* whose *population dynamics* are substantially influenced by periodic immigration from other populations. In the event of the decline or disappearance of *migrants* from other populations, a potentially independent population could become a *functionally independent* population.

**Prevalences.** Prevalence is the number of hosts infected with 1 or more individuals of a particular parasite species (or taxonomic group) divided by the number of hosts examined for that parasite species.

**Production.** The number of fish produced by a *population* in a year.

**Productivity.** The rate at which a *population* is able to produce fish.

**RIST.** Recovery Implementation Science Team.

**Recovery.** The reestablishment of a threatened or endangered species to a self-sustaining level in its natural ecosystem (in other words, to the point where the protective measures of the ESA are no longer necessary).

**Recovery domain.** The area and species that the TRT is responsible for.

**Recovery plan.** A document identifying actions needed to make *populations* of naturally produced fish comprising the Oregon Coast Coho Salmon *ESU* sufficiently *abundant*, *productive*, and diverse so that the ESU as a whole will be self-sustaining and will provide environmental, cultural, and economic benefits. A recovery plan will also include goals and criteria by which to measure the ESU's achievement of recovery, and an estimate of the time and cost required to carry out the actions needed to achieve the plan's goals.

**Recovery scenarios.** Various sequences of events expected to lead to *recovery* of Oregon Coast coho salmon.

**Run timing.** The time of year (usually identified by week) when spawning salmon return to the spawning beds.

**SONCC ESU.** Southern Oregon Northern California Coast Evolutionarily Significant Unit.

**Salmonids.** Any of the species included in salmon, trout, and char.

**Significant.** Biological significance refers to an effect that has a noteworthy impact on health or survival.

**Smolt.** A life stage of salmon that occurs just before the fish leaves freshwater. Smolting is the physiological process that allows salmon to make the transition from freshwater to salt water.

**Smolt capacity.** The maximum number of smolts a basin can produce. Smolt capacity is related to habitat quantity and quality.

**Spawners.** Adult fish on the spawning grounds.

**Species.** Biological definition: A small group of organisms formally recognized by the scientific community as distinct from other groups. Legal definition. Refers to joint policy of the USFWS and NMFS that considers a species as defined by the ESA to include biological species, subspecies, and *DPSs*.

**Stray rate.** As used in this document, the stray rate refers to the number of spawning adults that return to a stream other than their natal stream within a basin. See also *Migration rate*.

**Sustainability.** An attribute of a population that persists over a long period of time and is able to maintain its genetic legacy and long-term adaptive potential for the foreseeable future.

**Threatened species.** A species not presently in danger of extinction but likely to become so in the foreseeable future.

**TRT.** Technical Recovery Team.

**USFS.** United States Forest Service.

**USFWS.** U.S. Fish and Wildlife Service.

**USGS.** United States Geologic Survey.

**VSP.** Viable Salmonid Population.

**Valley constraint.** The valley width available for a stream or river to move between valley slopes.

**Viability.** The likelihood that a *population* will sustain itself over a 100-year time frame.

**Viability criteria.** A prescription of a *population* conservation program that will lead to the *ESU* having a negligible risk of extinction over a 100-year time frame.

**Warm-water fish.** Spiny-rayed fish such as sculpins, minnows, darters, bass, walleye, crappie, and bluegill that generally tolerate or thrive in warm water.