

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

Draft Report from the Biological Review Team

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Executive Summary

During 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 draft report summarizes 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 (OC coho salmon) as threatened under the ESA (NMFS 1998). From 2000 until 2008, there was considerable litigation surrounding 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 2009).

In the past, Biological Review Teams (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 (Good et al. 2005) 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 subsequent 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). The TRT's biological recovery criteria are intended to be used as a framework for approaching formal ESA recovery planning for OC coho salmon rather than for making listing decisions. However, by utilizing the decision support system developed as part of the biological recovery criteria, the BRT was able to assess VSP attribute information at the population, stratum and ESU scales. This helped to inform the BRT in their assessment of risk related to the VSP attributes.

The BRT conclusion for the OC Coho Salmon ESU reflected ongoing concerns for the long-term health of this ESU. The assessment of overall extinction risk for the OC Coho Salmon ESU also differed substantially depending on whether specific threats were considered or not. When the BRT considered the status of the ESU based only on recent conditions as reflected in the present biological condition of the populations, the BRT was uncertain about the status of the ESU. In particular, the BRT opinion was about evenly split between "low risk" and "moderate to high risk," with a slight majority of BRT opinion considering the ESU at "moderate to high risk" under the current conditions. The BRT's evaluation of risk under this scenario largely reflects the results of an updated viability assessment that indicated little overall change from conditions evaluated in the 2003 status review, which the BRT interpreted as indicating considerable uncertainty about ESU status under current conditions. However, when the BRT evaluated risk taking into account continuing and future threats not reflected in current biological status, the assessment became more pessimistic. Under this scenario, the BRT concluded that

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

the ESU was most likely to be at “moderate risk”, with the remainder of opinion split about evenly between “high risk and “low risk.” The shift in the opinion toward the moderate and high risk categories reflects the BRTs conclusions that on balance the threats facing Oregon Coast coho salmon are likely to grow more severe in the future. Although the BRT considered the significantly higher spawner returns in recent years to be encouraging, most members felt that the increases more likely reflect short- term favorable marine productivity conditions than long term improvement in freshwater productivity. While some previously identified threats such as those from over-harvest and hatchery practices have been greatly reduced, others continue as sources of significant risk to the ESU. The main threats of concern to the BRT were continued declines in freshwater habitat conditions, and effects of expected climate change on freshwater, estuarine and marine habitats. The BRT was particularly concerned that the long-term decline in productivity reflects deteriorating conditions in freshwater habitat.

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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 (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 ESU (Bryant 1994, NMFS 1994).

Oregon Coast coho salmon were first petitioned for listing in 1993 (NMFS 1993). 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, 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 2005).

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 2006).

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 2009). This BRT met in September and December of 2009. This

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

report summarizes new information and the preliminary BRT conclusions on the OC Coho Salmon ESU.

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. Oregon coast 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.

Artificial Propagation –Inclusion of Hatchery Stocks in the ESU

Good et al. (2005; p. 5-7, Fig. 1) provided the background information to the determination of ESU membership as a major focus of the 2003 West Coast Salmon Status Review. This review was intended to determine what hatchery stocks would be included in the salmon ESUs. After the 2003 BRT deliberations, NMFS (2004a) proposed that five artificial propagation programs should be considered part of the OC Coho Salmon ESU. The proposed coho salmon hatchery stocks were the North Fork Nehalem River (ODFW stock # 32), the North Umpqua River (ODFW stock # 55), Cow Creek (South Umpqua) (ODFW stock # 18), Coos Basin (ODFW stock # 37), and the Coquille River/Bandon Hatchery(ODFW stock # 44) programs. Hatchery stocks from the Trask, Salmon and Siletz were excluded from consideration for inclusion in the ESU in 2004 (NMFS 2004a). In 2008 NMFS published the final rule listing the OC Coho Salmon ESU as threatened, and based on comments from ODFW, limited the hatchery stock in the ESU to Cow Creek (ODFW stock #18) (NMFS 2008).

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.

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.

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.

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 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 relatively flat. 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 OCN⁴ dependent on marine survival and parental and grandparental spawning escapements. After review, exploitation rates under the Amendment ranged 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 Index⁵ 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 between 1998 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 between 1994 and 2003. 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 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.

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

⁵ OPI is Oregon Production Index.

Between 1991 and 2003 some Oregon coastal hatchery facilities were closed and, reduction in numbers of smolts released from the remaining facilities, 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.

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 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. 2007, 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.⁶ 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.

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.

⁶ Carlos Garza, SWFSC, 110 Shaffer Rd. Santa Cruz, CA., pers comm. November, 2009.

Artificial Propagation - Membership in the ESU

In 2004, NMFS (2004a, b) proposed the inclusion of five hatchery stocks (Cow Cr., Rock Cr. (N. Umpqua), Coos, Coquille and N. Fork Nehalem) in the OC Coho Salmon ESU. After review and comment was considered, it was decided that the N. Fork Nehalem River and Fishhawk Lake stocks were substantially reproductively isolated. However, those two programs were discontinued, with the last adults returning in 2007 (NMFS 2008). Calapooya Creek coho hatchery stock was not included in the 2004 (NMFS 2004 b) hatchery reviews as the program was a limited duration research program to evaluate the genetics of hatchery fish, was no longer collecting fish for brood stock or releasing smolts at the time and 2006 was the last year of returns. 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), and the Coquille River (ODFW stock #44) hatchery coho programs were considered part of the OC Coho Salmon ESU. All of the other hatchery stocks in propagation were determined to not be part of the ESU (NMFS 2008). 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. Because the North Umpqua River, Coos Basin, and Coquille River hatchery programs have been terminated, and 2007 was the last year of returns, these stocks were not considered part of the OC Coho Salmon ESU. As of 2009, only three coho hatchery stocks are in propagation within the OC Coho Salmon ESU. These are the North Fork Nehalem, Trask (Tillamook basin) and Cow Creek (South Umpqua) (NMFS 2009b).

The North Fork Nehalem coho stocks (stocks #32 and #99) are managed as an isolated harvest program. Natural-origin fish have not been intentionally incorporated into the brood stock since 1986 and only adipose fin clipped brood stock have been taken since late 1990's. Because of this, the stock is considered to have substantial divergence from the native natural population and is not included in the OC Coho Salmon ESU.

The Trask (Tillamook population) coho stock (stock #34) is also managed as an isolated harvest program. Natural-origin fish have not been incorporated into the brood stock since 1996 when all returns were mass marked. Therefore the stock is considered to have substantial divergence from the native natural population and is not included in the OC Coho Salmon ESU.

The Cow Creek stock (South Umpqua Population) (stock #18) is managed as an integrated hatchery program and is included as part of the ESU because the original brood stock was founded from the local wild population and wild coho salmon have been incorporated into the brood stock on a regular basis. This brood stock was founded in 1987 from wild coho salmon returns to the base of Galesville Dam on Cow Creek, a tributary to the South Umpqua River. Subsequently, brood stock has continued to be collected from returns to the dam, with wild coho salmon comprising 25% to 100% of the brood stock nearly every year since returning fish have been externally marked (ODFW 2008a). The Cow Creek stock is probably no more than moderately diverged from the local wild coho salmon population in the South Umpqua River because of these brood stock practices and is therefore considered a part of the OC Coho Salmon ESU.

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 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 1; Fig. 3) Oregon coast drainage basins of intermediate to large size are thought to have each supported a coho salmon population capable of persisting (25% extinction risk) 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 Dependant 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 was observed in the ESU in 1998 when no spawners returned to Cummins Creek.

Table 1. Independent and dependent historical populations (after Lawson et al. 2007).

Population	Population type	Population	Population type
Necanicum	Independent	Alesea	Independent
Ecola	Dependent	Big (near Alesea)	Dependent
Arch Cape	Dependent	Vingie	Dependent
Short Sands	Dependent	Yachats	Dependent
Nehalem	Independent	Cummins	Dependent
Spring	Dependent	Bob	Dependent
Watseco	Dependent	Tenmile Creek	Dependent
Tillamook Bay	Independent	Rock	Dependent
Netarts	Dependent	Big	Dependent
Rover	Dependent	China	Dependent
Sand	Dependent	Cape	Dependent
Nestucca	Independent	Berry	Dependent
Neskowin	Dependent	Sutton (Mercer Lake)	Dependent
Salmon	Independent	Siuslaw	Independent
Devils Lake	Dependent	Siltcoos	Independent
Siletz	Independent	Tahkenitch	Independent
Schoolhouse	Dependent	Threemile	Dependent
Fogarty	Dependent	Lower Umpqua	Independent
Depoe Bay	Dependent	Middle Umpqua	Independent
Rocky	Dependent	North Umpqua	Independent
Spencer	Dependent	South Umpqua	Independent
Wade	Dependent	Tenmile	Independent
Coal	Dependent	Coos	Independent
Moolack	Dependent	Coquille	Independent
Big (near Yaquina)	Dependent	Johnson	Dependent
Yaquina	Independent	Twomile	Dependent
Theil	Dependent	Floras/New	Independent
Beaver	Independent	Sixes	Independent

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

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 on 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 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

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

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.

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 Nickelson Habitat Limiting Factor Lifecycle Model 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 (*Salvelinus 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 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.

New Data and Updated Analyses

Current Biological Status

This section addresses new data and updated analyses for the VSP parameters of abundance, growth rates and productivity, population spatial structure, and population diversity. 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 Abundance

The 2009 BRT received updated estimates of total natural spawner abundance 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 for return years 1969–2008 in Table 2 and 1958-2008 in Fig. 4. Spawner abundance was generally up in the past 3 brood cycles, but 12 year trends were flat with the exception of the Mid-Coast Stratum which showed a positive trend. Present abundance is more evenly distributed within the ESU than it was in 1997 but about the same as 2003.

In the return years 1997–1999 recruits failed to replace the parental spawners: a recruitment failure occurred in all three brood cycles, even before accounting for harvest-related mortalities (Fig. 5). This is the first time this has happened since data collections began in the 1950's. Between 1999 and 2003, improving marine survival and higher rainfall are thought to be the factors contributing to an upswing in recruits. However, in the return years 2005, 2006, and 2007, recruits also failed to replace parental spawners (Fig. 6). This may reflect population dynamics that have not been allowed to occur since 1950, as prior to 1994, harvest had consistently maintained spawner abundance below 100,000 fish. Response of the system to escapements of 200,000 fish is essentially unknown.

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 3), marine survival exceeded 0.03 only in 2001 and 2003. Assuming natural spawners survive at twice the hatchery rate (Wainwright et al. 2008), in 11 out of 18 years since 1990 marine survivals were high enough to sustain the ESU. Increases in recruits and spawners (Fig. 6) reflect improved marine survival after 2000. It is uncertain whether favorable marine conditions will continue 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.

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.

Table 2. Oregon Coastal Natural coho salmon recruits and spawners (Rivers, Lakes, Total) from 1969 to 2008, with approximate ocean exploitation rates. Data are from PFMC2009 spreadsheet T6 version 1 (PFMC 2009).

Year	Spawners (thousands)			Exploitation Rate	Recruits (thousands)		
	Rivers	Lakes	Total		Rivers	Lakes	Total
1969	129.2	10.0	139.2	0.67	391.5	30.2	421.7
1970	51.2	21.5	72.7	0.65	183.1	61.7	244.8
1971	65.6	30.0	95.6	0.83	416.3	171.1	587.4
1972	24.1	10.6	34.7	0.84	185.5	67.5	253.0
1973	37.8	18.1	55.9	0.82	235.0	100.4	335.4
1974	28.1	6.8	34.9	0.84	196.4	41.0	237.4
1975	34.8	6.3	41.1	0.81	208.4	33.8	242.2
1976	39.2	1.7	40.9	0.90	451.7	17.1	468.8
1977	13.7	6.0	19.7	0.89	161.2	53.9	215.1
1978	18.2	1.8	20.0	0.83	111.6	10.3	121.9
1979	38.4	6.6	45.0	0.79	188.8	32.1	220.9
1980	25.6	5.0	30.6	0.73	108.3	18.6	126.9
1981	30.1	3.2	33.3	0.81	174.5	16.9	191.4
1982	68.3	8.3	76.6	0.62	188.4	22.0	210.4
1983	19.4	3.8	23.2	0.79	104.8	19.5	124.3
1984	59.7	16.3	76.0	0.32	95.3	24.1	119.4
1985	66.3	7.9	74.2	0.43	126.2	14.1	140.3
1986	58.2	12.3	70.5	0.34	98.9	18.7	117.6
1987	25.9	4.3	30.2	0.60	71.1	10.9	82.0
1988	51.0	6.2	57.2	0.56	127.3	14.6	141.9
1989	41.6	5.4	47.0	0.55	107.9	12.5	120.4
1990	16.5	4.7	21.2	0.69	60.6	15.3	75.9
1991	29.1	7.7	36.8	0.44	69.4	14.0	83.4
1992	38.6	2.1	40.7	0.51	87.7	4.4	92.1
1993	44.3	10.2	54.5	0.42	81.3	17.7	99.0
1994	37.5	5.9	43.4	0.07	40.3	6.0	46.3
1995	41.3	11.3	52.6	0.12	47.2	14.7	61.9
1996	59.5	13.6	73.1	0.08	64.9	15.9	80.8
1997	14.1	8.7	22.8	0.13	16.1	9.9	26.0
1998	19.8	11.2	31.0	0.08	21.5	12.0	33.5
1999	34.6	12.8	47.4	0.08	37.5	13.9	51.4
2000	54.1	12.8	66.9	0.07	58.4	13.8	72.2
2001	148.0	19.9	167.9	0.07	160.0	21.5	181.5
2002	231.4	22.3	253.7	0.12	264.2	25.2	289.4
2003	206.3	16.3	222.6	0.14	241.3	18.8	260.1
2004	149.2	19.3	168.5	0.15	175.2	21.8	197.0
2005	119.3	14.3	133.6	0.11	134.4	15.7	150.1
2006	87.2	22.7	109.9	0.06	92.8	23.6	116.4
2007	42.3	9.4	51.7	0.11	47.8	10.1	57.9
2008	142.1	23.6	165.7	0.04	146.5	24.6	171.1
2009	215.5	17.4	232.9	0.11	241.6	19.6	261.7

Table 3. OPI hatchery marine survival calculated as adults per smolt from adult recruits and smolts in previous year, 1970 -2008. Smolt data are from PFMC 2009 Table T3. Adult data are from OPITT 2009 Table T6 version 1. 2008 data are preliminary (PFMC 2009).

Year	Smolts (t-1) (millions)	Adults (t) (thousands)	Adults/Smolt
1970	28.8	2765.1	0.096
1971	33.3	3365.0	0.101
1972	35.3	1924.8	0.055
1973	33.6	1816.9	0.054
1974	32.6	3071.1	0.094
1975	34.0	1652.8	0.049
1976	34.2	3885.2	0.114
1977	36.6	987.5	0.027
1978	37.4	1824.2	0.049
1979	35.1	1476.7	0.042
1980	36.4	1223.9	0.034
1981	43.9	1064.5	0.024
1982	35.9	1250.8	0.035
1983	32.2	572.8	0.018
1984	35.9	679.2	0.019
1985	37.0	705.1	0.019
1986	42.6	2383.0	0.056
1987	35.5	876.7	0.025
1988	37.1	1634.6	0.044
1989	38.1	1660.7	0.044
1990	40.0	717.2	0.018
1991	42.1	1898.3	0.045
1992	39.7	538.5	0.014
1993	39.5	260.2	0.007
1994	32.3	201.2	0.006
1995	29.5	144.8	0.005
1996	31.6	185.5	0.006
1997	24.6	199.4	0.008
1998	29.1	211.6	0.007
1999	29.7	334.0	0.011
2000	32.1	668.8	0.021
2001	26.8	1410.7	0.053
2002	25.2	641.9	0.025
2003	24.5	934.1	0.038
2004	23.4	614.4	0.026
2005	22.0	433.4	0.020
2006	21.8	454.0	0.021
2007	22.7	546.2	0.024
2008	22.8	565.3	0.025
2009	22.3	1066.1	0.047

• Preseason estimate.

Growth Rates and Productivity

For the ESU as a whole, the 12 year Natural Return Ratio (NRR) is higher than the long term NRR mean, and an up-and-down trend over the recent 12 years (Fig. 7). 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 populations defined as independent were utilized for reporting OC coho salmon abundance, natural return ratio, recruits per spawner, and marine survival metrics (Table 1; Fig. 3). 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).

Within the OC Coho Salmon ESU, there is substantial genetic and geographic structure, with genetic similarities clustering into a few biogeographic units that were defined in Lawson et al. (2007) (Fig. 3). 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 2009 BRT used these strata as a way to organize their understanding of regional fish performance or threats.

Population Diversity

Loss of functioning estuaries may be an important factor in reducing population diversity in OC coho salmon. The Oregon coastal drainages supporting independent OC coho salmon populations terminate in tidally influenced freshwater 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/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, Healy 1991, 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. Koski (2009) summarized information from more 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.

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 for downstream migrating coho salmon fry. This zone is characterized by low salinity, warm temperatures in the summer, and an abundance of food for juvenile salmonids. In addition to serving as summer rearing habitats, these brackish water transition zones may serve as acclimation areas allowing coho salmon fry to adapt to the higher salinity levels associated with downstream subtidal reaches. Examples of Oregon coastal 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).

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. This interpretation is supported by the recent studies in Salmon River, where restoration of large amounts of wetland habitat has expanded life history variation within the Chinook salmon population, and thereby, may have strengthened population resilience to changing environmental conditions (Bottom et al. 2005).

Other new information on population diversity concerns local extirpations and the effect of hatchery fish on native populations. In the past few years, 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. Since 1990 there have been some years with extremely low escapements in some systems and many small systems have shown local extirpations. For example, Cummins Creek, on the central coast, had zero spawners in 1998, indicating the loss of a brood cycle. These small systems are apt to be repopulated by stray spawners during periods of higher abundance. Recent local extirpations may represent loss of genetic diversity in the context of normal metapopulation function.

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. 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 substantial underestimation (PFMC 2009).

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 0.8% 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 1996) 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 24% for commercial fisheries. In addition, drop-off mortalities were assumed to equal 5% of the number of fish brought to the boat. Based on these mortality rates, the PFMC uses 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 be greater (see 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 (Fig. 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.

Artificial Propagation

As of 2009, there are only three coho hatchery stocks in propagation within the Oregon Coast 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. 8; Oregon 2005e; ODFW 2009a). 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 1990's 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. 9; Table 4). 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 and North Umpqua 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 straying problem in these two populations should show 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 1996, 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 significantly 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.

Table 4. Hatchery influence at coho population, stratum, and ESU scales, 1995-2008. Hatchery influence expressed as percent of total spawning escapement. Tables taken from ODFW 2009a.

ESU / Strata / Population	Return Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008 Prelim.
		EL	EL	EL	EL	EL	L	L	M	L	M	M	L	L	M	EL
Oregon Coast ESU	Total	59,418	71,219	107,160	28,237	40,814	61,730	82,644	186,139	265,122	239,743	183,386	166,211	141,362	72,121	172,008
	Hatchery	12,394	10,448	28,128	4,576	8,139	4,888	8,953	24,321	12,028	12,186	10,633	11,618	12,784	5,650	6,285
	% Hatchery	20.9%	14.7%	24.4%	16.2%	20.0%	9.1%	10.8%	13.1%	4.5%	5.1%	5.8%	7.0%	9.0%	8.1%	3.7%
North Coast Strata	Total	8,239	7,026	9,484	3,451	2,837	8,860	16,704	33,944	50,465	58,768	29,953	16,509	25,824	18,126	28,473
	Hatchery	3,765	3,267	4,388	1,500	496	768	486	1,078	1,222	872	1,131	43	1,389	597	400
	% Hatchery	45.6%	46.5%	47.4%	43.5%	17.5%	8.6%	2.6%	3.2%	2.4%	1.1%	3.8%	0.3%	5.4%	3.3%	1.4%
Neponicum River	Total	440	301	693	161	958	370	378	5,112	2,143	2,535	2,339	1,252	843	484	1,208
	Hatchery	179	120	277	64	383	19	19	280	96	158	141	34	93	33	103
	% Hatchery	40.0%	39.9%	40.0%	39.8%	40.0%	5.1%	5.0%	5.5%	4.5%	6.2%	6.0%	2.7%	11.0%	7.1%	8.5%
Nehalem River	Total	5,556	3,818	4,293	2,538	1,257	4,155	14,580	22,342	17,862	32,801	18,825	10,451	12,818	14,458	15,890
	Hatchery	2,712	2,118	3,788	1,351	51	800	118	414	698	284	89	0	1,202	425	0
	% Hatchery	48.8%	55.5%	87.7%	53.2%	4.1%	14.4%	0.8%	1.9%	3.9%	0.9%	0.5%	0.0%	9.4%	2.9%	0.0%
Tillamook Bay	Total	1,922	1,096	979	481	384	1,978	2,477	2,119	13,707	13,129	3,360	1,995	8,774	2,429	5,538
	Hatchery	817	755	248	44	26	147	299	175	373	121	828	0	0	134	242
	% Hatchery	42.5%	69.9%	25.1%	9.1%	6.8%	7.4%	12.1%	8.3%	2.7%	0.9%	24.6%	0.0%	0.0%	5.5%	4.3%
Nesuzca River	Total	313	1,811	519	271	238	2,357	1,289	4,371	16,753	10,303	4,788	695	1,895	399	5,489
	Hatchery	47	274	79	41	56	0	50	207	59	109	73	9	19	5	58
	% Hatchery	15.0%	15.1%	15.2%	15.1%	15.1%	0.0%	3.9%	4.7%	0.3%	1.1%	1.5%	1.3%	1.0%	1.3%	1.0%
RC Dependents	Total											661	2,118	1,198	375	540
	Hatchery											0	0	75	0	0
	% Hatchery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.0%	0.0%	6.3%	0.0%	0.0%
Mid Coast Strata	Total	12,219	16,196	24,278	3,529	5,067	10,879	15,824	23,731	95,721	71,635	44,066	53,402	22,688	13,663	62,133
	Hatchery	4,805	4,104	9,633	1,197	2,626	1,261	262	2,656	1,514	2,135	1,996	1,995	1,471	1,393	4,261
	% Hatchery	39.3%	25.4%	39.7%	33.9%	51.8%	11.6%	1.7%	11.2%	1.6%	3.0%	4.5%	3.7%	6.5%	10.2%	6.8%
Salmon River	Total	1,554	1,325	2,703	417	432	173	394	877	1,108	1,738	3,525	817	1,160	993	3,853
	Hatchery	1,463	1,220	2,621	401	346	159	215	652	565	1,696	1,683	738	647	934	3,069
	% Hatchery	94.1%	92.1%	97.0%	96.2%	80.1%	91.9%	54.6%	74.3%	51.0%	97.8%	53.4%	90.3%	55.8%	94.1%	79.7%
Siletz River	Total	1,200	607	763	336	357	1,364	3,387	2,454	2,504	8,421	8,179	15,234	5,323	2,416	15,258
	Hatchery	579	283	368	38	41	155	0	858	375	383	0	687	118	219	737
	% Hatchery	48.3%	46.3%	48.2%	11.3%	11.5%	11.4%	0.0%	35.0%	15.0%	4.5%	0.0%	4.4%	2.2%	9.1%	4.8%
Yaquina River	Total	2,448	5,668	6,194	529	644	2,567	638	3,760	23,800	18,484	5,652	3,613	4,306	3,355	6,791
	Hatchery	408	945	1,526	110	134	4	1	171	0	0	113	172	59	197	81
	% Hatchery	16.7%	16.7%	25.0%	20.8%	20.8%	0.2%	0.2%	4.5%	0.0%	0.0%	2.0%	4.8%	1.4%	5.9%	0.9%
Beaver Cr.	Total	675	308	1,701	644	530	1,511	1,510	2,114	3,360	5,552	4,569	2,264	2,122	611	1,182
	Hatchery	0	0	405	147	119	0	48	282	143	0	0	0	172	0	0
	% Hatchery	0.0%	0.0%	23.8%	22.8%	22.9%	0.0%	3.0%	13.3%	4.3%	0.0%	0.0%	0.0%	8.1%	0.0%	0.0%
Assa River	Total	1,279	681	1,637	928	1,732	2,071	3,383	3,920	9,254	10,281	5,233	13,907	1,972	2,146	11,618
	Hatchery	451	240	577	327	1,624	730	0	692	181	0	0	0	0	0	187
	% Hatchery	35.3%	35.2%	35.2%	35.2%	93.8%	35.2%	0.0%	17.7%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%
Siuslaw River	Total	5,063	7,567	11,370	675	1,382	3,193	6,532	10,606	55,695	29,059	8,729	17,321	6,260	3,581	17,163
	Hatchery	1,904	1,406	4,138	174	362	213	0	250	56	0	414	391	29	29	121
	% Hatchery	37.6%	18.6%	36.4%	25.8%	26.2%	6.7%	0.0%	0.0%	0.4%	0.2%	0.0%	2.4%	0.2%	0.8%	0.7%
NC Dependents	Total											8,179	246	1,552	561	4,270
	Hatchery											0	4	84	14	86
	% Hatchery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.0%	1.6%	5.4%	2.5%	1.5%

Table 4 continued.

ESU / Strata / Population	Return Year Marine Survival	1994		1995		1996		1997		1998		1999		2000		2001		2002		2003		2004		2005		2006		2007		2008 Prelim		
		EL	EL	EL	EL	EL	EL	L	L	L	L	M	M	M	M	M	M	L	L	L	L	M	M	L	L	M	M	EL	EL			
Umpqua Strata	Total	9,638	22,423	32,756	5,126	14,858	11,004	22,787	52,842	52,036	43,702	37,160	51,645	27,647	15,830	33,864																
	Hatchery	2,735	2,311	11,578	1,782	4,868	2,428	8,193	17,758	8,532	8,919	7,240	9,313	9,555	3,847	1,558																
	% Hatchery	28.4%	10.3%	35.3%	35.0%	33.4%	22.1%	36.0%	33.6%	16.4%	20.4%	19.5%	18.0%	34.6%	24.6%	4.6%																
Lower Umpqua River	Total	2,918	10,854	8,435	1,445	4,552	2,706	5,896	12,872	19,787	16,529	9,053	19,014	9,478	4,661	13,235																
	Hatchery	156	0	450	188	0	85	115	1,233	906	35	64	423	1,484	424	968																
	% Hatchery	5.3%	0.0%	5.3%	13.0%	0.0%	3.1%	2.0%	9.6%	4.6%	0.2%	0.7%	2.2%	15.7%	9.1%	7.3%																
Middle Umpqua River	Total	2,308	3,250	5,431	801	1,358	1,814	4,719	9,817	11,869	11,030	6,433	8,203	6,111	1,783	4,731																
	Hatchery	147	0	345	38	79	156	164	877	931	0	58	595	1,259	176	437																
	% Hatchery	6.4%	0.0%	6.4%	6.3%	5.9%	8.7%	3.5%	8.9%	8.0%	0.0%	0.9%	7.3%	20.6%	10.0%	2.9%																
North Umpqua River	Total	1,889	3,049	4,812	1,956	4,144	3,173	9,252	16,728	10,083	11,746	10,265	10,264	9,692	3,975	3,991																
	Hatchery	990	1,756	3,743	1,379	3,379	1,979	7,585	14,094	6,695	8,884	6,706	8,295	6,662	2,965	153																
	% Hatchery	52.4%	57.6%	77.8%	70.5%	81.5%	62.4%	81.9%	84.3%	66.5%	75.6%	65.3%	80.8%	69.0%	64.5%	4.3%																
South Umpqua River	Total	2,523	5,070	14,080	1,124	4,807	3,209	2,910	13,426	10,517	4,337	11,409	14,364	2,398	5,231	12,307																
	Hatchery	1,442	555	7,040	187	1,430	196	329	1,554	0	0	412	0	150	882	300																
	% Hatchery	57.2%	10.9%	50.0%	16.6%	31.0%	6.2%	11.3%	11.6%	0.0%	0.0%	3.6%	0.0%	6.3%	13.0%	2.4%																
Lakes Strata	Total	5,642	11,216	13,484	8,603	11,108	12,711	12,747	19,668	22,097	16,091	18,642	14,725	24,127	8,956	23,570																
	Hatchery	130	132	68	16	0	188	0	65	120	15	45	0	251	0	0																
	% Hatchery	2.3%	1.2%	0.5%	0.2%	0.0%	1.3%	0.0%	0.3%	0.5%	0.1%	0.2%	0.0%	1.0%	0.0%	0.0%																
Sibcoos	Total	1,426	4,497	4,775	2,853	3,122	2,819	3,835	5,104	4,749	6,628	7,898	4,364	5,452	1,447	3,835																
	Hatchery	124	82	68	0	0	63	0	0	113	0	27	0	21	0	0																
	% Hatchery	8.7%	1.8%	1.4%	0.0%	0.0%	2.2%	0.0%	0.0%	2.2%	0.0%	0.3%	0.0%	0.4%	0.0%	0.0%																
Tahleontch	Total	1,062	1,627	1,627	1,558	2,817	3,769	834	3,526	3,487	3,203	3,496	1,697	3,511	3,551	2,604																
	Hatchery	6	50	0	16	0	105	0	16	7	15	0	107	0	0																	
	% Hatchery	0.6%	3.1%	0.0%	0.9%	0.0%	2.8%	0.0%	0.5%	0.2%	0.5%	0.0%	3.0%	0.0%	0.0%																	
Tenmile	Total	3,354	5,092	7,092	4,092	5,169	6,123	8,278	11,039	13,961	6,260	7,148	8,464	16,064	3,957	17,131																
	Hatchery	0	0	0	0	0	0	0	49	0	0	18	0	123	0	0																
	% Hatchery	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.3%	0.0%	0.8%	0.0%	0.0%																
Mid-South Coast Strata	Total	23,479	14,398	30,136	7,528	6,963	8,276	12,582	55,963	44,803	49,647	53,645	29,730	41,359	15,747	23,966																
	Hatchery	989	834	481	71	129	65	12	2,768	640	445	221	266	118	13	66																
	% Hatchery	4.1%	4.4%	1.6%	0.9%	1.9%	0.8%	0.1%	4.9%	1.4%	0.9%	0.4%	0.9%	0.3%	0.1%	0.3%																
Cove River	Total	15,207	10,447	12,120	1,127	2,965	4,018	4,704	34,259	33,265	25,950	23,450	17,305	11,266	1,342	13,353																
	Hatchery	707	146	0	15	0	0	0	564	145	189	113	257	0	13	41																
	% Hatchery	4.6%	1.4%	0.0%	1.3%	0.0%	0.0%	0.0%	1.6%	0.4%	0.7%	0.5%	1.5%	0.0%	1.0%	0.3%																
Coquille River	Total	5,119	2,118	18,189	5,720	2,412	2,867	6,253	15,865	7,866	22,585	22,182	11,808	28,577	13,968	9,874																
	Hatchery	0	82	355	0	0	0	0	1,832	190	182	44	0	0	0	0																
	% Hatchery	0.0%	3.9%	2.2%	0.0%	0.0%	0.0%	0.0%	11.7%	2.4%	0.7%	0.2%	0.0%	0.0%	0.0%	0.0%																
Floras Creek	Total	2,993	1,751	1,628	525	959	730	1,477	5,752	3,568	1,038	7,446	506	1,314	340	650																
	Hatchery	240	400	109	43	79	80	0	86	296	86	0	0	110	0	13																
	% Hatchery	8.3%	22.8%	6.7%	8.2%	8.2%	8.2%	0.0%	1.5%	8.3%	8.3%	0.0%	0.0%	9.1%	0.0%	2.0%																
Sizem River	Total	260	84	211	156	508	61	148	277	104	94	467	113	302	89																	
	Hatchery	22	7	17	13	50	5	12	182	9	8	64	3	8	0	12																
	% Hatchery	8.5%	8.3%	8.1%	8.3%	8.2%	8.2%	6.1%	65.7%	8.7%	8.5%	13.7%	7.1%	2.6%	0.0%	13.5%																
MS-Dependent	Total																															
	% Hatchery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.																

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) (Fig. 10). 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 (ESUs) life history diversity into the foreseeable future. The criteria within the DSS (Table Fig. 3) 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 population size was evaluated. The TRT then used recent observations of these population metrics to inform their assessment of risk to the Oregon Coast 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 (Kelly Moore, personal communication) from various survey and monitoring studies. Data include: Spawner survey (peak counts and Area Under the Curve (AUC) estimates); estimates of wild and hatchery fish at the spawning grounds; distribution of spawners and summer juveniles; and estimates of habitat capacity. These contribute to a set of objectively measurable criteria. ESU-level diversity is more difficult to evaluate, 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.

Table 5. Biological Recovery Criteria Definitions.

ESU-Level Criteria

- EP.** ESU Persistence: The ESU will persist over the next 100 years. All biogeographic strata are persistent (see Stratum Persistence, SP).
- ES.** ESU Sustainability: The ESU is self-sustaining into the foreseeable future.
- ES-1.** All Strata Sustainable: All biogeographic strata are sustainable (see Stratum Sustainability, SS).
- ES-2.** ESU-Level Diversity: The ESU has sufficient broad-scale diversity to maintain its ecological and evolutionary functions into the foreseeable future.
- ED-1.** Genetic Diversity: ESU-level genetic diversity is sufficient for long-term sustainability of the ESU.
- ED-1a.** Genetic Structure: Genetic diversity within the ESU is comparable to healthy coho salmon ESUs and forms the basis for life-history diversity.
- ED-1b.** Effects of Selection: Human-driven selection is not sufficient to decrease genetic diversity.
- ED-1c.** Effects of Migration: Genetic diversity is not compromised by changes in the movements of fish.
- ED-2.** Phenotypic and Habitat Diversity: ESU-level phenotypic and habitat diversity are sufficient for long-term sustainability of the ESU.
- ED-2a.** Phenotypic Diversity: Phenotypic diversity is present within the ESU at levels comparable to healthy ESUs or the historical template.
- ED-2b.** Habitat Diversity: Habitats are sufficiently productive, diverse, and accessible to promote phenotypic plasticity.
- ED-3.** Small Populations: Dependent populations within the ESU are not permanently lost.

Biogeographic Stratum-Level Criteria

- SS.** Stratum Persistence: Most of the historically independent populations in the stratum are persistent (see Population Persistence, PP).
- SS.** Stratum Sustainability: The stratum is self-sustaining (in terms of both diversity and functionality) into the foreseeable future.
- SD.** Stratum Diversity: Most of the historically independent populations in the stratum are at present sustainable (see Population Sustainability, PS).
- SF.** Stratum Functionality: All of the historically independent populations in the stratum are functional (see Population Functionality, PF).

Population-Level Criteria

- PS.** Population Sustainability: The population is able to sustain itself into the future. Requires both Population Persistence (PP) and Population Diversity (PD).
- PP.** Population Persistence: The population will persist for the next 100 years.
- PP-1.** Population Productivity: Productivity at low abundance is sufficient to sustain the population through an extended period of adverse environmental conditions.
- PP-2.** Probability of Persistence: The population has a high likelihood of persisting over the next 100 years, as estimated from PVA models.
- PP-3.** Critical Abundance: Population abundance is maintained above levels where small-population demographic risks are likely to become significant.

- PD. Population Diversity:** The population has sufficient diversity and distribution to ensure continued fitness in the face of environmental change.
- PD-1. Spawner Abundance:** The population has sufficient naturally produced spawners to prevent loss of genetic variation due to random processes over a 100-year time frame.
- PD-2. Artificial Influence:** The abundance of naturally spawning hatchery fish will not be so high as to be expected to have adverse effects on natural populations.
- PD-3. Spawner Distribution:** On average, the historically occupied watersheds in the population's range have spawners occupying the available spawning habitat (see Watershed Spawner Occupancy, W-Sp).
- PD-4. Juvenile Distribution:** On average, the historically occupied watersheds in the population's range have juveniles occupying the available juvenile habitat (see Watershed Juvenile Occupancy, W-Ju).
- PF. Population Functionality:** Habitat quality and quantity are adequate to support sufficient abundance to maintain long-term genetic integrity of the population.

Watershed-Level Criteria

- W-Sp. Watershed Spawner Occupancy:** Spawners occupy a high proportion of the available spawning habitat within the watershed.
- W-Ju. Watershed Juvenile Occupancy:** Juveniles occupy a high proportion of the available juvenile habitat within the watershed.

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 (Fig. 3, Table 6.a, and Fig. 10) are not directly comparable to the results presented in Wainwright et al. (2008). Table 6.b is presented for historical comparison but was not used by the BRT in their considerations. Data used in the update were provided by ODFW.⁹

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 (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 several 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 Threats discussion). In the future it may be possible to incorporate a habitat trend index in the DSS.

⁹ Kelly Moore, ODFW, pers. comm. December, 2009.

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. 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 (2008) DSS values based on AUC spawner estimates are also presented.

The DSS result for ESU persistence was 0.34 (Table 6.a.). Recall that a value of 1 (Fig. 11) 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 6.a). 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 tree remaining strata had persistence scores ranging 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 6.a), 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. 8). Hatchery production has been reduced to a small fraction of the wild production (Fig. 8, 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 3). 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. 8).

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 6.a.)

Table 6.a. DSS Results by criterion and independent population, stratum and ESU. Critical abundance data (PP.3) from peak counts. See Fig. 11 for color representation of truth value for each stratum.

ESU		EP	ED.1.A	ED.1.B	ED.1.C	ED.2.A	ED.2.B	ED.3	ED.1	ED.2	ES.1	ES.2	ES
OC coho salmon		0.34	0.28	-0.01	0.26	0.30	-0.20	0.40	0.18	0.05	0.42	0.13	0.24
	Stratum	SP	SD	SF	SS								
	North Coast	0.27	0.33	0.53	0.39								
	Mid-Coast	0.25	0.36	0.47	0.40								
	Lakes	0.88	0.64	0.38	0.47								
	Umpqua	0.40	0.26	0.88	0.45								
	Mid-South Coast	0.24	0.37	0.68	0.48								
Stratum	Population	PP.1	PP.2	PP.3	PD.1	PD.2	PF.1	PD.3	PD.4	PP	PD	PS	PF
North Coast	Necanicum River	0.95	-0.44	0.06	0.10	0.35	0.18	0.85	0.96	-0.26	0.36	-0.15	0.18
North Coast	Nehalem River	0.80	0.92	0.51	1.00	0.66	1.00	0.46	0.63	0.69	0.62	0.65	1.00
North Coast	Tillamook Bay	0.90	0.50	0.15	0.35	0.42	1.00	0.35	0.60	0.36	0.40	0.37	1.00
North Coast	Nestucca River	0.82	0.74	-0.08	0.26	0.92	0.89	0.66	0.77	0.18	0.51	0.28	0.89
Mid-Coast	Salmon River	-0.51	-1.00	-1.00	-0.14	-1.00	0.20	-0.14	1.00	-1.00	-1.00	-1.00	0.20
Mid-Coast	Siletz River	0.91	0.66	0.09	0.24	0.67	0.98	0.54	0.91	0.34	0.46	0.38	0.98
Mid-Coast	Yaquina River	0.97	0.76	0.20	0.46	0.69	1.00	0.80	1.00	0.47	0.66	0.54	1.00
Mid-Coast	Beaver Creek	0.97	0.62	0.90	0.08	0.86	0.14	1.00	1.00	0.79	0.44	0.56	0.14
Mid-Coast	Alsea River	0.63	0.96	-0.29	0.51	0.97	1.00	0.47	0.88	-0.03	0.65	0.13	1.00
Mid-Coast	Siuslaw River	0.89	0.98	-0.14	1.00	0.81	1.00	0.65	0.85	0.17	0.80	0.35	1.00
Lakes	Siltcoos River (Lake)	0.81	1.00	0.86	0.47	0.99	0.32	1.00	1.00	0.88	0.76	0.81	0.32
Lakes	Tahkenitch Lake	0.69	0.70	1.00	0.21	0.95	0.32	1.00	1.00	0.78	0.56	0.64	0.32
Lakes	Tenmile Lake	0.96	0.98	1.00	0.85	0.98	0.59	1.00	-0.36	0.98	-0.05	0.20	0.59
Umpqua	Lower Umpqua River	0.68	0.86	0.48	0.96	0.42	1.00	0.66	0.59	0.63	0.59	0.60	1.00
Umpqua	Middle Umpqua River	0.73	0.84	0.00	0.32	0.35	1.00	0.27	0.48	0.26	0.33	0.28	1.00
Umpqua	North Umpqua River	-0.96	0.52	0.22	0.97	-0.96	0.67	-0.37	-0.87	-0.95	-0.95	-0.95	0.67
Umpqua	South Umpqua River	0.92	0.94	0.26	0.28	0.50	1.00	-0.05	0.41	0.54	0.11	0.23	1.00
Mid-South Coast	Coos Bay	0.92	0.86	0.33	1.00	0.94	1.00	0.95	1.00	0.58	0.97	0.74	1.00
Mid-South Coast	Coquille River	0.96	0.96	0.72	1.00	0.98	1.00	0.67	0.81	0.86	0.83	0.85	1.00
Mid-South Coast	Floras Creek	0.99	0.92	-0.38	0.18	0.81	0.87	0.27	1.00	-0.11	0.40	0.01	0.87

Table 7.b. DSS Results based on AUC spawner estimates for comparison with Wainwright et al. 2008.

ESU		EP	ED.1.A	ED.1.B	ED.1.C	ED.2.A	ED.2.B	ED.3	ED.1	ED.2	ES.1	ES.2	ES
OC coho salmon		0.70	0.28	-0.01	0.26	0.30	-0.20	0.40	0.18	0.05	0.53	0.13	0.28
	Stratum	SP	SD	SF	SS								
	North Coast	0.69	0.54	0.53	0.53								
	Mid-Coast	0.55	0.54	0.47	0.50								
	Lakes	0.92	0.64	0.38	0.47								
	Umpqua	0.66	0.36	0.88	0.53								
	Mid-South Coast	0.91	0.74	0.68	0.70								
Stratum	Population	PP.1	PP.2	PP.3	PD.1	PD.2	PF.1	PD.3	PD.4	PP	PD	PS	PF
North Coast	Necanicum River	0.95	-0.44	0.54	0.10	0.35	0.18	0.85	0.96	-0.22	0.36	-0.11	0.18
North Coast	Nehalem River	0.80	0.92	0.85	1.00	0.66	1.00	0.46	0.63	0.85	0.62	0.72	1.00
North Coast	Tillamook Bay	0.90	0.50	0.80	0.35	0.42	1.00	0.35	0.60	0.68	0.40	0.50	1.00
North Coast	Nestucca River	0.82	0.74	0.60	0.26	0.92	0.89	0.66	0.77	0.70	0.51	0.58	0.89
Mid-Coast	Salmon River	-0.51	-1.00	-1.00	-0.14	-1.00	0.20	-0.14	1.00	-1.00	-1.00	-1.00	0.20
Mid-Coast	Siletz River	0.91	0.66	0.46	0.24	0.67	0.98	0.54	0.91	0.62	0.46	0.51	0.98
Mid-Coast	Yaquina River	0.97	0.76	0.82	0.46	0.69	1.00	0.80	1.00	0.84	0.66	0.74	1.00
Mid-Coast	Beaver Creek	0.97	0.62	1.00	0.08	0.86	0.14	1.00	1.00	0.82	0.44	0.57	0.14
Mid-Coast	Alsea River	0.63	0.96	0.15	0.51	0.97	1.00	0.47	0.88	0.39	0.65	0.48	1.00
Mid-Coast	Siuslaw River	0.89	0.98	0.19	1.00	0.81	1.00	0.65	0.85	0.49	0.80	0.60	1.00
Lakes	Siltcoos River (Lake)	0.81	1.00	1.00	0.47	0.99	0.32	1.00	1.00	0.92	0.76	0.83	0.32
Lakes	Tahkenitch Lake	0.69	0.70	1.00	0.21	0.95	0.32	1.00	1.00	0.78	0.56	0.64	0.32
Lakes	Tenmile Lake	0.96	0.98	1.00	0.85	0.98	0.59	1.00	-0.36	0.98	-0.05	0.20	0.59
Umpqua	Lower Umpqua River	0.68	0.86	0.85	0.96	0.42	1.00	0.66	0.59	0.78	0.59	0.66	1.00
Umpqua	Middle Umpqua River	0.73	0.84	0.34	0.32	0.35	1.00	0.27	0.48	0.54	0.33	0.40	1.00
Umpqua	North Umpqua River	-0.96	0.52	0.76	0.97	-0.96	0.67	-0.37	-0.87	-0.94	-0.95	-0.95	0.67
Umpqua	South Umpqua River	0.92	0.94	0.75	0.28	0.50	1.00	-0.05	0.41	0.86	0.11	0.31	1.00
Mid-South Coast	Coos Bay	0.92	0.86	0.94	1.00	0.94	1.00	0.95	1.00	0.90	0.97	0.94	1.00
Mid-South Coast	Coquille River	0.96	0.96	0.93	1.00	0.98	1.00	0.67	0.81	0.95	0.83	0.89	1.00
Mid-South Coast	Floras Creek	0.99	0.92	0.85	0.18	0.81	0.87	0.27	1.00	0.92	0.40	0.58	0.87

Table 8. VSP attributes related to DSS results. [I updated this table and now cannot get it to display – all it shows is the upper left-hand corner (VSP Factor)–PWL]

VSP Factor

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 8 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 9. 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)

Table 9. Factors for decline and habitat limiting factors for Oregon Coast coho salmon (after NMFS 1997c.)

MODIFICATION OR CURTAILMENT OF RANGE	HARVEST	DISEASE AND PREDATION	REGULATORY MECHANISMS	OTHER NATURAL OR MANMADE FACTORS
Fish Passage (hydro, tide gates, culverts)	Marine	Disease	NW Forest Plan	Droughts
Water withdrawal	Recreational	Predation	Forest Practices	Floods
Land use/Management			Dredge and Fill	Ocean Conditions
Logging			Ag Practices (sedimentation, temperature)	Artificial Propagation
Agricultural activities			Logging Practices (sedimentation, temperature)	
Estuary loss			Urban growth	
Wetland loss				
Riparian area/quality loss				
Channel complexity				
Floodplain connectivity loss				
Splash damming, log drives				
Gravel/placer mining				
Forest and Ag conversion to urban				
Urbanization				

Table 10. Threats to OC Coho Salmon ESU identified by NMFS NWR (after NMFS 1997c).

HUMAN THREATS	NATURAL THREATS
Agriculture: Instream wood, water temperature, substrate sediment	Drought
Forestry – and private lands: Instream wood, water temperature, substrate sediment	Floods
Gravel mining: Particular concern on the southern Oregon Coast, where the Umpqua and Coquille River Basins have significant sediment deficits	Wildfire
Water withdrawals or diversions: Current concern on the southern Oregon coast; future concern on mid-coast as urban areas grow Drought interaction	Tsunami
Urbanization: Floodplain functions, instream wood, substrate sediment, stormwater	

Because the list of threats has changed over the years, Table 10 compares the list of threats and limiting factors between those identified in 2003 (Good 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.

Table 11. Threats to OC Coho Salmon ESU identified by NMFS NWR and 2009 BRT(after NMFS 1997c)

THREATS PREVIOUSLY IDENTIFIED BY NWR	THREATS BRT 2009
Agriculture and Forestry	Agriculture and Forestry
Instream wood	stream complexity (includes disturbance, roads, splash damming, stream cleaning)
water temperature	water temperature
substrate sediment	substrate sediment-analyzed in stream complexity section
estuary, wetland habitat loss - not identified as major threat	estuary, wetland habitat loss - due to effect on life history diversity
beaver dam loss- not identified as major threat	beaver dam loss- analyzed in stream complexity section
Fish Passage Restriction- not identified as major threat	Fish Passage Restriction
Gravel mining: Umpqua and Coquille River Basins	Gravel mining:
Water withdrawals or diversions: Mid-south Coast, Umpqua Strata Drought interaction	Water withdrawals or diversions: Mid-south Coast, Umpqua Strata Drought interaction Global Climate Change
Urbanization	Land Use conversion-Urbanization
floodplain functions	floodplain functions not addressed
instream wood	instream wood- addressed in stream complexity analysis
substrate sediment	substrate sediment- addressed in stream complexity analysis
stormwater	Stormwater not addressed
Disease and Parasitism not identified as a major threat	Disease and Parasitism
Artificial Propagation	Artificial Propagation
Harvest	Harvest
Predation not identified as a major threat	Predation
Global Climate Change not identified as a major threat	Global Climate Change
Marine Productivity not identified as a major threat by NWR, was identified by 2003 BRT	Marine Productivity
Drought	Addressed under Global Climate Change
Floods	Addressed under Global Climate Change
Wildfire	Addressed under Global Climate Change
Tsunami	Not addressed

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. 12), 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 audax*), Dorado (*Coryphaena hippurus*), and Pacific barracuda (*Sphyrna 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 (Mekia-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. 2006b, Zeidberg and Robison 2007), and can move horizontally nearly 200 km in a week (Gilly et al. 2006b). 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.¹⁰ 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.¹¹

A recent analysis of factors contributing to the collapse of Sacramento fall Chinook salmon includes on 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 substantial percent (>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 mark¹², 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 the previous year (see Appendix C) (Van Doornik et al. 2007). This 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.

¹⁰ Dezhang Chu, NWFSC, National Marine Fisheries Service 2725 Montlake Blvd. E. Seattle, WA 98112-2097 Pers. comm. November, 2009.

¹¹ R. Emmett, NWFSC, Newport Research Station, 2032 SE OSU Drive, Newport, OR. Pers. comm., December, 2009

¹² L. Weitkamp, NWFSC, Newport Research Station, 2032 SE OSU Drive, Newport, OR. Pers. comm., December, 2009

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 Humbolt squid will directly lead to reduced abundance of Oregon Coast 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), 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). Here, we review the major potential effects that have been identified, present an approach to integrating these effects across life-history stages, and apply that approach to evaluate potential effects on the OC Coho Salmon ESU. To date, there have been no published studies of climate change effects specific to the Oregon Coast, although a number of studies of past and projected change in the Pacific Northwest include information that covers the range of the ESU. Details of the method and results can be found in Appendix C.

To understand the risks to salmon populations associated with climate change, we need to consider the complexity of the problem and consider means of integrating across habitats and through the entire salmon life cycle (Fig. 13). 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 (e.g., Cederholm & Reid, 1987).

Climate conditions have effects on each of these habitats, thus affecting different portions of the life cycle through different pathways (Fig. 13). This leads to a very complex set of potential effects to assess. 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 we present here is qualitative: we summarize likely trends in climate, identify the pathways by which those trends are likely to affect salmon, and assess the likely direction and rough magnitude of coho salmon population response. as recognizing potential interactions of these effects with other natural and human- Below, we identify and describe potential effects of climate change on OC coho salmon as individual effects, but recognize that in assessing the resulting risks, we must consider the accumulation of these effects through the life

cycle and across generations, as well induced changes in the ecosystems on which coho salmon depend.

Physical and Chemical Climate Change in the Pacific Northwest. There have been a few reviews of physical climate change patterns in the Pacific Northwest (Mote et al., 2003; Leung et al., 2004; Mote et al., 2008b; Karl et al., 2009). Their results were corroborated in a broader-scale review for all of North America (Christensen et al., 2007, section 11.5). We have reviewed these and more specific studies to summarize the key physical and chemical changes expected in the Pacific Northwest over the next few decades, including trends in terrestrial conditions (air temperature, precipitation, and snowpack) freshwater conditions (stream flow, water temperature, flood events), estuarine conditions (flow, water temperature, sea level), and coastal ocean conditions (ocean temperature, circulation, upwelling, and ocean acidity). Key findings from this review are summarized in Table 9; detailed discussion is in Appendix C.

Effects on Oregon Coast Coho Salmon There have been numerous studies examining the effects of long-term climate change to salmon population dynamics, beginning in the early 1990s (Chatters et al., 1991; Neitzel et al., 1991) and continuing to recent reviews (Battin et al., 2007; ISAB, 2007; Crozier et al., 2008; Mantua et al., 2009). These studies have identified a number of common mechanisms by which climate variation or trends influence salmon sustainability, including physiological heat tolerance and metabolic costs, disease resistance, shifts in seasonal timing of important life-history events (upstream migration, spawning, emergence, outmigration), changes in growth and development rates, changes in freshwater habitat structure, and changes in the structure of ecosystems on which salmon depend (especially in terms of food supply and predation risk) (Francis & Mantua, 2003; ISAB, 2007; Crozier et al., 2008; Mantua et al., 2009).

The effects of the physical and chemical changes outlined above can be expected to influence salmon during all life history stages. Based on available scientific literature, we summarized these influences by habitat type in order from the mountains to the sea: terrestrial, freshwater, estuarine, and marine environments. These effects are summarized in Table 12; detailed discussion of these effects can be found in Appendix C. Effects of individual physical changes ranged from strongly negative to strongly positive with certainties ranging from low to high. The majority of effects are negative.

While there are some expected positive effects, negative effects of climate change predominate for each life history stage (Table 12). While many of the individual effects of climate change on Oregon Coast 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 Oregon Coast coho salmon over the next few decades.

Table 12. Summary of expected physical and chemical climate changes in the Pacific Northwest.

Pattern	Certainty	Sources
Increased air temperature	High	Mote et al., 2003; Mote, 2003; Leung et al., 2004; Mote et al., 2008b; Karl et al., 2009
Increased winter precipitation	Low	Mote et al., 2003; Mote, 2003; Leung et al., 2004; Mote et al., 2008b; Karl et al., 2009
Decreased summer precipitation	Low	Mote et al., 2003; Leung et al., 2004; Mote et al., 2008b; Karl et al., 2009
Reduced winter/spring snowpack	High	Barnett et al., 2004; Barnett et al., 2008; Stewart et al., 2004; Stewart et al., 2005; Mote et al., 2005; Mote, 2006; Hamlet et al., 2005; Karl et al., 2009
Reduced summer stream flow	High	Mote et al., 2003; Karl et al., 2009
Earlier spring peak flow	High	Mote et al., 2003; Leung et al., 2004; Karl et al., 2009
Increased flood frequency & intensity	Moderate	Mote et al., 2003; Leung et al., 2004; Hamlet & Lettenmaier, 2007
Higher summer stream temperature	Moderate	Morrison et al., 2002; Ferrari et al., 2007; Lettenmaier et al., 2008
Higher sea level	High	Bindoff et al., 2007; Mote et al., 2008a; Karl et al., 2009
Higher ocean temperature	High	Auad et al., 2006; Bindoff et al., 2007; Mote et al., 2008b
Intensified upwelling	Moderate	Bakun, 1990; Mote & Mantua, 2002; Snyder et al., 2003; Diffenbaugh, 2005; Bograd et al., 2009
Delayed spring transition	Moderate	Snyder et al., 2003; Bograd et al., 2009
Increased ocean acidity	High	Bindoff et al., 2007; Feely et al., 2004; Fabry et al., 2008; Feely et al., 2008

Table 13. Summary of climate effects on the Oregon Coast Coho Salmon ESU. Effect ratings are: ++, strongly positive; +, positive; 0, neutral; -, negative, --, strongly negative. Certainty level combines the certainty of the physical change (Table 11) with the certainty of the effect.

Habitat	Physical Change	Process Affecting Salmon	Effect on		Main Sources
			OC Coho	Certainty	
<i>Terrestrial</i>	Warmer, drier summers	Increased fires, increased tree stress & disease affect LWD, sediment supplies, riparian zone structure	-- to 0	Low	Cederholm & Reid, 1987; Mote et al., 2003; ISAB, 2007; Peterson et al., 2008
	Reduced snowpack, warmer winters	Increased growth of higher elevation forests affect LWD, sediment, riparian zone structure	0 to +	Low	Cederholm & Reid, 1987; Mote et al., 2003; ISAB, 2007; Peterson et al., 2008
<i>Freshwater</i>	Reduced summer flow	Less accessible summer rearing habitat	-	Moderate	Crozier & Zabel, 2006; Crozier et al., 2008; ISAB, 2007; Mantua et al., 2009
	Earlier peak flow	Potential migration timing mismatch	- to 0 (-- to 0 in Umpqua)	Moderate	Crozier et al., 2008
	Increased floods	Redd disruption, juvenile displacement, upstream migration	- to 0 (-- to - in Umpqua)	Moderate	ISAB, 2007; Mantua et al., 2009
	Higher stream temperature	Thermal stress, restricted habitat availability, increased susceptibility to disease and parasites	-- to -	Moderate	Marine & Cech, 2004; ISAB, 2007; Crozier et al., 2008; Farrell et al., 2008; Marcogliese, 2008; Mantua et al., 2009;
<i>Estuarine</i>	Higher Sea Level	Reduced availability of wetland habitats	-- to -	High	Kennedy, 1990; Scavia et al., 2002; Roessig et al., 2004; Mote et al., 2008a
	Higher water temperature	Thermal stress, increased susceptibility to disease and parasites	-- to -	Moderate	Marine & Cech, 2004; Marcogliese, 2008
	Combined effects	Changing estuarine ecosystem composition and structure	-- to +	Low	Kennedy, 1990; Scavia et al., 2002; Roessig et al., 2004
<i>Marine</i>	Higher ocean temperature	Thermal stress, shifts in migration, susceptibility to disease & parasites	-- to -	Moderate	Welch et al., 1995; Cole, 2000; Marine & Cech, 2004; Marcogliese, 2008
	Intensified upwelling	Increased nutrients (food supply), coastal cooling, ecosystem shifts; increased offshore transport	0 to ++	Moderate	Nickelson, 1986; Fisher & Percy, 1988

Delayed spring transition	Food timing mismatch with outmigrants, ecosystem shifts	- to 0	Moderate	Schwing et al., 2006; Brodeur et al., 2005; Emmett et al., 2006
Increased acidity	Disruption of food supply, ecosystem shifts	-- to -	Moderate	Fabry et al., 2008
Combined effects	Changing composition and structure of ecosystem; changing food supply and predation	-- to +	Low	Fabry et al., 2008; Peterson & Schwing, 2003; Brodeur et al., 2005; Emmett et al., 2006; Bograd et al., 2009

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

Fish Passage

The effect of hydropower development in the ESU was reviewed in the Oregon Coast Coho Assessment (State of Oregon 2005). Oregon's conclusion was that

“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)

However, fish passage problems are not just related to blockage by hydro projects.

In 2005, 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 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 2005).

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) 2009). 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) and 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. 14 do not include barriers from private timber or agricultural lands.

Fish passage barriers have not been identified as a major limiting factor for OC coho salmon by ODFW, however, the BRT's analysis shows that within the OC Coho Salmon ESU, of barriers that are in the dataset, nearly half (49%) are of unknown status. The NMFS NW Regional Office (NMFS 2005) considered that 30% of fish passage facilities in unknown status constituted a risk to the OC Coho Salmon ESU at that time. The incompleteness of the information that is included in the 2009 barriers database led this BRT to consider that fish passage may continue to be a significant information gap in identification of habitat problems in the ESU. As more information is included in the OFPBDS dataset, and in the absence of information from Oregon Department of Forestry, Oregon Water Resources, soil and water

conservation districts, watershed councils, and tribes, it is clear that there is a great deal of uncertainty as to the true effect that fish passage barriers present to OC coho salmon.

For the purposes of 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 systems. 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 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.

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 1 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 streamflows 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 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 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 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 the Oregon Department of Fish and Wildlife (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 13 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 Habitat Subcommittee decided that stream complexity was such an important component to any risk assessment of habitat, that they would pursue some new analyses based on techniques utilized by the USFS.

Table 14. Primary and secondary limiting factors for independent populations in the OC Coho Salmon ESU. (Source: Oregon 2005)

Population	Primary Limiting Factor	Secondary Limiting factor
Necanicum	Stream Complexity	--
Nehalem	Stream Complexity	Water Quality
Tillamook	Stream Complexity	Water Quality
Nestucca	Stream Complexity	--
Salmon	Hatchery Impacts	Stream Complexity
Siletz	Stream Complexity	--
Yaquina	Stream Complexity	Water Quality
Beaver	Spawning Gravel	Stream Complexity
Alesea	Stream Complexity	Water Quality
Siuslaw	Stream Complexity	Water Quality
Lower Umpqua	Stream Complexity	Water Quality
Middle Umpqua	Water Quantity	Stream Complexity Water Quality
North Umpqua	Hatchery Impacts	Stream Complexity
South Umpqua	Water Quantity	Stream Complexity Water Quality
Siltcoos	Exotic Fish Species	Stream Complexity Water Quality
Tahkenitch	Exotic Fish Species	Stream Complexity Water Quality
Tenmile	Exotic Fish Species	Stream Complexity Water Quality
Coos	Stream Complexity	Water Quality
Coquille	Stream Complexity	Water Quality
Floras	Stream Complexity	Water Quality
Sixes	Stream Complexity	Water Quality

Background- 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 15 shows sites identified by Maser and Sedell (1994) and Miller (2009) (Fig. 15) for splash dams and log drives in the OC Coho Salmon ESU. Legacy effects from these activities may still be affecting geomorphic processes and 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 practiced by ODFW. Information presented in The Elliott Forest Watershed Analysis (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.

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 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). Several lines of evidence that 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).¹³ As Pollock et al. 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. Pollock et al. (2004)

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 Oregon Coast 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 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 Mid-Coast 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 14). The intra-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. 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. 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.

¹³ Peter Lawson, NWFSC, Newport Research Station, 2032 SE OSU Drive, Newport, OR. Pers. comm., January, 2010.

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.

Table 15. Beaver Dam Summary from Tillamook Basin snorkel survey (Biosurveys 2009).

Year	Tillamook	Trask	Wilson	Kilchis	Miami	Bay Tribs	Total
2006	99	16	7	-	9	5	136
2007	70	23	13	-	7	-	113

Based on these limited sources of information, the BRT concluded that there is some evidence for declines in beaver abundance over the past five years, but of very uncertain extent of scope. If beaver abundance has in fact declined substantially throughout the ESU, the BRT would consider this to be a significant threat to the availability of high quality habitat for OC coho salmon. Possible causes for loss of beaver dams could be due to natural population fluctuations, forest succession, disease (Tularemia), trapping, increased cougar depredations, reduced food supply and reduced supply of building materials or a combination of all.

Because the number of empirical studies available is limited, a brief analysis was pursued based on the published literature. Pollock et al. (2003) identified that remote or protected beaver populations¹⁴ have a density that ranges between 0.4 and 0.9 colonies/km², while recovering or managed populations have a range between 0.1 to 0.4 colonies/km². 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 km². Assuming a watershed size of 500 km² 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.

The number of dams/km is quite variable. Pristine populations can range between 2 to 74 dams/km, while the average is approximately 10 dams/km (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 that 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.

¹⁴ where no trapping is occurring and they are either protected with regulations or due to their remoteness

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 2008b). 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 would probably fall into the category of managed, not recovering and not protected. Thus the range of number of beaver colonies would be expected to decline from 0.4 colonies per km² to 0.1-0.3 colonies/km² (Pollock et al. 2003). This would mean a decrease in beaver ponds within the OC Coho Salmon ESU over the next several decades. The loss of beavers brought about by the change in application of the predatory animal regulations since 2004 are probably not yet reflected in the current biological status. If the number of beaver colonies declines as anticipated in this analysis, loss of beaver colonies and their important contribution to OC coho salmon habitat would lead to continued degradation of stream complexity in the ESU.

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 decline of this important habitat forming species, with resultant declines in the abundance of high quality habitat for OC coho salmon. The BRT concluded that declines in beaver abundance is an ongoing threat to OC coho salmon that is not fully manifest in the current biological status of the species.

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/km² compared to 1.5-4 km/km² in the OC Coho Salmon ESU (Fig. 16). The road densities for the OC Coho Salmon ESU in Figure 16 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/km² 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. 16).

Pess et al. (2002) also found a negative relationship between road density and the number of fish days 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 that are known and included in the BLM roads GIS layer, and the probable road densities that are not known,¹⁵ 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.

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). 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

¹⁵ Industrial forest land road density data sets are not generally available and therefore not included in the GIS layer.

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

Despite this connection between 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 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 Oregon Coast 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 Oregon Coast ESU over the past 23 years (for more information on methods, see Appendix B).

Disturbance was widespread over the ESU, and predominantly of high intensity (Fig.17). Disturbance patterns varied over space, time, and land ownership. Some river systems have experienced higher disturbance than others (Fig. 18). 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. 19. 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 disturbance by land ownership has shown a dramatic shift (Fig. 20.) 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 private industrial 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.

The recent availability of Landsat images, along with the development of tools for analysis, allowed a comprehensive, uniform picture of disturbance patterns that was heretofore 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.

Loss/Gain of Large Wood -Future Habitat Conditions-Large wood is a key component of habitat complexity for coho salmon in the Oregon Coast 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 on primarily private, 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 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 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 of potential source of wood.

Habitat Complexity-The BRT's analysis indicates that the OC coho salmon ESU is in better condition, particularly in terms of total abundance, than it was during the previous status reviews. However, productivity remains below replacement, highlighting the long-standing concern for this ESU that freshwater habitat may not be sufficient to maintain the ESU at times when marine conditions are poor. The BRT noted that the criteria in the decision support system do not meaningfully evaluate freshwater habitat conditions for this ESU. To address this deficiency, the BRT undertook new analyses of habitat complexity across the freshwater habitat of this ESU.

The BRT relied on habitat monitoring data from the ODFW Habitat Monitoring Program. ODFW has been monitoring the wadeable stream (streams that would be shallow enough for an adult to wade across during survey efforts) portion of the freshwater rearing habitat for the OC coho salmon ESU over the past decade (1998 to present) collecting data 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, 2008). The ODFW habitat survey design is based on 1st through 3rd order streams (USGS 1:100k and ODFW 1:24k). The sampling design is based on a generalized random-tessellation stratified survey (Stevens and Olsen, 2004) that selects potential sample sites from all candidate stream reaches in a spatially balanced manner. The full survey design incorporates a "rotating panel" of sampling sites; 25 percent of the sites are surveyed annually, 25 percent every 3 years, 25 percent every 9 years, and 25 percent new surveys each year. This provides a balanced way to monitor short-term and long-term trends and to evaluate new areas. Due to the availability of these data, the BRT was able to examine trends in habitat complexity over the past 11 years.

In addition, ODFW provided more information to the BRT on the status of aquatic habitats in the OC coho salmon ESU in the form of presentations, comments, and a publication (Anlauf et al., 2009, ODFW 2009a). ODFW analyzed trends in individual stream habitat attributes, including wood volume, percent fine sediments and percent gravel. They analyzed these attributes separately as significant linear trends by year in the North Coast, Mid-Coast, Umpqua River, and Mid-South Coast strata. They also analyzed winter rearing capacity for juvenile coho salmon with their Habitat Limiting Factors Model (HLFM (version 7)), which integrates habitat attributes. This model emphasizes percent and complexity of pools, and amount of off-channel pools and beaver ponds. In the ODFW/Anlauf et al. (2009) HLFM analysis, ODFW used parametric statistical methods to produce a point estimate of habitat condition. They concluded that for the most part, at the ESU and strata scale, habitat for the OC coho salmon has not changed significantly in the last decade. They did find some small but significant trends. For instance the Mid-South Coast Stratum did show a positive increase in winter rearing capacity.

The BRT was concerned that the analysis of trends of individual habitat attributes presented by ODFW/Anlauf et al. (2009) does not capture interactions among the various habitat

attributes and does not adequately represent habitat complexity. In addition, the HLFM analysis presented by ODFW/Anlauf et al. (2009) used monitoring data for sites that had been surveyed only once or twice. The BRT concluded that using sites that had been visited at least three times would enhance their ability to discern trends. To address these concerns, the BRT: (1) asked ODFW to re-run the HLFM using only data from sites that had been surveyed at least three times during the 1998--2008 period, and (2) used the ODFW habitat monitoring data in a model developed by the U.S. Forest Service Aquatic and Riparian Effectiveness Monitoring Program (AREMP) (Reeves et al. 2004; Reeves et al. 2006). For the re-running of the HLFM analysis, ODFW estimated both summer and winter rearing capacity (the ability to predict summer rearing capacity was a new function of the model not available at the time Anlauf et al. (2009) prepared their report). In the AREMP model, the BRT used the ODFW monitoring program's data for key wood pieces, residual pool depth and percent fine sediment to generate habitat complexity indicators for stream reaches within populations of the OC coho salmon. Using several models allowed the BRT to compare multiple estimates of stream habitat complexity.

The BRT anticipated that there may be spatial structure in trends of habitat complexity patterns over time due to biogeographic differences present at the scale of strata. For instance, habitat complexity in streams in the Umpqua River Stratum might be expected to change at a rate different than the streams in the North Coast Stratum. This is because the Umpqua River Stratum is further south and drains part of the Cascade Mountains, while the North Coast streams are at the northern extent of this ESU's range and drain only the Oregon Coastal Mountains. There are biological, geological, hydrological, and precipitation pattern differences that affect stream habitat conditions in these basins. The BRT therefore applied a Bayesian mixed regression model to estimate rate of change for habitat complexity scores at the stratum, population and site (habitat monitoring trend site) levels, in contrast to the analytical method employed by ODFW/Anlauf et al. (2009). For more information on methods, see Appendix E.

The results from the trend analyses generated by both the AREMP and HLFM (second run of the model at the BRT's request) were negative (see Table 15), indicating there is a high likelihood that habitat complexity has declined over the past decade. General patterns among the AREMP channel condition, the HLFM summer rearing capacity, and the HLFM winter rearing capacity were consistent. All three modeling results showed a moderate probability that habitat complexity has declined across the range of this ESU. The North Coast Stratum and Mid-South Coast Stratum showed the strongest and most consistent declines. In the Mid-Coast Stratum, the HLFM models showed no trend in summer and winter juvenile rearing capacity, while the AREMP models showed moderate decline in channel condition. The biggest difference between model results was observed in the Umpqua River Stratum. The AREMP model showed no trend in channel condition, while the HLFM models showed a strong decline in summer and winter juvenile rearing capacity. There was no consistent pattern in the differences between model results; in the Mid-Coast Stratum the AREMP showed declines while the HLFM models did not. In the Umpqua River Stratum, the HLFM models showed declines while the AREMP model did not. There were no strong positive trends observed in any stratum. The BRT's analyses indicate that habitat complexity over the ESU has not improved over the past decade. At best, habitat complexity has been holding steady in some areas while declining in others.

Table 15. Habitat complexity analysis results.

STRATUM	CHANNEL CONDITION		SUMMER PARR		WINTER JUVENILES	
	Slope	Pr<0	Slope	Pr<0	Slope	Pr<0
ESU	-0.01	0.87	-0.04	0.83	-0.02	0.87
North Coast	-0.02	1.00	-0.02	0.80	-0.02	0.90
Mid-Coast	-0.01	0.88	0.02	0.24	0.00	0.48
Mid-South Coast	-0.02	1.00	-0.08	1.00	-0.03	0.99
Umpqua River	0.00	0.48	-0.08	1.00	-0.03	0.99

Like the ODFW/ Anlauf et al. (2009) trend analysis of individual habitat attributes, the BRT's analyses found that habitat complexity across the ESU did not improve over the period of consideration (1998--2008) regardless of the habitat metric chosen for comparison. The ODFW/ Anlauf et al. (2009) trend analysis based on individual habitat attributes found no evidence of trends in the Umpqua River or Mid-Coast strata. In the BRT analyses, results from the AREMP channel complexity model do not show a trend up or down in the Umpqua River Stratum. However, the HLFM summer and winter rearing capacity analyses (second run of the model conducted at the BRT's request) do show negative trends in the Umpqua River Stratum. The AREMP channel complexity and HLFM model results for the Mid-Coast Stratum are mixed, with no consistent indication of a trend in either direction.

In the ODFW/Anlauf et al. (2009) trend analysis of individual habitat attributes, all of the statistically significant trends in habitat complexity were observed in the North Coast and Mid-South Coast strata (Anlauf et al., 2009). The results for the North Coast Stratum showed a declining trend in sediment and wood volume, but an increase in gravel. The Mid-South Coast Stratum showed an increase in sediment but a decreasing trend in the proportion of gravel. Although the ODFW /Anlauf et al. (2009) analysis of individual habitat attributes showed that trends in gravel and sediment in the North Coast and Mid-South Coast strata are in opposite directions, the multivariate AREMP channel condition analysis performed by the BRT found that both North Coast and Mid-South Coast strata showed strong negative declines. While these results may seem contradictory, the observation that individual metrics (ODFW trend analysis) behave differently than integrated, multivariate indicators (AREMP and HFLM analyses) is a key point -- fish habitat is multidimensional, potentially declining even as components such as large wood or sediment increase at different spatial scales.

The ODFW/Anlauf et al. (2009) HLFM model run showed an 8.9 percent annual increase in winter rearing capacity in the Mid-South Coast. The BRT's results (including the second running of the HLFM model by ODFW) showed that the Mid-South Coast Stratum had the most certain negative trends for AREMP channel condition and HLFM summer and winter rearing capacity analyses. Compared to the 8.9 percent estimated increase in winter capacity by ODFW/Anlauf et al. (2009) for the Mid-South Coast Stratum, the second run of the HLFM summer and winter rearing model estimated a summer capacity decline of 8 percent and a winter capacity decline of 3 percent.

There are several important differences between the BRT analyses and the ODFW/Anlauf et al. (2009) analyses. These differences are likely responsible for different conclusions. First, the habitat variables considered in the BRT analyses represented aggregate indices (winter rearing capacity score, summer rearing capacity score, or AREMP Channel Condition score). One portion of the ODFW/Anlauf et al. (2009) trend analysis examined trends only in measured individual habitat variables (wood volume, fine sediment, gravel), although the HLFM winter rearing capacity analysis produced an aggregate index. The second difference is that for the HLFM winter rearing capacity analysis, ODFW/ Anlauf et al. (2009) utilized the entire suite of sampled sites for wood volume, fine sediment and gravel, and the second run of the HLFM winter and summer rearing capacity analysis used a subset of sites sampled (only those sites that had been sampled 3 times). A third important difference is the model framework used. The BRT analysis was done using Bayesian methods as opposed to the parametric statistical methods employed by ODFW.

In summary, the BRT considered the quality of available freshwater habitat using revised data sets from ODFW. The BRT examined evidence of trends in complexity, with the understanding that an increasing trend would indicate that stream habitat was improving. The BRT found that, for the most part, stream complexity is decreasing. The BRT noted that legacy effects of splash damming, log drives, and stream cleaning activities still affect the amount and type of wood and gravel substrate available and, therefore, stream complexity across the ESU (Miller, 2009; Montgomery et al., 2003). Road densities remain high and affect stream quality through hydrologic effects like runoff and siltation and by providing access for human activities. Beaver (*Castor canadensis*) activities, which produce the most favorable coho salmon rearing habitat especially in lowland areas, appear to be reduced. Stream habitat restoration activities may be having a short-term positive effect in some areas, but the quantity of impaired habitat and the rate of continued disturbance appears to be outpacing the efforts to restore complex instream habitat.

Stream Complexity Summary- Stream complexity 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 reduced the complexity of today's Oregon coastal streams. 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 stream complexity across the ESU.

The BRT analyzed the complexity of available freshwater habitat using the well established methods of the AREMP channel complexity and HLFM winter and summer rearing capacity models. These models utilized updated ODFW data sets. Newly available Landsat data were analyzed to examine disturbance to the landscape of the OC Coho Salmon ESU. Other disturbance, such as roads, were discussed with reference to their effects on coho smolt densities from Washington and British Columbia. 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 OC Coho Salmon ESU and an analysis based on published literature.

Legacy effects of splash damming, log drives and stream cleaning activities still affect the amount and type of wood and gravel substrate available and, therefore, stream complexity across the ESU (Miller 2009, 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 sinuous with pools and side-channels favored by coho salmon offering higher capacity for spawning and rearing. Eleven-year trends of stream complexity were analyzed at the level of the stream, population, and stratum (AREMP and HLFM version 7). The ESU as a whole showed decline of complexity over time in both protocols, as did the North Coast and Mid-South Coast strata. The results for the Mid-Coast Stratum were mixed depending on the protocol and there is strong evidence for the Umpqua River Stratum declining in stream complexity with the HLFM protocol.

To help understand these patterns we examined several other lines of evidence. Clearcut logging removes wood from upslope and disturbs the riparian zone. This activity 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 enabled us to look at patterns of clearcuts and thinning from 1986 to 2009. Disturbance activities were widespread throughout the ESU, with about 40% of the total forest area experiencing disturbance in the 23 year period. Disturbance rates varied by basin, but there was no evidence of a general reduction in the pace of logging. The cumulative percent of basin area was highest in the Siletz basin, 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.

These patterns of disturbance caused by forestry activities are consistent with other information (ODFW 2005c, 2009) 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. Loss of beaver and their dams has been identified by ODFW (OCSRI 1997, Oregon Coast Coho Conservation Plan 2005) 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. Continued loss of this important keystone species constitutes a continuing risk to stream complexity and impediment to habitat improvement.

In summary, there is weak indication of improvement in stream complexity in the Mid-Coast Stratum, with stronger evidence of decline in the Mid-South Coast and Umpqua River strata. Higher disturbance rates in the southern basins are consistent with the pattern of complexity. 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 produce the most highly favorable coho salmon rearing habitat, appear to be reduced, and recovery of beaver populations is impaired by their classification as a nuisance species. Stream

habitat restoration activities may be having a short-term positive effect in some areas, but the quantity of impaired habitat and the rate of continued disturbance appears to be outstripping the efforts to restore complex instream habitat.

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 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 16) 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. 21). Land use is projected to change in the ESU- primary changes are expected to be from agriculture, forest and rural residential to urban (Table 17). Figure 21 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).

Table 16. Results of Kline (2003) by biogeographic stratum in Oregon Coast Coho Salmon ESU.

STRATUM	YEAR	LAND USE %		
		Other	Rural Residential	Urban
1994				
Lakes		91.87	7.18	0.96
Mid-Coast		97.91	1.88	0.21
Mid-South Coast		96.61	2.32	1.07
North Coast		97.31	2.51	0.18
Umpqua		97.15	2.48	0.36
2044				
Lakes		92.85	5.59	1.56
Mid-Coast		97.22	1.93	0.85
Mid-South Coast		95.69	2.67	1.64
North Coast		96.11	2.99	0.89
Umpqua		95.82	3.29	0.88
2094				
Lakes		89.95	6.47	3.58
Mid-Coast		95.58	3.21	1.21
Mid-South Coast		93.05	4.66	2.3
North Coast		91.97	5.89	2.14
Umpqua		93.32	4.97	1.71

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. 22, Table 17) (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.

Conversion of lower disturbance land use to higher disturbance 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 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 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 agricultural are dependent on many factors including economic conditions and land use planning and are therefore uncertain. 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.

Conversion of lower disturbance land use to higher disturbance 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 NWR (NMFS1997c). The BRT considered that the existing land use in the ESU was reflected in the current biological status of OC coho salmon, however, the effects of conversion of land to uses with high levels of impervious surface in the future were considered a future if yet unquantified threat to OC coho salmon populations.

Table 17. Change in land use types predicted by Lettman et al. 2009.

LAND USE TYPE	LAKES STRATUM			MID-COAST STRATUM			MID-SOUTH COAST STRATUM			NORTH COAST STRATUM			UMPQUA STRATUM		
	05	35	hectares	05	35	hectares	05	35	hectares	05	35	hectares	05	35	hectares
%Wildland forest	81.56	81.09	-266	93.95	93.76	-1065	85.41	85.18	-1157	94.0	94.84	+ 4145	87.88	87.63	-3036
%Mixed forest agriculture	0	0	0	1.67	1.66	-56	4.80	4.80	0	0.59	0.50	-444	5.61	5.52	-1093
%Intensive Ag	1.06	1.06	0	1.18	1.18	0	5.0	4.93	-352	2.82	2.58	-1184	4.12	3.84	-3400
%Low density residential	5.64	6.07	+244	2.57	2.56	-56	3.33	3.44	+553	1.63	2.03	+ 1977	1.60	1.98	+4615
%Urban	0.49	0.53	+23	0.44	0.67	+1288	0.86	1.07	+1057	0.59	0.71	+592	0.55	0.79	+2914
% Other	11.25	11.25	0	0.18	0.16	-112	0.59	0.58	-50	0.37	0.34	-148	0.24	0.24	0

Land Management Loss/Gain of Estuarine Habitat (Life History Diversity)

The Oregon coastal drainages supporting independent OC coho salmon populations terminate in tidally influenced freshwater wetland/estuarine habitats (e.g., Good, 2000). Sampling in coastal rivers from northern California to Alaska indicates that coho salmon juveniles are often present in these lower river/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, Sandercock 1991, Koski, 2009). Chapman (1962) used the term 'nomads' to characterize coho salmon juveniles moving downstream between emergence and early fall. However, little direct quantitative 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.

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. Koski (2009) summarized information from more 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.

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 lower Clearwater River, a major tributary to the Queets River on the Washington coast (Peterson, 1982). A portion of the coho salmon juveniles that had emigrated downstream and reared over the summer in the brackish portion of Winchester Creek (South Slough, Coos Bay Oregon) migrated into off-channel beaver pond habitats to overwinter (Miller and Sadro, 2003). Wallace & 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. Koski (2009) 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 to rear in estuarine marsh habitats. Scale pattern analysis of adult returns indicates that some of these juveniles migrate to

sea as subyearlings. Between 1997 and 2003, the annual proportions of adult coho returning to the Salmon River that entered the ocean as subyearlings varied from 1% to 18% (Jones et al. 2007).

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 for downstream migrating coho salmon fry. The stream estuary ecotone is defined as the transition zone from tidal fresh to tidal brackish waters. This zone is characterized by low salinity, warm temperatures in the summer, and an abundance of food for juvenile salmonids. In addition to serving as summer rearing habitats, these brackish water transition zones may serve as acclimation areas allowing coho salmon fry to adapt to the higher salinity levels associated with downstream subtidal reaches. Examples of Oregon Coastal 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).

Two recent reports summarize estimates of current and historical tidal wetland habitats within Oregon coastal drainages with independent coho salmon populations (Good 2000, Adamus et al. 2005). Although the estimated quantities of wetland habitat loss by these two sources vary, the two analyses yield similar trends among coastal basins (Tables D-3 and D-4 in Appendix D).

Each of the major biogeographic strata identified by the ONCC TRT include independent populations with a relatively large amount of estuarine/wetlands habitat (Table 20; Fig. 23). Although the population order differs among the two analyses, each identifies the same four populations as having the largest estuarine wetlands habitats (Table 20). The differences among the two studies are likely attributable to alternative methods for translating GIS mapping data, including selection criteria for calculating the areas of diked and filled wetlands.¹⁶

Table 18. Population or population aggregates with the largest estimated area of intertidal marsh habitat.

Rank	Good (2000)	Adamus et al. (2005)
1	Coos Bay	Umpqua River
2	Coquille River	Coquille River
3	Tillamook Bay	Coos Bay
4	Umpqua River	Tillamook Bay

¹⁶ (R. Scranton Bonneville Power Administration, pers. communication, November, 2009).

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 (see Table 18). The Umpqua River represents the largest single drainage on the Oregon coast and includes four independent populations. Adamus et al. (2005) similarly estimated the highest proportion of historical lower river wetlands habitat in the Umpqua River. 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 rearing has declined substantially relative to historical estimates across all of the biogeographic strata (Table 19, Fig. 24). 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. Estuarine 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 and USFWS projects are incorporated into the summary Tables D-3 and D-4 in Appendix D.

Aggregated across Oregon coastal coho salmon independent populations recent restoration efforts have targeted a total area equivalent to 14-20% of current baseline of intertidal habitat (Table 19). 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 one drainage, the Nestucca River, accounted for the change in the aggregate North Coast area total. 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 19).

The OC coho salmon biological recovery criteria directly consider the status of tidally influenced habitats at the population and ESU levels (Wainwright 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.

Table 19. Summary of recent restoration vs. current and historical estimates of intertidal marsh habitats aggregated across populations within Oregon Coastal Coho Salmon ESU biogeographic strata.

BIOGEOGRAPHIC STRATA	RECENT RESTORATION VS. CURRENT (%)		RECENT RESTORATION VS. HISTORICAL (%)	
	Good	Adamus et al.	Good	Adamus et al.
North Coast	14	11	0.03	0.02
Mid-Coast	19	11	0.07	0.04
Umpqua	2	2	0.01	0.01
Mid-South Coast	37	28	0.07	0.03
Total	20	14	0.05	0.02

Nonetheless, the results of recent coho salmon surveys imply that beyond the potential effects on the rearing capacity of coastal basins, widespread estuarine wetland losses have likely diminished the expression of subyearling migrant life histories within and among coho salmon populations. This interpretation is supported by recent studies in Salmon River, where restoration of large amounts of wetland habitat has expanded life history variation within the Chinook salmon population, and thereby, may have strengthened population resilience to changing environmental conditions (Bottom et al. 2005). The effect of estuarine rearing habitat losses and diminished life history diversities may already be reflected in current biological status. However, with an increasingly variable marine ecosystem, the loss of life history diversity may constitute a future threat.

Future threats to OC coho salmon from loss of estuarine habitat may also come in the form of sea level rise in Oregon's estuaries. If the human response to sea level rise is to raise the protection level of dikes and levees, then there will be widespread loss of salt marsh habitat in favor of mudflats because the opportunity for salt and brackish marshes to move to higher ground will be blocked by the protection structures. Salt and brackish marshes are substantial contributors to the estuarine food chain in direct and indirect ways (Gray 2005). Loss of more marshlands through sea level rise could have a significantly negative effect on feeding and rearing in estuarine habitats.

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 on the Oregon Coast in the OC Coho Salmon ESU that were converted to 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 9,3831 acres, lake associated wetlands were reduced by only 13 acres and subtidal habitat suffered 0 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 20, 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.

Table 20. Summary of Wetland Fill, Compensatory Wetland Creation, Enhancement and Restoration, and OWEB-Funding Restoration Projects (non-mitigation) authorized/completed from July 1, 2000 to June 30, 2004 in acres (Table 1, ODSL 2005).

COUNTY	WETLAND FILL PERMITTED BY DSL (COUNTY AREA)	CWM REQUIRED BY DSL (CREATION, ENHANCEMENT OR RESTORATION)*(COUNTY AREA)	OWEB-FUNDED WETLAND RESTORATION PROJECTS (NON-MITIGATION) (ESU)
Clatsop	5.2	4.3	
Coos	9.0	20.1	
Douglas	41.2	90.1	(Dawson Creek) 30
Lane	48.7	44.4	(EnChanted Valley) 30
Lincoln	.3	.4	(Lint Slough) 70
Tillamook	.6	1.8	
Totals	105.0	161.2	130

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.¹⁷ 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

¹⁷ Joy Vaughn, ODSL. Pers. Comm. Dec. 2009.

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 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.

Land Management-Mining

Mining in general and gravel mining in particular was identified as a factor for decline in NMFS (1997). Until recently, gravel mining, particularly in the Umpqua and Tillamook River Basins has been a serious concern to fishery managers. 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 13 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. 25 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. 26 (ODEQ 2007) the temperature impairments in the OC Coho Salmon ESU are 40% of OC coho salmon distribution stream miles.

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 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, 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 *N. 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 *Nanophyetus 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. 26) and with the expectation of rising stream temperatures due to global climate change, increases in infection rates of juvenile coho by parasites 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 2004). However, when examining the question of predation, the IMST (1998) 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 conditions, the size of the predator and availability of salmon juveniles. They concluded, that when populations are low, however, predation can have a significant effect on extinction risk. Their conclusion agrees with Fresh (1997) that predation is probably not a primary factor in OC coho salmon population declines.

Birds and Marine Mammals-Cormorants (*Phalacrocorax* spp.), terns (*Sterna* spp.), brown pelicans (*Pelecanus occidentalis*), sooty shearwaters (*Puffinus griseus*), common murre (*Uria aalge*), mergansers (*Mergus* spp.), gulls (*Larus* spp.), belted kingfisher (*Megascops 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 system, terns are perceived to affect juvenile salmonid survival significantly, (citation) but river basins in the OC Coho Salmon ESU

do not have dredge spoil islands to attract large tern colonies that provide access and concentrated predation of juveniles migrating to sea.

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 at present. The breeding population in the north coast stratum has been severely affected by bald eagle predation and have abandoned their nesting sites there. 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.¹⁸ The IMST (1998) reviewed the literature for OC coho salmon and concluded that there is little evidence to suggest that avian predation was a significant factor for the decline of the species.

Because of the abundance and visibility of marine mammal predators on the Oregon Coast, and their interactions with fishers and other users of coastal resources, the perception is that reducing predation by harbor seals and California sea lions is important for the restoration of OC coho salmon (Smith et al. 1997). However, 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.

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.”

NMFS (1997) 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.

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 (1997) 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 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.”

It is possible that changes in management of various factors such as hatchery releases could lead to higher impacts of avian and mammal predation on OC coho salmon in some populations because predators cue in on the large numbers of fish released at one time, and wild fish can be entrained in hatchery releases¹⁹

Exotic Fish- In contrast to mammalian and avian predators discussed above, OC coho salmon have not evolved with exotic and invasive fish species. Fish predation can be a

¹⁸ R. Lowe, Pers. Comm. Oct. 2009

¹⁹ Robert Buckman ODFW District Biologist Pers. Comm. November 2009.

significant source of mortality of coho salmon juveniles in lake and slow water systems. Largemouth bass is a particularly efficient predator of juvenile coho salmon (Bonar 2004). Smallmouth bass is also an efficient predator on juvenile coho salmon.²⁰

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 have produced consistent returns during that time period. However, the effect of the introduction of exotic fish in the Tenmile lakes system in the 1970s show the effect of exotic fish on OC coho salmon that may increase with increasing temperatures in the lakes and slow water areas of the Oregon Coast. The Tenmile Lakes returns plummeted from highs of over 28,000 adult spawners in 1972 to nearly zero in 1978 after the lake was treated with rotenone). An attempt was made to rid the lakes of warmwater fish with rotenone and returns may reflect that treatment in the years immediately afterward. However, returns in the Tenmile Lakes system remain substantially lower than returns prior to the introduction of the exotic fish. For Siltcoos and Tahkenitch Lakes, which had introductions of these warm water game fish in the 1930's it is impossible to discern changes due to lack of data that far back in the time series. Effects of current populations of exotic warmwater fish are presumably reflected in OC coho salmon current biological status of these populations.

The effects of these exotic 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 because summer temperatures in these systems favor exotic fish. (ODFW 2005g).

EPA (EPA 2009) commented that exotic fish are capable of ecosystem changing effects as well of those of predation. Exotic 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. Predation and competition, particularly in light of the warming water temperatures from global climate change, could seriously affect the lakes and slow- water rearing life history of OC coho salmon. As water temperatures increase, warm water fish will be at an even greater advantage to coho in lake and slow water situations in both predation and competition.

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 21.

²⁰ Lance Kruzic NWR, Pers Comm. Dec. 2009

Table 21. BRT summary comments on threats.

2009 BRT THREATS	COMMENTS
Agriculture and Forestry	
Stream complexity (includes disturbance, roads, splash damming, stream cleaning substrate sediment)	Legacy effects, continued decline
water temperature	High certainty of worsening with GCC
estuary, wetland habitat loss - due to effect on life history diversity	Legacy effects, some improvements, high certainty of negative effects due to sea level rise (GCC)
water availability	High certainty of worsening with GCC
beaver dam loss- due to effect on stream complexity	Legacy effects, loss may be increasing in some systems
Fish Passage Restriction	Legacy effects, future threat and severity of problem unknown due to poor data
Gravel mining:	Legacy effects, future threats uncertain
Land Use conversion-Urbanization	
floodplain functions	not addressed
instream wood-	addressed in stream complexity analysis, significant future threat
substrate sediment-	addressed in stream complexity analysis, significant future threat
stormwater	not addressed
Disease and Parasitism	Emerging problem, potentially worsening with higher stream temps, a moderate certainty with GCC
Artificial Propagation-	low threat if management continues
Harvest	low threat if management continues
Predation	Emerging problem, potentially worsening with higher stream temps, a moderate certainty with GCC
Global Climate Change	Emerging problem see Table 11- many effects- low to high certainty
Marine Productivity	Emerging problem, high certainty of worsening with GCC, increased marine variability
Drought	Low certainty of reduced summer precipitation with GCC, may be shorter term variability
Floods	Moderate certainty of increased flood frequency and intensity
Wildfire	High certainty of increased wildfire risk due to higher summer temperatures with GCC
Tsunami	Not addressed

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 "not at risk" of extinction. Under the ESA, a species or distinct population segment (DPS) is the listing unit. For Pacific salmon, the DPS is known as the Evolutionarily Significant Unit (ESU) (Waples 1991). 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 compensatory 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. The overall extinction risk determination reflected informed professional judgment by each BRT member. This assessment was guided by the results of the decision support system (Table 6) and the risk matrix analysis (see below), 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), Pacific herring (Stout et al. 2001b; Gustafson et al. 2006), and black abalone (Butler et al. 2008). 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 22). 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. These 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, each BRT member assigns a risk score (Table 22) to each of the four demographic criteria. The scores are 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 helps to integrate and summarize a large amount of diverse information, there is 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 sub-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 demographic 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 species extinction risk categories, reflecting their opinion of how likely that category correctly reflects the true species status. 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), Pacific herring (Stout et al. 2001a; Gustafson et al. 2006), Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), and black abalone (Butler et al. 2008).

Table 22. Risk Matrix utilized by the BRT to capture comments and assessment of risk.

Risks for each VSP factor are ranked on a scale of 1 (very low risk) to 5 (very high risk):

1. Very Low Risk. Unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors.
2. Low Risk. Unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.
3. Moderate Risk. This factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.
4. High Risk. This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the foreseeable future.
5. Very High Risk. This factor by itself indicates danger of extinction in the near future.

Oregon Coast Coho Salmon ESU Risk Matrix

Risk category	Current status/current trends	With changes expected in the future
<u>Abundance</u> Comments:		
<u>Growth Rate/Productivity</u> Comments		
<u>Spatial Structure and Connectivity</u> Comments:		
<u>Diversity</u> Comments:		
<u>Threats</u> Comments:		

For the OC Coho Salmon ESU, the BRT conducted both the risk matrix analysis and the overall extinction risk assessment under two different sets of assumptions:

Case 1: The BRT evaluated extinction risk based on the demographic risk criteria (abundance, growth rate, spatial structure and diversity) currently exhibited by the ESU, assuming that the threats influencing ESU status would continue unchanged into the future. This case in effect assumes that all of the threats evaluated in the previous section of the report are fully manifest in the current ESU status and will in aggregate neither worsen nor improve in the future.

Case 2: 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.

Summary of Risk Conclusions

The risk matrix scores differed considerably for the two cases the BRT evaluated (Tables 23 and 24). When only current biological status was considered, the median scores for each demographic risk criterion was 2 (low risk) and the mean scores ranged from 2 to 2.47. Current abundance was rated as less of a risk factor than productivity, spatial structure and diversity (Table 23). When future conditions were taken into account, median scores increased to 3 (moderate risk) for each factor, and mean scores ranged from 2.8 for abundance to 3.27 for productivity (Table 24). BRT members also separately scored the overall risk associated with threats that they believed were not yet manifest in current demographic criteria, and the median score for these threats was 4 (high risk).

Table 23. Assessment of the risk associated with each of four demographic risk factors, assuming that recent conditions continue in the future and that the threats facing the ESU are largely manifest in its current biological status (case 1). Risks for each demographic factor are ranked on a scale of 1 (very low risk) to 5 (very high risk).

	ABUNDANCE	PRODUCTIVITY	STRUCTURE	DIVERSITY
Mean	2.0	2.47	2.33	2.33
Median	2	2	2	2
Minimum	1	1	2	2
Maximum	3	4	4	4

Table 24. Assessment of the risk associated with each of four demographic risk factors, taking into account predicted positive or negative changes in ongoing or future threats (case 2). Risks for each demographic factor are ranked on a scale of 1 (very low risk) to 5 (very high risk).

	ABUNDANCE	PRODUCTIVITY	STRUCTURE	DIVERSITY	THREATS
Mean	2.8	3.27	3.13	3.13	3.60
Median	3	3	3	3	4
Minimum	2	2	2	2	3
Maximum	4	4	5	5	4

The assessment of overall extinction risk for the OC Coho Salmon ESU also differed substantially depending on what was assumed about the future (Tables 25 and 26). When only current biological status was considered, the overall assessment was roughly split between low risk (49% of the likelihood points) and moderate risk (44%), with high risk receiving 7% of the likelihood points. The BRT's evaluation of risk under this scenario largely reflects the results of the DSS (Table 6), which the BRT interpreted as indicating uncertainty about ESU status under current conditions. When the BRT evaluated risk while taking into account future changes to threats, the assessment became more pessimistic with 25% of the likelihood points falling in low risk, 54% in moderate risk, and 21% in high risk (Table 25). The increases in the proportion of the likelihood points in the moderate and high risk categories reflects the BRT's conclusions that the threats facing the OC Coho Salmon ESU are likely to grow more severe in the future.

Table 25. Overall assessment of extinction risk, taking into account predicted positive or negative changes in ongoing or future threats (case 2). Each of 15 BRT members allocated 10 likelihood points among the three status categories.

	ESU at High Risk	ESU at Moderate Risk	ESU at Low Risk
Percent of points	0.21	0.54	0.25

Under the assumption that current conditions continue into the future, the BRT's primary concern was that current freshwater habitat conditions may not be able sustain the ESU in the face of normal fluctuations in marine survival. 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). Like the 1997 and 2003 BRT's, the current BRT was also concerned about the long-term downward trend in productivity of this ESU (Fig. 8). The BRT noted that natural spawning abundance and total (pre-harvest) adult abundance has increased over the past decade due to a combination of improved ocean survival, lower harvest rates, and reduced hatchery production. However, the BRT was concerned that much of the increase in pre-harvest adult abundance could be attributed to increases in marine survival that are expected to fluctuate naturally, with a smaller proportion of the increase

attributable hatchery and harvest recovery actions (Buhle et al. 2009). In addition, although some increase in abundance has been seen in the past 10 years, the period prior to the last 10 years were marked by historically low abundance numbers that included hatchery fish. Moreover, the increase in the past 10 years remain extremely low compared to historical estimates. 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-19990's. On balance, however, the BRT was uncertain about the ESU's ability to survive another prolonged period of low ocean survivals, and therefore was uncertain about the overall risk status of the ESU under current conditions (Table 26).

Table 26. Overall assessment of extinction risk, assuming that recent conditions continue in the future and that the threats facing the ESU are largely manifest in its current biological status (case 1). Each of 15 BRT members allocated 10 likelihood points among the three status categories.

	ESU at High Risk	ESU at Moderate Risk	ESU at Low Risk
Percent of points	0.07	0.44	0.49

The BRT as a whole was more certain about overall risk status when taking into account predictable changes to the threats facing the population, with a clear majority of the likelihood points falling in the moderate or high risk categories (Table 25). The BRT was particularly concerned that changes in environmental conditions, including 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). The BRT evaluated the available scientific information on the effects of predicted climate change on the freshwater and marine environments inhabited by OC Coho Salmon ESU (Appendix C). Although there was considerable uncertainty about the magnitude of most effects, 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 12). Some members of the BRT noted that freshwater effects of climate change may not be as severe in the Oregon coast as in other parts of the Pacific Northwest, and the distribution of overall risk scores reflects some of this uncertainty.

In addition to effects due to global climate change, the BRT was also concerned that freshwater habitat for the ESU would continue to degrade from current conditions due to local effects. In the BRT's stream complexity analysis, there is strong indication that habitat conditions have declined over the past decade. Conversion of forests to urban uses was also a concern (e.g., Kline et al. 2001), particularly for North Coast, Mid-South Coast, and Umpqua River strata. The BRT was also concerned that a lack of protection for beaver would result in downward trends for this important habitat forming species. Some BRT members, however, felt that the data indicating that freshwater habitat conditions were likely to worsen from current levels in the future were equivocal, and the distribution of risk matrix and overall threats scores reflects this uncertainty.

The BRT did note 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 survival for these populations in future. In addition, the BRT expected that reductions in hatchery releases that have occurred over the past decade would 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.

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.

References

- Abbe, T. B., and D. R. Montgomery. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. *Regulated Rivers: Research and Management* 12:201–221.
- Adamus, P.R., J. Larsen, and R. Scranton. 2005. Wetland Profiles of Oregon's Coastal Watersheds and Estuaries. Part 3 of a Hydrogeomorphic Guidebook. Report to Coos Watershed Association, US Environmental Protection Agency, and Oregon Depart. of State Lands, Salem.
- American Forest Resource Council. 2009. Status review for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon. RIN 0648-XO28. Aug. 20, 2009. 8p
- Anlauf, K. J., K. K. Jones, and C.H. Stein. 2009. The Status and Trend of Physical Habitat and Rearing Potential in Coho Bearing Streams in the Oregon Coastal Coho Evolutionary Significant Unit. OPSW-ODFW-2009-5, Oregon Department of Fish and Wildlife, Salem.
- Araki, H., Berejikian, B.A., Ford, M.J., and Blouin, M.S. 2008. Fitness of hatchery-reared salmonids in the wild. *Evolutionary Applications* 1: 342-355.
- Auad, G., A. Miller, and E. Di Lorenzo. 2006. Long-term forecast of oceanic conditions off California and their biological implications. *Journal of Geophysical Research* 111(C09008):doi:10.1029/2005JC003219.
- Bakun, A. 1990. Global climate change and intensification of coastal ocean upwelling. *Science* 247(4939):198-201.
- Barnett, T. P., D. W. Pierce, H. G. Hidalgo, C. Bonfils, B. D. Santer, T. Das, G. Bala, A. W. Wood, T. Nozawa, A. A. Mirin, D. R. Cayan, and M. D. Dettinger. 2008. Human-induced changes in the hydrology of the western United States. *Science* 319:1080-1083.
- Barnett, T., R. Malone, W. Pennell, D. Stammer, B. Semtner, and W. Washington. 2004. The effects of climate change on water resources in the West: introduction and overview. *Climatic Change* 62(1-3):1-11.
- Battin, J., M. W. Wiley, M. H. Ruckelshaus, R. N. Palmer, E. Korb, K. K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences, USA* 104(16):6720-6725.
- Beamish, R.J., G. A. McFarlane, and J.R. King. 2000. Fisheries climatology: understanding decadal scale processes that naturally regulate British Columbia fish populations. In P. J. Harrison, and T. R. Parsons (eds.), *Fisheries Oceanography: an integrative approach to fisheries ecology and management*, p. 94-139. Blackwell Science, Oxford.
- Beechie, T., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for restoration. *North American Journal of Fisheries Management* 14:797–811.
- Benner, P.A. 1992. Historical reconstruction of the Coquille river and surrounding landscape. Sections 3.2 and 3.3 in: Oregon Department of Environmental Quality (ed.). *Near coastal waters national pilot project: The Coquille river, Oregon. Action plan for Oregon coastal watersheds, estuary, and ocean waters, 1988-1991.* Oregon Department of Environmental Quality, Portland.

- Bigelow, P.E., L.E. Benda, J. Miller, and K.M. Burnett. 2007. Debris flows, river networks, and spatial structure of channel morphology. *For. Sci.* 53: 220-238.
- Bilby, R. E., P. A. Bisson, C. C. Coutant, D. Goodman, S. Hanna, N. Huntly, E. J. Loudenslager, L. McDonald, D. P. Philipp, B. Riddell, J. Olsen, and R. Williams. 2005. Viability of ESUs containing multiple types of populations. Independent Scientific Advisory Board for the Northwest Power and Conservation Council, ISAB Report 2005-2. Online at <http://www.nwcouncil.org/library/isab/isab2005-2.htm> [accessed 28 February 2008].
- Bilby, R.E. and J.W. Ward. 1991. Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington. *Canadian Journal of Fisheries and Aquatic Sciences* 48:2499-2508.
- Bindoff, N. L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C. K. Shum, L. D. Talley, and A. S. Unnikrishnan. 2007. Observations: oceanic climate change and sea level. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, p. 385-432. Cambridge University Press, Cambridge.
- Biosurveys. 2009. Rapid Bioassessment 2007. Prepared for Tillamook Estuary Partnership. Available at: http://www.tbnep.org/images/stories/documents/resource_center_docs/salmonids/Tillamook%20RBA%20Final%202007.pdf [Accessed May 6, 2010].
- Bograd, S. J., I. Schroeder, N. Sarkar, X. Qui, W. J. Sydeman, and F. B. Schwing. 2009. Phenology of coastal upwelling in the California Current. *Geophysical Research Letters* 36(L01602):1-5.
- Botkin, D., K. Cummins, T. Dunne, H. Reiger, M. Sobel, and L. Talbot. 1995. Status and future of salmon of western Oregon and northern California: Findings and options. The Center for the Study of the Environment, Santa Barbara, CA. Online at <http://www.naturestudy.org>) (Accessed December 2009).
- Bottom, D.L., K.K. Jones, T.J. Cornwell, A. Gray, and C.A. Simenstad. 2005. Patterns of chinook salmon migration and residency in the Salmon River estuary (Oregon). *Estuarine, Coastal and Shelf Science* 64:79-93.
- Bonar, S., B. Bolding, M. Divens, and W. Meyer. 2004. Effects of introduced fishes on wild juvenile coho salmon using three shallow western Washington lakes. Washington Dept. of Fish and Wildlife, Fish Program, Science Division. Available at: <http://wdfw.wa.gov/fish/warmwater/library/fpt04-03.pdf>. [accessed May 5, 2010].
- Booth, D.B. 1990. Stream Channel incision following drainage basin urbanization, *Water Resources Bulletin* 26: 407-417.
- Booth, D.B. 1991. Urbanization and the natural drainage system- Impacts, solutions, and prgnoses. *Northwest environmental Journal* 7:93-118.
- Bradford, M. J. 1995. Comparative review of Pacific salmon survival rates. *Canadian Journal of Fisheries and Aquatic Sciences* 52(6):1327-1338.
- Bradford, M.J., and Irvine, J.R. 2000. Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. *Can. J. Fish. Aquat. Sci.* 57: 13–16.

- Brodeur, R. D., J. P. Fisher, R. L. Emmett, C. A. Morgan, and E. Casillas. 2005. Species composition and community structure of pelagic nekton off Oregon and Washington under variable oceanographic conditions. *Marine Ecology Progress Series* 298(1):41-57.
- Brodeur, R. D., S. Ralston, R. L. Emmett, M. Trudel, T.D. Auth, and A. J. Phillips. 2006. Anomalous pelagic nekton abundance, distribution, and apparent recruitment in the northern California Current in 2004 and 2005. *Geophysical Research Letters* 33(L22S08):doi:10.1029/2006GL026614.
- Brown, C. J., E. A. Fulton, A. J. Hobday, R. J. Matear, H. P. Possingham, C. Bulman, V. Christensen, R. E. Forrest, P. C. Gehrke, N. A. Gribble, S. P. Griffiths, H. Lozano-Montes, J. R. Martin, S. Metcalf, T. A. Okey, R. Watson, and A. J. Richardson. 2009. Effects of climate-driven primary production change on marine food webs: implications for fisheries and conservation. *Global Change Biology* xx(xx):(Accepted Article).
- Bryant, G. 1994. Unpublished report dated April 1994: Status review of coho salmon populations in Scott Creek and Waddell Creek, Santa Cruz County, California. (Available from National Marine Fisheries Service, SW Regional Office, 501 W. Ocean Boulevard, Suite 4200, Long Beach, CA 90802.)
- Buhle, E.R., K.K. Holsman, M.D. Scheuerell, A. Albaugh. 2009. Using an unplanned experiment to evaluate the effects of hatcheries and environmental variation on threatened populations of wild salmon. *Biological Conservation* 142: 2449-2455.
- Burnett, K. M., G. Reeves, D. Miller, S. Clarke, K. Christiansen, and K. Vance-Borland. 2003. A first step towards broad-scale identification of freshwater protected areas for Pacific salmon and trout in Oregon, U.S.A. Pages 144–154 in J. P. Beumer, A. Grant, and D. C. Smith, editors. *Protected areas: what works best and how do we know? Proceedings of the world congress on aquatic protected areas, Cairns, Australia, 2002.* Australian Society for Fish Biology, North Beach.
- Burnett, K.M., G.H. Reeves, S.E. Clarke, and K.R. Christiansen. 2006. Comparing riparian and catchment-wide influences on salmonid habitat in Elk River, Oregon. Pages 175-196 in R.M. Hughes and L. Wang (eds), *Influences of Landscapes on Stream Habitat and Biological Communities.* American Fisheries Society Symposium 48. Bethesda, MD.
- Burnett, K.M., G.H. Reeves, D.J. Miller, S. Clarke, K. Vance-Borland, and K.R. Christiansen. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. *Ecol. Appl.* 17: 66-80.
- Butler, J., A. DeVogelaere, R. Gustafson, C. Mobley, M. Neuman, D. Richards, S. Rumsey, B. Taylor, G. VanBlaricom. 2008. Status review report for black abalone (*Haliotis cracherodii* Leach, 1814), DRAFT – 4 January 2008. NOAA Tech. Memo. NMFS-SWR-##. Online at http://swr.nmfs.noaa.gov/media/BASR_Report_Draft_11_January_2008.pdf.
- Cairns, M. J. Ebersole, J. Parker, and P. Wigington, Jr. 2005. Influence of summer stream temperatures on black spot infestation of juvenile coho salmon in the Oregon Coast Range. *Transactions of the American Fisheries Society* 134:1471-1479.
- Cederholm, C. J., and L. M. Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater River, Washington: a project summary. In E. O. Salo, and T. W. Cundy (eds.), *Streamside Management: Forestry and Fishery Interactions*, Proceedings of a Symposium held at University of Washington, 12-14 February 1986. IFR Contribution no. 57, p. 373-398. Institute of Forest Resources, Seattle, Washington.

- Chapman, D.W. (1962) Aggressive behavior in juvenile coho salmon as a cause of emigration. *J. Fish. Res. Bd. Can.* 19:1047-1080
- Chatters, J. C., D. A. Neitzel, M. J. Scott, and S. A. Shankle. 1991. Potential impacts of global climate change on Pacific Northwest spring Chinook salmon (*Oncorhynchus tshawytscha*): An exploratory case study. *Northwest Environmental Journal* 7(1):71-92.
- Chavez, F. P., and M. Messié. 2009. A comparison of eastern boundary upwelling ecosystems. *Progress in Oceanography* xxx(In press):doi:10.1016/j.pocean.2009.07.032.
- Checkley, D. M., and J. A. Barth. 2009. Patterns and processes in the California Current System. *Progress in Oceanography* xxx:(in press).
- Chilcote, M. W. 2002. Spreadsheet with 2002 Oregon steelhead escapement updates. (Available from Oregon Department of Fish and Wildlife, Fish Division, 3406 Cherry Drive NE, Salem, OR 97303.)
- Chilcote, M., T. Nickelson, and K. Moore. 2005. Oregon coastal coho assessment. Part 2: Viability criteria and status assessment of Oregon coastal coho. Oregon Dept. Fish and Wildlife, Portland. Online at <http://www.dfw.state.or.us/fish/ONFSR/final/Vol%20II%20References.pdf> [accessed 11 March 2008].
- Christensen, J. H., B. Hewiston, A. Busuioac, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton. 2007. Regional climate projections. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, p. 847-940. Cambridge University Press, Cambridge and New York.
- Christy, J. 2004. Estimated loss of salt marsh and freshwater wetlands within the Oregon coastal coho ESU. Department of State Lands Factors for Decline Report, Oregon Coastal Coho Salmon Final Assessment. Available at <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PRFNM#> [Accessed May 5, 2010].
- Cole, J. 2000. Coastal sea surface temperature and coho salmon production off the north-west United States. *Fisheries Oceanography* 9:1-16.
- Coquille Tribe. 2009. Initiation for Status Review and request for information for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon. Aug. 18, 2009. 10 p.
- Cornwell, T.J., D.L. Bottom and K.K. Jones (2001) Rearing of juvenile salmon in recovering wetlands of the Salmon River estuary. Ore. Dept. Fish and Wildlife Information Reports 2001-2005.
- Coronado, C., and R. Hilborn. 1998. Spatial and temporal factors affecting survival in coho salmon (*Oncorhynchus kisutch*) in the Pacific Northwest. *Canadian Journal of Fisheries and Aquatic Sciences* 55(9):2067-2077.
- Crone, R. A., and C. E. Bond. 1976. Life history of coho salmon, *Oncorhynchus kisutch*, in Sashin Creek, southeastern Alaska. *Fish. Bull.* 74(4):897-923.

- Crozier, L. G., A. P. Hendry, P. W. Lawson, T. P. Quinn, N. J. Mantua, J. Battin, R. G. Shaw, and R. B. Huey. 2008a. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. *Evolutionary Applications* 1(2):252-270.
- Crozier, L. G., R. W. Zabel, and A. F. Hamlet. 2008b. Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. *Global Change Biology* 14:236-249.
- Crozier, L., and R. W. Zabel. 2006. Climate impacts at multiple scales: evidence for differential population responses in juvenile Chinook salmon. *Journal of Animal Ecology* 75(5):1100-1109.
- Coulton, K., Williams, P. and P. Benner. 1996. An environmental history of the Tillamook bay estuary and watershed. Prepared for The Tillamook Bay National Estuary Project, Garibaldi, Oregon 97118. Available at: http://www.tbnep.org/images/stories/documents/resource_center_docs/watershed_area_info/Environmental%20History%20Text.pdf [accessed May 12, 2010].
- Daly, E. A., R. D. Brodeur, and L. A. Weitkamp. 2009. Ontogenetic shifts in diets of juvenile and subadult coho and Chinook salmon in coastal marine waters: important for marine survival?. *Transactions of the American Fisheries Society* 138(1420-1438).
- Diffenbaugh, N.S. 2005. Response of large-scale eastern boundary current forcing in the 21st century. *Geophysical Research Letters* 32(L19718):1-4, doi:10.1029/2005GL023905.
- Douglas County. 2009. Comments submitted for the Status Review of Oregon Coast Coho Salmon ESU. Received October 9, 2006. 29 p.
- Ebersole, J., P.J. Wigington Jr., J. P. Baker, M.A. Cairns, M. R. Church, B. P. Hansen, B. A. Miller, H. R. LaVigne, J. E. Compton and S.G. Leibowitz. 2006. Juvenile coho salmon growth and survival across stream network seasonal habitats. *Transactions of the American Fisheries Society* 2006; 135: 1681-1697.
- Einum, S., and I. A. Fleming. 2001. Implications of stocking: Ecological interactions between wild and released salmonids. *Nordic J. Freshw. Res.* 75:56–70.
- Emmett, R. L., G. K. Krutzikowski, and P. Bentley. 2006. Abundance and distribution of pelagic piscivorous fishes in the Columbia River plume during spring/early summer 1998–2003: Relationship to oceanographic conditions, forage fishes, and juvenile salmonids. *Progress in Oceanography* 68(1):1-26.
- Everest, F.H. and G.H.Reeves. 2007. Riparian and aquatic habitats of the Pacific Northwest and southeast Alaska: management history, and potential management strategies. U.S.Forest Service, General Technical Report PNW-GTR-692. Portland, Oregon.
- Fabry, V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science* 65(3):414-432.
- Farrell, A. P., S. G. Hinch, S. J. Cooke, D. A. Patterson, G. T. Crossin, M. Lapointe, and M. T. Mathes. 2008. Pacific salmon in hot water: Applying aerobic scope models and biotelemetry to predict the success of spawning migrations. *Physiological and Biochemical Zoology* 81(6):697-708.
- Feely, R. A., C. L. Sabind, K. Lee, W. Berelson, J. Kleypas, V. J. Fabry, and F. J. Millero. 2004. Impact of anthropogenic CO₂ on the CaCO₃ system in the oceans. *Science* 305:362-366.

- Feely, R.A., C.L. Sabine, J.M. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. Evidence for upwelling of corrosive "acidified" water onto the continental shelf. *Science* 320:1490-1493.
- FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, National Marine Fisheries Service, Bureau of Land Management, and Environmental Protection Agency. No. 793-071, IX-24. U.S. Government Printing Office, Washington, DC.
- Ferrari, M.R., J.R. Miller, and G.L. Russell. 2007. Modeling changes in summer temperature of the Fraser River during the next century. *Journal of Hydrology* 342:336-346.
- Fisher, J.P., and W.G. Pearcy. 1988. Growth of juvenile coho salmon (*Oncorhynchus kisutch*) off Oregon and Washington, USA, in years of differing coastal upwelling. *Canadian Journal of Fisheries and Aquatic Sciences* 45(6):1036-1044.
- Flagg, T. A., B. A. Berejikian, J. E. Colt, W. W. Dickhoff, L. W. Harrell, D. J. Maynard, C. E. Nash, M. S. Strom, R. N. Iwamoto, and C. V. W. Mahnken. 2000. Ecological and behavioral impacts of artificial production strategies on the abundance of wild salmon populations. U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-NWFSC-41.
- Flagg, T. A., and C. E. Nash, 1999. A conceptual framework for conservation hatchery strategies for Pacific salmonids. U.S. Dept. of Commer. NOAA Tech. Memo. NMFS-NWFSC-38.
- Ford, M.J., Teel, D., Van Doornik, D.M., Kuligowski, D., and Lawson, P.W. 2004. Genetic population structure of central Oregon coast coho salmon (*Oncorhynchus kisutch*). *Conservation Genetics* 5: 797-812.
- Francis, R. C., and N. J. Mantua. 2003. Climatic influences on salmon populations in the Northeast Pacific. In MacCall, A. D., and T. C. Wainwright (eds.), *Assessing extinction risk for West Coast salmon*. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-56. U.S. Department of Commerce. pp. 37-76.
- Fresh, K.L. 1997. The role of competition and predation in the decline of Pacific salmon and steelhead, In *Pacific salmon and their ecosystems: Status and future options*. Edited by D.J. Stoutder, P. A Bisson, and R. J. Naiman. Chapman and Hall, New York. Pp. 245-275.
- Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management* 10:199-214.
- Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. Special Publication 19, American Fisheries Society. Pp. 297-323.
- Garrison, R. L. 1965. Effects of rapid growth on coho maturation. *Journal of Wildlife Management* 35(4):762-766.
- Gilbert, C. H. 1912. Age at maturity of Pacific coast salmon of the genus *Oncorhynchus*. *Bull. U.S. Fish Comm.* 32:57-70.
- Godfrey, H., K.A. Henry, and S. Machidori. 1975. Distribution and abundance of coho salmon in offshore waters of the North Pacific Ocean. *Int. North Pac. Fish. Comm. Bull.* 31.
- Good, J.W. (2000). Summary of current status of Oregon's estuarine ecosystems. In: *Oregon state of the environment report 2000*. Chap. 3.3.

- Good, T.P., Waples, R.S., and Adams, P. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66.
- Grey, A. 2005. The Salmon River estuary: restoring tidal inundation and tracking ecosystem response. PhD. Dissertation, School of Aquatic and Fishery Science, University of Washington, Seattle, WA.
- Gustafson, R. G., J. Drake, M. J. Ford, J. M. Myers, E. E. Holmes, R. S. Waples. 2006. Status review of Cherry Point Pacific herring (*Clupea pallasii*) and updated status review of the Georgia Basin Pacific herring distinct population segment under the Endangered Species Act. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-76, 182 p.
- Gustafson, R. G., W. H. Lenarz, B. B. McCain, C. C. Schmitt, W. S. Grant, T. L. Builder, R. D. Methot. 2000. Status review of Pacific hake, Pacific cod, and walleye pollock from Puget Sound, Washington. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-44, 275 p.
- Hamlet, A. F., and D. P. Lettenmaier. 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S. *Water Resources Research* 43(W06427): [doi:10.1029/2006WR005099].
- Hamlet, A. F., P. W. Mote, M. P. Clark, and D. P. Lettenmaier. 2005. Effects of temperature and precipitation variability on snowpack trends in the western United States. *Journal of Climate* 18(21):4545-4561.
- Hamm, D. In prep. Using ecoinformatic tools to evaluate salmonid habitat restoration efforts.
- Hard, J. J., J. M. Myers, M. J. Ford, R. G. Kope, G. R. Pess, R. S. Waples, G. A. Winans, B. A. Berejikian, F. W. Waknitz, P. B. Adams, P. A. Bisson, D. E. Campton, R. Reisenbichler. 2007. Status review of Puget Sound steelhead (*Oncorhynchus mykiss*). U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-81, 117 p.
- Hartt, A. C., and M. B. Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. *Bulletin (International North Pacific Fisheries Commission)* 46:1-105.
- Healey, M. C. 1991. The life history of Chinook salmon (*Oncorhynchus tshawytscha*). In C. Groot and L. Margolis (eds.), *Life history of Pacific salmon*, p. 311–393. University of British Columbia Press, Vancouver, BC.
- Hoekstra, J.M., Bartz, K.K., Ruckelshaus, M.H., Moslemi, J.M., and Harms, T.K. 2007. Quantitative threat analysis for management of an imperiled species-Chinook salmon (*Oncorhynchus tshawytscha*). *Ecological Applications* 17: 2061-2073.
- Hollis, G.E. 1975. The effects of urbanization on floods of different recurrence intervals. *Water Resour. Res.* 11: 431–435.
- IMST (Independent Multi-disciplinary Science Team).1998. Pinniped and seabird predation: Implications for recovery of threatened stocks of salmonids in Oregon under the Oregon Plan for Salmon and Watersheds. Technical Report 1998-2. Available at: <http://www.fsl.orst.edu/imst/reports/1998-2.pdf> (Accessed May 5, 2010).
- IMST (Independent Multi-disciplinary Science Team). 2001. The scientific basis for artificial propagation in the recovery of wild anadromous salmonids in Oregon. Technical report 2000-1 to the Oregon Plan for Salmon and Watersheds. Governor's Natural Resources Office, Salem, OR.

- IMST (Independent Multidisciplinary Science Team). 2005. IMST review of State of Oregon's draft Oregon coastal coho assessment documents: Viability assessment, PECE certainty analysis and synthesis. Online at: <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&path=ftp/reports/Reviewer%20Comments&title=&link=#> [accessed May 5, 2010].
- ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River Basin fish and wildlife. Northwest Power and Conservation Council, Portland, Oregon, Report ISAB 2007-2. 146 p. [<http://www.nwcouncil.org/library/isab/isab2007-2.htm>]
- Institute for Natural Resources. 2005. Oregon Coastal Community Water Supply Assessment. A Report to Oregon Sea Grant in fulfillment of Program Development Grant # NA084B-RDF5. Available at: <http://ir.library.oregonstate.edu/jspui/handle/1957/534>
- IPCC. 2007. Summary for policymakers. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, p. 1-18. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.
- ISG (Independent Scientific Group). 2000. Return to the river: An ecological vision for the recovery of Columbia River salmon. Prepared for the Northwest Power Planning Council, Portland, OR.
- Jacobs, S., 2002. Calibration of estimates of coho spawner abundance in the Smith River basin, 2001; Monitoring Program Report Number OPSW-ODFW-2002-06. Oregon Department of Fish and Wildlife, Portland, Oregon.
- Jacobson, K. M. Arkoosh, A Kagley, E. Clemens, T. Collier, and E. Casillas. 2003. Cumulative effects of natural and anthropogenic stress on immune function and disease resistance in juvenile Chinook salmon. *J. of Aquatic Animal Health* 15:1-12.
- Jacobson, K. D. Teel, D. Van Doornik, E. Casillas. 2008. Parasite-associated mortality of juvenile Pacific salmon cused by the trematode *Nanophyetus salmincola* during early marine residence. *Mar. Ecol. Prog. Vol.* 354:235-244.
- Jenkins, S.H. 1979. *Castor Canadensis*. *Mammalian Species* 120:1-8
- Johnson, O.W., T.A. Flagg, D.J. Maynard, G.B. Milner, and F.W. Waknitz. 1991. Status review for lower Columbia River coho salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFSF/NWC-202.
- Johnson, M.A., and Banks, M.A. 2008. Genetic structure, migration, and patterns of allelic richness among coho salmon (*Oncorhynchus kisutch*) populations of the Oregon coast. *Canadian Journal of Fisheries and Aquatic Sciences* 65(7): 1274-1285.
- Johnson, S. L. 1988. The effects of the 1983 El Niño on Oregon's coho (*Oncorhynchus kisutch*) and Chinook (*O. tshawytscha*) salmon. *Fisheries Research* 6:105-123.
- Jones, K., T. Cornwall, D. Haring, L. Borgerson, D. Bottom, S. Simenstad and A. Bierber. 2007. Patterns of coho salmon migration and residency in Oregon estuaries. Oregon AFS presentation.
- Kahler, T., P. Roni, and T. Quinn. 2001. Summer movement and growth of juvenile anadromous salmonids in small western Washington streams. *Can. J. Fish. Aquat. Sci.* 58: 1947-1956.
- Karl, T. R., J. M. Melillo, and T. C. Peterson (eds.). 2009. *Global climate change impacts in the United States*. Cambridge University Press, New York. 188.

- Kennedy, V. S. 1990. Anticipated effects of climate change on estuarine and coastal fisheries. *Fisheries* 15(6):16-24.
- Kline, J.D., A. Moses, and R.J. Alig. 2001. Integrating urbanization into landscape-level ecological assessments. *Ecosystems*, 4(1):3-18.
- Kline, J., D. Azuma and A. Moses. 2003. Modeling the spatially dynamic distribution of humans in the Oregon (USA) Coast Range. *Landscape Ecology* 18(4) 347-361.
- Koski, K. V. 2009. The fate of coho salmon nomads: The story of an estuarine-rearing strategy promoting resilience. *Ecology and Society* 14(1):4 [online].
- Koslow, J. A., A. J. Hobday, and G. W. Boehlert. 2002. Climate variability and marine survival of coho salmon (*Oncorhynchus kisutch*) in the Oregon production area. *Fisheries Oceanography* 11(2):65-77.
- Kostow, K. 1995. Biennial report on the status of wild fish in Oregon. Oregon Department of Fish and Wildlife. (Available from Oregon Dept. Fish and Wildlife, 3406 Cherry Ave. NE, Salem, OR 97303.)
- Laufle, J. C., G. B. Pauley, and M. F. Shepard. 1986. Species profiles. Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Coho salmon. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.48).
- Lawson, P. W. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. *Fisheries* 18(8):6-10.
- Lawson, P. W., E. A. Logerwell, N. J. Mantua, R. C. Francis, and V. N. Agostini. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences* 61:360-373.
- Lawson, P.W., E.P. Bjorkstedt, M.W. Chilcote, C.W. Huntington, J.S. Mills, K.M.S. Moore, T.E. Nickelson, G.H. Reeves, H.A. Stout, T.C. Wainwright, and L.A. Weitkamp. 2007. Identification of historical populations of Coho salmon (*Oncorhynchus kisutch*) in the Oregon coast evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-79, 129 p.
- Lawson, P.W. 2009. What are we missing? Butterflies, flowers, and salmon models. Pages 33-44 in E.E. Knudsen and J.H. Michael, Jr., editors. *Pacific salmon environmental and life history models: advancing science for sustainable salmon in the future*. American Fisheries Society, Symposium 71, Bethesda, Maryland.
- Lawson, P. W., and D. B. Sampson. 1996. Gear-related mortality in selective fisheries for ocean salmon. *North American Journal of Fisheries Management* 16:512-520.
- Lee, D.J., J.R. Sedell, B.E. Rieman, R.F. Thurow, and J.E. Williams. 1997. BROADSCALE assessment of aquatic species and habitats. U.S. Forest Service, General Technical Report PNW-GTR-405 (volume 3). Portland, Oregon
- Lehodey, P., J. Alheit, M. Barange, T. Baumgartner, G. Beaugrand, K. Drinkwater, J. Fromentin, S. R. Hare, G. Ottersen, R. I. Perry, C. Roy, C. D. van der Lingen, and F. Werner. 2006. Climate variability, fish, and fisheries. *Journal of Climate* 19:5009-5030.
- Lettenmaier, D. P., D. Major, L. Poff, and S. Running. 2008. Water resources. In P. Backlund, A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B. A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M. A. Ryan, S. R. Archer, R.

- Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, Huxman, T Okin, G, R. Oren, R. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B. P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.), *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*, p. 121-150. U.S. Department of Agriculture, Washington, DC.
- Lettman, G., D. Azuma, A. Herstrom, N. McKay, T. Robinson, E. Hanson, D. Stoelb, and T Gamache. 2009. *Forest, farms and people. Land Use change on Non-federal lands in Oregon 1974-2005.* Oregon Department of Forestry.
- Leung, L. R., Y. Qian, X. Bian, W. M. Washington, J. Han, and J. O. Roads. 2004. Mid-century ensemble regional climate change scenarios for the western United States. *Climatic Change* 62(1-3):75-113.
- Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, and T. H. Williams. 2009. *What caused the Sacramento River fall Chinook stock collapse?.* NOAA Southwest Fisheries Science Center, NOAA Technical Memorandum NMFS-SWFSC-447. 121 p.
- Logerwell, E. A., N. Mantua, P. W. Lawson, R. C. Francis, and V. N. Agostini. 2003. Tracking environmental processes in the coastal zone for understanding and predicting Oregon coho (*Oncorhynchus kisutch*) marine survival. *Fisheries Oceanography* 12(6):554-568.
- Mackas, D. L., W. T. Peterson, M. D. Ohman, and B. E. Lavaniegos. 2006. Zooplankton anomalies in the California Current system before and during the warm ocean conditions of 2005. *Geophysical Research Letters* 33(L22S07):doi:10.1029/2006GL027930.
- Magnusson, A., and R. Hilborn. 2003. Estuarine influence on survival rates of coho (*Oncorhynchus kisutch*) and Chinook salmon (*Oncorhynchus tshawytscha*) released from hatcheries on the U. S. Pacific Coast. *Estuaries* 26(4B):1094-1103.
- Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78:1069-1079.
- Mantua, N., I. Tohver, and A. Hamlet. 2009. Impacts of climate change on key aspects of freshwater salmon habitat in Washington State. In McGuire Elsner, M., J. Littlell, and L. Whitely Binder (eds.), *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate.* Climate Impacts Group, University of Washington, Seattle, Washington. pp. 217-253.
- Marcogliese, D. J. 2008. The impact of climate change on the parasites and infectious diseases of aquatic animals. *Revue Scientifique et Technique (Office International des Epizooties)* 27(2):467-484.
- Marine, K. R., and J. J. Cech. 2004. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon. *North American Journal of Fisheries Management* 24(1):198-210.
- Maser, C. and J. Sedell. 1994. *From the forest to the sea: the ecology of wood in streams, rivers, estuaries, and oceans.* CRC Press. 216p.

- May, C.L., and D.C. Lee 2004. The relationships among in-channel sediment storage, pool depth, and summer survival of juvenile salmonid in Oregon Coast Range streams. *TAFS* 24:761–774.
- McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42.
- Merriam Webster online Dictionary <http://www.merriam-webster.com/dictionary/fuzzy%20logic>. Accessed May 6, 2010.
- MCWC (MidCoast Watershed Council). 2010. Beaver Study in the Yaquina. Report to Oregon Watershed Enhancement Board. In Prep. Available from Dr. Wayne Hoffman, MCWC, 23 N. Coast Highway, Newport, Oregon 97365.
- Miller, B. A., and S. Sadro. 2003. Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. *Transactions of the American Fisheries Society* 132:546-559.
- Miller, R. 2009. Western Oregon splashdam sites between 1880-1957. In Prep. MS Thesis, Oregon State University.
- Montgomery, D.R., J.M. Buffington, R.D. Smith, K.M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. *Water Resources Research* 31:1097-1105.
- Montgomery, D.R., T.M. Massong, and S.C.S. Hawley, 2003. Influence of Debris Flows and Logjams on the Location of Pools and Alluvial Channel Reaches, Oregon Coast Range. *Geological Society of America Bulletin* 115(1):78-88.
- Montgomery, D.R., T.M. Massong, and S.C.S. Hawley, 2003. Influence of Debris Flows and Logjams on the Location of Pools and Alluvial Channel Reaches, Oregon Coast Range. *Geological Society of America Bulletin* 115(1):78-88.,
- Moore, K.M.S, K.K. Jones, and J.M. Dambacher. 2008. Methods for Stream Habitat Surveys: Aquatic Inventories Project. Information Report 2007-01, Oregon Department of Fish & Wildlife, Corvallis. 67p.
- Morlan, J. 2000. Summary of Current Status and Health of Oregon's Freshwater Wetlands. In: Oregon state of the environment report 2000. Chap. 3.4.
- Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy.
- Morris, J. F. T., M. Trudel, M. E. Thiess, R. M. Sweeting, J. Fisher, S. A. Hinton, E. A. Fergusson, J. A. Orsi, E. V. Farley, and D. W. Welch. 2007. Stock-specific migrations of juvenile coho salmon derived from coded-wire tag recoveries on the continental shelf of western North America. *American Fisheries Society Symposium* 57:81-104.
- Morrison, J., M. C. Quick, and M. G. G. Foreman. 2002. Climate change in the Fraser River watershed: flow and temperature projections. *Journal of Hydrology* 263:230-244.
- Moscrip, A. L. and Montgomery, D.R. 1997. Urbanization, flood frequency, and salmon abundance in Puget lowland streams. *Journal of the American Water Resources Association* 33: 1289-1297.
- Mote, P. W. 2003a. Trends in snow water equivalent in the Pacific Northwest and their climatic causes. *Geophysical Research Letters* 30(12):1601 (doi:10.1029/2003GL017258).

- Mote, P. W. 2003b. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. *Northwest Science* 77(4):271-282.
- Mote, P. W. 2006. Climate-driven variability and trends in mountain snowpack in western North America. *Journal of Climate* 19(23):6209-6220.
- Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society* 86(1):39-49.
- Mote, P. W., and N. J. Mantua. 2002. Coastal upwelling in a warmer future. *Geophysical Research Letters* 29(23):2138.
- Mote, P. W., E. A. Parson, A. F. Hamlet, W. S. Keeton, D. Lettenmaier, N. Mantua, E. L. Miles, D. W. Peterson, D. L. Peterson, R. Slaughter, and A. K. Snover. 2003. Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. *Climatic Change* 61(1):45-88.
- Mote, P., A. Peterson, S. Reeder, H. Shipman, and L. Whitely Binder. 2008a. Sea level rise in the coastal waters of Washington State. Climate Impacts Group, University of Washington, Seattle. 11 p. [<http://www.cses.washington.edu/db/pdf/moteetal579.pdf>]
- Mote, P., E. Salathé, V. Dulière, and E. Jump. 2008b. Scenarios of future climate for the Pacific Northwest. Climate Impacts Group, University of Washington, Seattle. 12 p. [<http://www.cses.washington.edu/db/pdf/moteetal2008scenarios628.pdf>]
- Murphy, M.L. and K.V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. *North American Journal of Fisheries Management* 9:427-436.
- Naiman, R.J, R.E. Bilby, and P.A. Bisson. 2000. Riparian ecology and management in the Pacific coastal rain forest. *BioScience* 50:996-1011.
- Naiman RJ, Johnston CA, Kelley JC. 1988. Alteration of North American streams by beaver. *BioScience* 38:753-62
- Naish, K.A., Taylor, J.E., Levin, P.S., Quinn, T.P., Winton, J.R., Huppert, D., and Hilborn, R. 2008. An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. *Advances In Marine Biology* 53: 61-194.
- NMFS (National Marine Fisheries Service). 1991a. Endangered and threatened species: Lower Columbia River Coho Salmon. Federal Register [Docket No. 910648-1148, 27 June 1991] 56(124):29553-29554.
- NMFS. (National Marine Fisheries Service). 1991b. Notice of policy: Policy on applying the definition of species under the Endangered Species Act to Pacific salmon. Federal Register 56(224): 58612-58618.
- NMFS. (National Marine Fisheries Service). 1993. Listing endangered and threatened species and designating critical habitat: Petition to list five stocks of Oregon coho salmon. Federal Register [Docket No. 27 October 1993] 58(206) 57770-57771.
- NMFS (National Marine Fisheries Service). 1994. Endangered and threatened species: Coho salmon in Scott and Waddell creeks, California. Federal Register [Docket No. 940408-4108; ID 031594A,26 April 1994] 59(80):21744.

- NMFS (National Marine Fisheries Service). 1995. Endangered and threatened species: Proposed threatened status for three contiguous ESUs of coho salmon ranging from Oregon through central California. Federal Register [Docket No. 950407093-5179-02; ID 012595A, 25 July 1995] 60(142):38011.
- NMFS (National Marine Fisheries Service). 1996a. Status review update for coho salmon from Washington, Oregon, and California. Draft document prepared by the West Coast Coho Salmon Biological Review Team, 20 December 1996.
- NMFS (National Marine Fisheries Service). 1996b. Supplemental report of the Biological Review Team on central California coast coho salmon. Memorandum dated 17 October 1996 from M. Schiewe to W. Stelle. (Available from NMFS Northwest Regional Office, 1202 NE Lloyd Blvd. Suite 1100, Portland, OR.)
- NMFS (National Marine Fisheries Service). 1996c. Endangered and threatened species: Threatened status for Central California Coast coho salmon evolutionarily significant unit (ESU). Federal Register [Docket No. 950407093-6298-03; ID 012595A, 31 October 1996] 61(212):56138.
- NMFS (National Marine Fisheries Service). 1997a. Status review update for coho salmon from the Oregon and Northern California coasts. West Coast Coho Salmon Biological Review Team, 28 March 1997. (Available from L. Weitkamp, Northwest Fisheries Science Center, 2032 S.E. OSU Drive, Newport, Oregon 97365.)
- NMFS (National Marine Fisheries Service). 1997b. Endangered and threatened species: Threatened status for Southern Oregon/Northern California coasts evolutionarily significant unit (ESU) of coho salmon. Federal Register [Docket No. 950407093-6298-03; ID 012595A, 6 May 1997] 62(87):24588-24609.
- NMFS (National Marine Fisheries Service). 1997c. Coastal Coho Habitat Factors for Decline and Protective Efforts in Oregon. Habitat Conservation Program, April 24, 1997. (Available from Eric Murray, Northwest Regional Office 1201 NE Lloyd Blvd. Suite 1100 Portland, OR 97232.)
- NMFS (National Marine Fisheries Service). 1998. Endangered and threatened species: Threatened status for the Oregon Coast evolutionarily significant unit of Coho Salmon. Federal Register [Docket No. 950407093-8201-04; ID 063098A, 10 August 1998] 63(153):42587-42591.
- NMFS. (National Marine Fisheries Service). 2001. Status review update for lower Columbia River coho salmon. West Coast Coho Salmon Biological Review Team, May 2001. (Available from L. Weitkamp, Northwest Fisheries Science Center, 2032 S.E. OSU Drive, Newport, Oregon 97365.)
- NMFS. (National Marine Fisheries Service). 2004a. Endangered and threatened Species: Proposed Listing Determinations for 27 ESUs of West Coast Salmonids. Federal Register [Docket No. 040525161-4161-01; I.D. No.052104F, 14 June 2004] 69(113) 33102-33179.
- NMFS. (National Marine Fisheries Service). 2004b. Salmon hatchery inventory and effects evaluation report: an evaluation of the effects of artificial propagation on the status and likelihood of extinction of West Coast salmon and steelhead under the Federal Endangered Species Act. U.S. Dept. of Commerce, Tech. Memo., NOMFS-NWR/SWR, 557p.
- NMFS. (National Marine Fisheries Service). 2005. Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead [Docket No. 040511148-5151-02; I.D. 050304B 28 June 2005] 70(123) 37204-37216.

- NMFS. (National Marine Fisheries Service). 2006. Endangered and threatened species: Withdrawal of Proposals to List and Designate Critical Habitat for the Oregon Coast Evolutionarily Significant Unit (ESU) of Coho Salmon. Federal Register [Docket No. 051227348-5348-01; I.D.020105C, 19 January 2006] 71(12):3033-3048.
- NMFS. (National Marine Fisheries Service). 2008. Endangered and threatened species: Final Threatened Listing Determination, Final Protective Regulations, and Final Designation of Critical Habitat for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon. Federal Register [Docket No. 071227892-7894-01; February 11, 2008] 73 (28): 7816-7873.
- NMFS. (National Marine Fisheries Service). 2009. Listing Endangered and Threatened Species: Initiation of Status Review for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon. Federal Register [Docket No. E9-9823 29April 2009] 74(81):19528-19530
- Native Fish Society. 2009. Oregon Coast Coho Status Review. RIN 0648-XO28. Aug. 25, 2009. 10p plus attachments.
- Neitzel, D. A., M. J. Scott, S. A. Shankle, and J. C. Chatters. 1991. The effect of climate change on stream environments: the salmonid resource of the Columbia River Basin. Northwest Environmental Journal 7:271-293.
- Nicholas, J., B. McIntosh, E. Bowles. 2005. Synthesis of the Coastal Coho ESU Assessment. State of Oregon. Available at: [//nrimp.dfw.state.or.us/Oregon Plan/](http://nrimp.dfw.state.or.us/OregonPlan/).
- Nickelson, T. E. 1986. Influences of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon (*Oncorhynchus kisutch*) in the Oregon production area. Canadian Journal of Fisheries and Aquatic Sciences 43:527-535.
- Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. F. Solazzi. 1992. Seasonal Changes in Habitat Use by Juvenile Coho (*Oncorhynchus kisutch*) in Oregon Coastal Streams. Canadian Journal of Fisheries and Aquatic Sciences 49:783-789.
- Nickelson, T. 2001. Population assessment: Oregon coast coho salmon ESU. (Available from Northwest Region Research and Monitoring Program, Oregon Department Fish and Wildlife, 17330 SE Evelyn St., Clackamas, OR 97015.)
- Nickelson, T. 2003. The influence of hatchery coho salmon (*Oncorhynchus kisutch*) on the productivity of wild coho salmon populations in Oregon coastal basins. Canadian Journal of Fisheries and Aquatic Sciences 60:1050-1056.
- Nickelson, T. E. 1998. A Habitat-Based Assessment of Coho Salmon Production Potential and Spawner Escapement Needs for Oregon Coastal Streams. Oregon Department. Fish and Wildlife, Information Report, 98-4, Salem
- Nickelson, T. and P. Lawson. 1998. Population viability of coho salmon *Oncorhynchus kisutch* in Oregon coastal basins: Application of a habitat-based life cycle model. Can. J. Fish. Aquat. Sci. 55:2383-2392.
- Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77(1):118-125.
- Oosterhout, G.R., C.W. Huntington, T. E. Nickelson, and P.W. Lawson. 2005. Potential benefits of a conservation hatchery program for supplementing Oregon coast coho salmon (*Oncorhynchus*

- kisutch) populations: a stochastic model investigation. Canadian Journal of Fisheries and Aquatic Sciences 62:1920-1935.
- Oregon. 2005. Coho Assessment Part 1: Synthesis. Oregon Coastal Coho Assessment. Available at: <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].
- Oregon 2007. Oregon Coast Coho Conservation Plan For the State of Oregon. March 16, 2007. http://www.oregon.gov/OPSW/cohoproject/PDFs/November2007_pdfs/Coho_Plan.pdf
- Oregon 2009a. Oregon Plan for Salmon and Watersheds 2007-2009 Biennial Report. http://www.oregon.gov/OWEB/biennialreport_0507.shtml accessed Feb 16, 2010.
- Oregon 2009b. Letter of comment in response to FRN: RIN 0648-XO28. Aug. 21, 2009. 10p.
- OCSRI (Oregon Coastal Salmon Restoration Initiative) Science Team. 1997. Recommendations related to population status. (Available at <http://www.oregon-plan.org/OPSW/archives/reports-subpage.shtml>)
- ODEQ (Oregon Department of Environmental Quality). 2005. Water Quality Report. Oregon Department of Water Quality Oregon Coastal Coho Assessment. Part 4(B) DEQ Water Quality. Available online at: <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PRFNM#> [Accessed May 7, 2010]
- ODEQ (Oregon Department of Environmental Quality). 2007. Streams in Oregon 2004-2006 Integrated report on water quality. Available at: www.deq.state.or.us/wq/assessment/rpt0401.htm.
- ODFW (Oregon Department of Fish and Wildlife). 1995. Oregon coho salmon biological status assessment and staff conclusions for listing under the Oregon Endangered Species Act. Oregon Department of Fish and Wildlife, Portland, OR. 22 February 1995. (Attachment to II-B-I to the Draft OCSRI Plan dated 8/20/96.) OCSRI (Oregon Coastal Salmon Restoration Initiative) Science Team. 1996. Recommendations related to population status. Draft report dated 8/21/96. (Available at <http://www.oregon-plan.org/OPSW/archives/archived.shtml#Anchor-Plan.>)
- ODFW (Oregon Department of Fish and Wildlife) 2004. A review of pinniped predation on salmonids. Presentation at Aug. 20, 2004 Stakeholder meeting. Available at: http://www.oregon.gov/OPSW/cohoproject/PDFs/RobinBrown8_24_04.pdf [Accessed May 6 2010].
- ODFW (Oregon Department of Fish and Wildlife) 2005a. The Importance of Beaver (*Castor Canadensis*) to Coho Habitat and Trend in Beaver Abundance in the Oregon Coast Coho ESU. Oregon Coastal Coho Assessment. Part 4(C) ODFW (7) Beaver. Available at: <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].
- ODFW (Oregon Department of Fish and Wildlife) 2005b. Fish Health Assessment of Oregon Coastal Coho Salmon Stocks. Oregon Coastal Coho Assessment, Part 4(C) ODFW (6) Disease Report. Available at: <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 5 2010].
- ODFW (Oregon Department of Fish and Wildlife) 2005c. Habitat. Oregon Coastal Coho Assessment, Part 4(C) ODFW (3) Habitat. Available at:

<http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].

ODFW(Oregon Department of Fish and Wildlife) 2005d. Harvest. Oregon Coastal Coho Assessment, Part 4(C) ODFW (2) Harvest. Available at:

<http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].

ODFW(Oregon Department of Fish and Wildlife) 2005e. Hatchery. Oregon Coastal Coho Assessment, Part 4(C) ODFW (1) Hatchery. Available at:

<http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].

ODFW(Oregon Department of Fish and Wildlife) 2005f. Hydro. Oregon Coastal Coho Assessment, Part 4(C) ODFW (8) Hydro. Available at:

<http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].

ODFW(Oregon Department of Fish and Wildlife) 2005g. Introduced fishes impacts. Oregon Coastal Coho Assessment, Part 4(C) ODFW (6) Exotic Fish Report. Available at:

<http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].

ODFW(Oregon Department of Fish and Wildlife) 2005h. Predation. Oregon Coastal Coho Assessment, Part 4 (C) ODFW (5) Predation. Available at:

<http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PREZX#> [Accessed May 6 2010].

ODFW (Oregon Department of Fish and Wildlife) 2005 2005 stakeholder report

ODFW (Oregon Department of Fish and Wildlife) 2007. Oregon Coast Coho Conservation Plan For the State of Oregon. Available at

http://www.oregon.gov/OPSW/cohoproject/PDFs/November2007_pdfs/Coho_Plan.pdf

ODFW (Oregon Department of Fish and Wildlife). 2008a. Umpqua Basin Coho Program Hatchery and Genetics Management Plan [HGMP] draft April 21, 2008. Roseburg, Oregon. (Available from L. Kruzic, NWR. Roseburg, Oregon.)

ODFW (Oregon Department of Fish and Wildlife). 2008b. Furbearer Regulations. Available at:

http://www.dfw.state.or.us/resources/hunting/small_game/regulations/2008-2010_Furbearer_Regulations.pdf.

ODFW (Oregon Department of Fish and Wildlife). 2009a. Oregon Department of Fish and Wildlife Comments, Oregon Coast Coho ESU, NOAA Fisheries Status Review 2009. Aug. 18, 2009. Fish Division. Salem, Oregon. 52 pages.

ODFW (Oregon Department of Fish and Wildlife) ODFW. 2009b. Email from Guy Chilton, ODFW, to Lance Kruzic, NMFS, dated October 22, 2009 with attachment on the actual releases of hatchery fish in the Oregon Coast ESU from 1999-2008.

ODEQ (Oregon Department of Environmental Quality). 2005. Water Quality Report. Oregon Department of Water Quality Oregon Coastal Coho Assessment. Part 4(B) DEQ Water Quality. Available online at:

- <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PRFNM#> [Accessed May 7, 2010]
- ODEQ (Oregon Department of Environmental Quality). 2007. Streams in Oregon 2004-2006 Integrated report on water quality. Available at: www.deq.state.or.us/wq/assessmentrpt0401.htm.
- ODF (Oregon Department of Forestry). 2003. Elliott Forest Watershed Assessment. Available at: http://www.oregon.gov/ODF/STATE_FORESTS/watershed.shtml#Elliott_State_Forest_Analysis [Accessed May 7, 2010].
- ODSL (Oregon Department of State Lands). 2005. Oregon Plan for Salmon and Watershed Oregon Coastal Coho Assessment Wetlands, Estuaries Dredge, Fill and Inwater Construction Prepared by Department of State Lands, Oregon Coastal Coho Assessment. Part 4(G) DSL Wetlands, Estuaries. Available online at: <http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=152&token=RmluYWwgUmVwb3J0cy9BZ2VuY3kgUmVwb3J0cy9PRFNM#>
- OSL (Oregon State Legislature). 2002a. Joint interim task force on salmon recovery: Summary of the scientific workshop on measurable salmonid recovery criteria. Oregon State Legislature, Salem. Online at http://www.leg.state.or.us/comm/commsrvs/jt_salmon/ [Accessed May 5, 2010].
- Overland, J. E., J. Alheit, A. Bakun, J. W. Hurrell, D. L. Mackas, and A. J. Miller. 2009. Climate controls on marine ecosystems and fish populations. *Journal of Marine Systems* doi:10.1016/j.jmarsys.2008.12.009.
- OWEB (Oregon Watershed Enhancement Board). 2009. OWEB monitoring and reporting. http://www.oregon.gov/OWEB/MONITOR/monitoringreports_linked.shtml#Instream_Habitat [Accessed May 12, 2010].
- PFMC (Pacific Fishery Management Council). 1998. Preseason report III. Analysis of council adopted management measures for 1998 ocean salmon fisheries. (Prepared by the Salmon Technical Team and Staff Economist, Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220.)
- PFMC (Pacific Fishery Management Council). 2000. Preseason report III. Analysis of council adopted management measures for 2000 ocean salmon fisheries. (Prepared by the Salmon Technical Team and Staff Economist, Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220.) PFMC 2009
- PFMC (Pacific Fishery Management Council). 2009. Preseason Report 1: Stock Abundance Analysis for 2009 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.
- Pacific Rivers Council. 2009. Comments on Oregon Coast Status Review. July 28, 2009. 24p.
- Parnesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology Evolution and Systematics* 37:637-669.
- Partnership for the Umpqua Rivers. 2007. Umpqua Basin Action Plan. Available at [:www.umpquarivers.org](http://www.umpquarivers.org) accessed Feb 16, 2010.

- Pearcy, W. G. 1992. Ocean ecology of North Pacific salmonids. Washington Sea Grant Program, Seattle. 179 pp.
- Pearcy, W. G. 2002. Marine nekton off Oregon and the 1997–98 El Niño. *Progress in Oceanography* 54(1-4):399-403.
- Pearcy, W. G., and J. P. Fisher. 1988. Migrations of coho salmon, *Oncorhynchus kisutch*, during their first summer in the ocean. *Fishery Bulletin (U.S.)* 86(2):173-195.
- Perry, R. I., P. Cury, K. Brander, S. Jennings, C. Möllmann, and B. Planque. 2009. Sensitivity of marine systems to climate and fishing: Concepts, issues and management responses. *Journal of Marine Systems* doi:10.1016/j.jmarsys.2008.12.017.
- Pess, G.R., D.R. Montgomery, T. J. Beechie, L. Hosinger. 2002. Anthropogenic alterations to the biogeography of salmon in Puget Sound. Pages 129-154 In Montgomery, D.R., S. Bolton, D. B. Booth. (Eds.) *Restoration of Puget Sound Rivers*. University of Washington Press, Seattle, WA.
- Peterson, N.P. (1982) Immigration of Juvenile Coho Salmon (*Oncorhynchus kisutch*) into Riverine Ponds. *Can. J. Fish. Aquatic Sci.* 39: 1308-1310.
- Peterson, T. C., D. M. Anderson, S. J. Cohen, M. Cortez-Vázquez, R. J. Murnane, C. Parmesan, D. Phillips, R. S. Pulwarty, and J. M. R. Stone. 2008. Why weather and climate matter. In T. R. Karl, G. A. Meehl, C. D. Miller, S. J. Hassol, A. M. Waple, and W. L. Murray (eds.), *Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*, p. 11-34. U.S. Department of Commerce, National Climatic Data Center, Washington, D.C.
- Peterson, W. T., and F. B. Schwing. 2003. A new climate regime in northeast pacific ecosystems. *Geophysical Research Letters* 30(17):1896.
- Platts, W.S., Torquemada, R.J., McHenry, M.L., and Graham, C.K. 1989. Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. *Trans. Am. Fish. Soc.* 118: 274–283.
- Poff, N. L., M. M. Brinson, and J. W. Day. 2002. Aquatic ecosystems & global climate change: Potential impacts on inland freshwater and coastal wetland ecosystems in the United States. Pew Center on Global Climate Change. 56 p. [http://www.pewclimate.org/global-warming-in-depth/all_reports/aquatic_ecosystems]
- Pollock MM, Heim M, Werner D. 2003. Hydrologic and geomorphic effects of beaver dams and their influence on fishes. In *The Ecology and Management of Wood in World Rivers*, Gregory SV, Boyer K, Gurnell A. (eds). American Fisheries Society: Bethesda, MD; 213–233.
- Pollock, M. M., G. R. Pess, T. J. Beechie, D. R. Montgomery. 2004. The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA. *North American Journal of Fisheries Management*, 24:749-760.
- Pollock, M. M., T. J. Beechie, and C. E. Jordan. 2007. Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. *Earth Surface Processes and Landforms* 32:1174-1185.

- Pritchard, A. L. 1940. Studies on the age of the coho salmon (*Oncorhynchus kisutch*) and the spring salmon (*Oncorhynchus tshawytscha*) in British Columbia. *Trans. R. Soc. Can., Serv.* 3, 34(V):99–120
- Puget Sound TRT (Technical Recovery Team). 2002. Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook salmon evolutionarily significant unit. Puget Sound Technical Recovery Team Report. Online at <http://www.nwfsc.noaa.gov/trt/trtpopESU.pdf>
- Quinn TP, Peterson NP. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. *Can J Fish Aqua Sci* 53:1555–64.
- Rauscher, H. M. 1999. Ecosystem management decision support for federal forests in the United States: A review. *Forest Ecol. Manag.* 114:173–197.
- Reeves, Gordon H., Fred H. Everest, Thomas E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. Gen. Tech. Rep. PNW-GTR-245. U.S. Forest Service, Pacific Northwest Research Station, Portland, OR.
- Reeves, G.H., F.H. Everest, and J.R. Sedell. 1993. Diversity of juvenile anadromous salmonids assemblages in coastal Oregon basins with different levels of timber harvest. *Transactions of the American Fisheries Society* 122:309-317
- Reeves, G.H., K.M. Burnett, and E.V. McGarry. 2003. Sources of large woody debris in the main stem of a fourth-order watershed in coastal Oregon. *Can. J. For. Res.* 33: 1363-1370.
- Reeves, G.H., D.B. Hohler, D.P. Larsen, D.E. Busch, K. Kratz, K. Reynolds, K.F. Stein, T. Atzet, P. Hays, and T. Tehan. 2004. Effectiveness monitoring for the Aquatic and Riparian Component of the Northwest Forest Plan: conceptual framework and options. Gen. Tech. Rep. PNW GTR 577. USDA Forest Service, PNW Research Station, Portland, OR. 71 p.
- Reeves, G.H., J.E. Williams, K.M. Burnett and K. Gallo. 2006. The Aquatic Conservation Strategy of the Northwest Forest Plan. *Conservation Biology* Volume 20, No. 2, 319–329.
- Reynolds, K. M., M. Jensen, J. Andreasen, and I. Goodman. 2000. Knowledge-based assessment of watershed condition. *Comput. Electron. Agr.* 27:315–333.
- Roessig, J. M., C. M. Woodley, J. J. Cech, and L. J. Hansen. 2004. Effects of global climate change on marine and estuarine fishes and fisheries. *Reviews in Fish Biology and Fisheries* 14:251-275
- Ryan, M. G., S. R. Archer, R. A. Birdsey, C. N. Dahm, L. S. Heath, J. A. Hicke, D. Y. Hollinger, T. E. Huxman, G. S. Okin, R. Orin, J. T. Randerson, and W. H. Schlesinger. 2008. Land resources: forests and arid lands. In P. Backlund, A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B. A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M. A. Ryan, S. R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, Huxman, T. Okin, G. R. Oren, R. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B. P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.), *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*, p. 75-120. U.S. Department of Agriculture, Washington, DC.
- Salathé, E. P. 2005. Downscaling simulations of future global climate change with application to hydrologic modelling. *International Journal of Climatology* 25(4):419-436.

- Sandercock, F. K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). In C. Groot and L. Margolis (eds.), *Pacific salmon life histories*, p. 396–445. University of British Columbia Press, Vancouver, BC.
- Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, C. Mason, D. J. Reed, T. C. Royer, A. H. Sallenger, and J. G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. *Estuaries* 25(2):149-164.
- Schwing, F. B., N. A. Bond, S. J. Bograd, T. Mitchell, M. A. Alexander, and N. Mantua. 2006. Delayed coastal upwelling along the U.S. West Coast in 2005: A historical perspective. *Geophysical Research Letters* 33(L22S01):doi:10.1029/2006GL026911.
- Sharma, R. and R. Hilborn. 2001. Empirical relationships between watershed characteristic and coho salmon (*Oncorhynchus kisutch*) smolt abundance in 14 western Washington stream. *Canadian Journal of Fisheries and Aquatic Sciences* 58:1453-1463.
- Simenstad, C. A., G. W. Hood, R. M. Thom, D. A. Levy, and D. L. Bottom. 2000. Landscape structure and scale constraints on restoring estuarine wetlands for Pacific coast juvenile fishes. In D. A. Kreeger, and M. P. Weinstein (eds.), *Concepts and controversies in tidal marsh ecology*, p. 597-630. Kluwer Academic, Boston, MA.
- Skeesick, D.G. (1970) The fall immigration of juvenile coho salmon into a small tributary. *Res. Rept. Fish Comm. Oregon*. 2:90-95
- Smith, C., Gilden, J., Cone, J. and Steel, B. 1997. Contrasting views of coastal residents and coastal coho restoration planners. *Fisheries* 22:8-15.
- Snyder, M. A., L. C. Sloan, N. S. Diffenbaugh, and J. L. Bell. 2003. Future climate change and upwelling in the California Current. *Geophysical Research Letters* 30(15):1823 (doi:10.1029/2003GL017647).
- Springer, T. 2009. Comments on Oregon Coast Coho Status Review RIN 0648-XO28. Aug. 18, 2009. 1p.
- Stevens, Jr., D.L., and A. R. Olsen. 2004. Spatially-Balanced Sampling of Natural Resources. *Journal of the American Statistical Association*. 99:262-277
- Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under a 'business as usual' climate change scenario. *Climatic Change* 62(1-3):217-232.
- Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. Changes toward earlier streamflow timing across Western North America. *Journal of Climate* 18(8):1136-1155.
- Stout, H. A., B. B. McCain, R. D. Vetter, T. L. Builder, W. H. Lenarz, L. L. Johnson, R. D. Methot. 2001a. Status Review of Copper Rockfish (*Sebastes caurinus*), Quillback Rockfish (*S. maliger*), and Brown Rockfish (*S. auriculatus*) in Puget Sound, Washington. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-46, xxiv, 158 p.
- Stout, H. A., R. G. Gustafson, W. H. Lenarz, B. B. McCain, D. M. Van Doornik, T. L. Builder, R. D. Methot. 2001b. Status review of Pacific herring in Puget Sound, Washington. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-45, 175 p.
- Suzuki, N., and W. C. McComb. 1998. Habitat classification models for beaver (*Castor canadensis*) in the streams of the central Oregon Coast Range. *Northwest Science* 72:102–110.

- Sydeman, W. J., R. W. Bradley, P. Warzybok, C. L. Abraham, J. Jahncke, K. D. Hyrenbach, V. Kousky, J. M. Hipfner, and M. D. Ohman. 2006. Planktivorous auklet *Ptychoramphus aleuticus* responses to ocean climate, 2005: Unusual atmospheric blocking? *Geophysical Research Letters* 33(L22S09):doi:10.1029/2006GL026736.
- Trout Unlimited. 2009. Comments on Status Review for Oregon Coast Coho; RIN 0648-XO28. July 28, 2009. 2 p.
- Turban, E., and J. E. Aronson. 2001. *Decision support systems and intelligent systems*. Prentice Hall, Upper Saddle River, NJ.
- USEPA (U.S. Environmental Protection Agency). 2009. Comments on Federal Register Notice dated 04/29/09. July 28, 2009. 8p.
- Van Doornik, D. M., D. J. Teel, D. R. Kuligowski, C. A. Morgan, and E. Casillas. 2007. Genetic analyses provide insight into the early ocean stock distribution and survival of juvenile coho salmon of the coasts of Washington and Oregon. *North American Journal of Fisheries Management* 27(1):220-237.
- Van Doornik, D., Banks, M., Garza, J., Gilbert, L., Kassler, T., LaHood, E., Lewis, C., Moran, P., Theriault, V., Warheit, K., and Wenburg, J. 2008. Allele ladder-based standardization of existing coho salmon microsatellite data and implementation in the GAPS database. Report to the Pacific Salmon Commission Southern Boundary Restoration & Enhancement Fund; Project SF-2008-I-4. Available from Don Van Doornik (don.vandoornik@noaa.gov).
- Wallace M. and S. Allen (2009) Juvenile salmonid use of the tidal portions of selected tributaries to Humboldt Bay, California 2007-2009. Calif. Dept. of Fish and Game and Pacific States Marine Fisheries Commission. Final Contract Report P0610522. Aug. 2009. 32p.
- Waples, R.S. 1991. Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. *Marine Fisheries Review* 53: 11-22.
- Wainwright, T. C., and R. G. Kope. 1999. Methods of extinction risk assessment developed for U.S. West Coast salmon. *ICES J. Mar. Sci.* 56:444-448.
- Wainwright, T.C., M.W. Chilcote, P.W. Lawson, T.E. Nickelson, C.W. Huntington, J.S. Mills, K.M.S. Moore, G.H. Reeves, H.A. Stout, and L.A. Weitkamp. 2008. Biological recovery criteria for the Oregon Coast coho salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-91, 199 p
- Wainwright, T. C., L. R. Feinberg, R. C. Hooff, and W. T. Peterson. 2006. A comparison of two lower trophic models for the California Current system. *Ecological Modelling* 202:120-131.
- Weitkamp, L. A., T. C. Wainwright, G. J. Bryant, G. B. Milner, D. J. Teel, R. G. Kope, and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-24. 258 p.
- Weitkamp, L. A. 2009. Marine distributions of Chinook salmon (*Oncorhynchus tshawytscha*) from the West Coast of North America determined by coded wire tag recoveries. *Transactions of the American Fisheries Society* xx(In Press):xxx-xxx.
- Weitkamp, L., and K. Neely. 2002. Coho salmon (*Oncorhynchus kisutch*) ocean migration patterns: insight from marine coded-wire tag recoveries. *Canadian Journal of Fisheries and Aquatic Sciences* 59(7):1100-1115.

- Welch, D. W., A. I. Chigirinsky, and I. Ishida. 1995. Upper thermal limits on the oceanic distribution of Pacific salmon (*Oncorhynchus* spp.) in the spring. *Canadian Journal of Fisheries and Aquatic Sciences* 52(3):489-503.
- Wells, B. K., C. B. Grimes, J. C. Field, and C. S. Reiss. 2006. Covariation between the average lengths of mature coho (*Oncorhynchus kisutch*) and Chinook salmon (*O. tshawytscha*) and the ocean environment. *Fisheries Oceanography* 15(1):67-79.

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

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.

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=AIProjOrPInSalWtrshd>

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 ESU

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

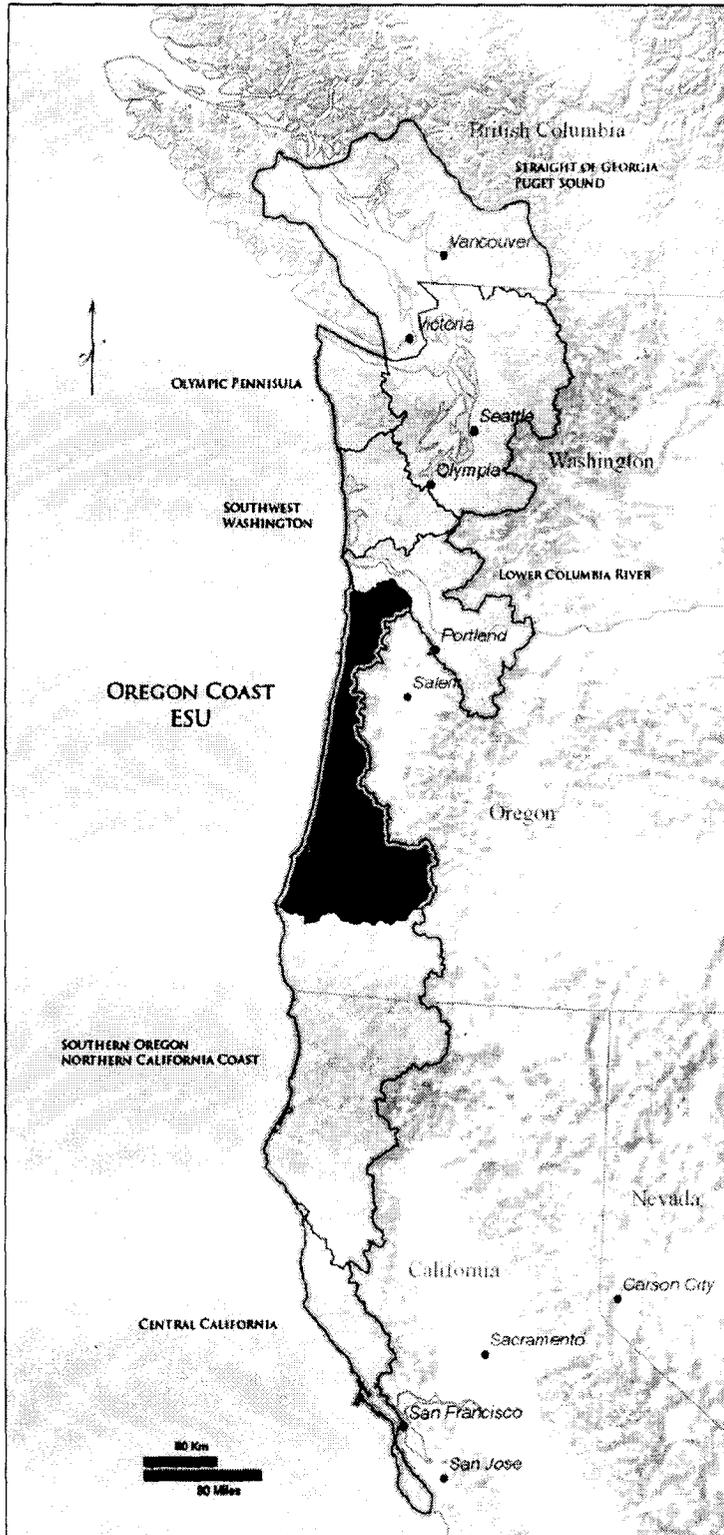
Valley constraint. The valley width available for a stream or river to move between valley slopes.

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.

Figures

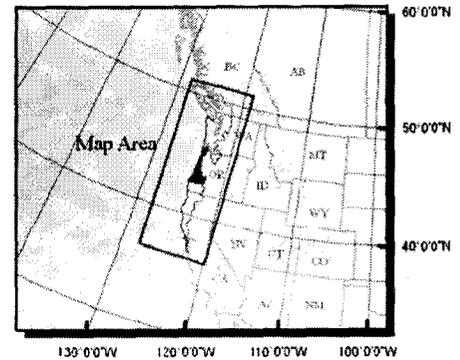


Coho Salmon Evolutionarily Significant Units

-  Evolutionarily Significant Units
-  Oregon Coast ESU
-  Coastal Coho ESU Boundary

Lawson, P. et al. 2007. Identification of Historical Populations of Coho Salmon (*Oncorhynchus kisutch*) in the Oregon Coast Evolutionarily Significant Unit. U.S. Department of Commerce, NOAA Tech. Memo NMFS-NWFSC-79, 129 p.

Weitkamp, L. A. et al. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-24.



United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

March 2010

This map for reference use only.



Figure 1. West Coast Coho Salmon Evolutionarily Significant Units.

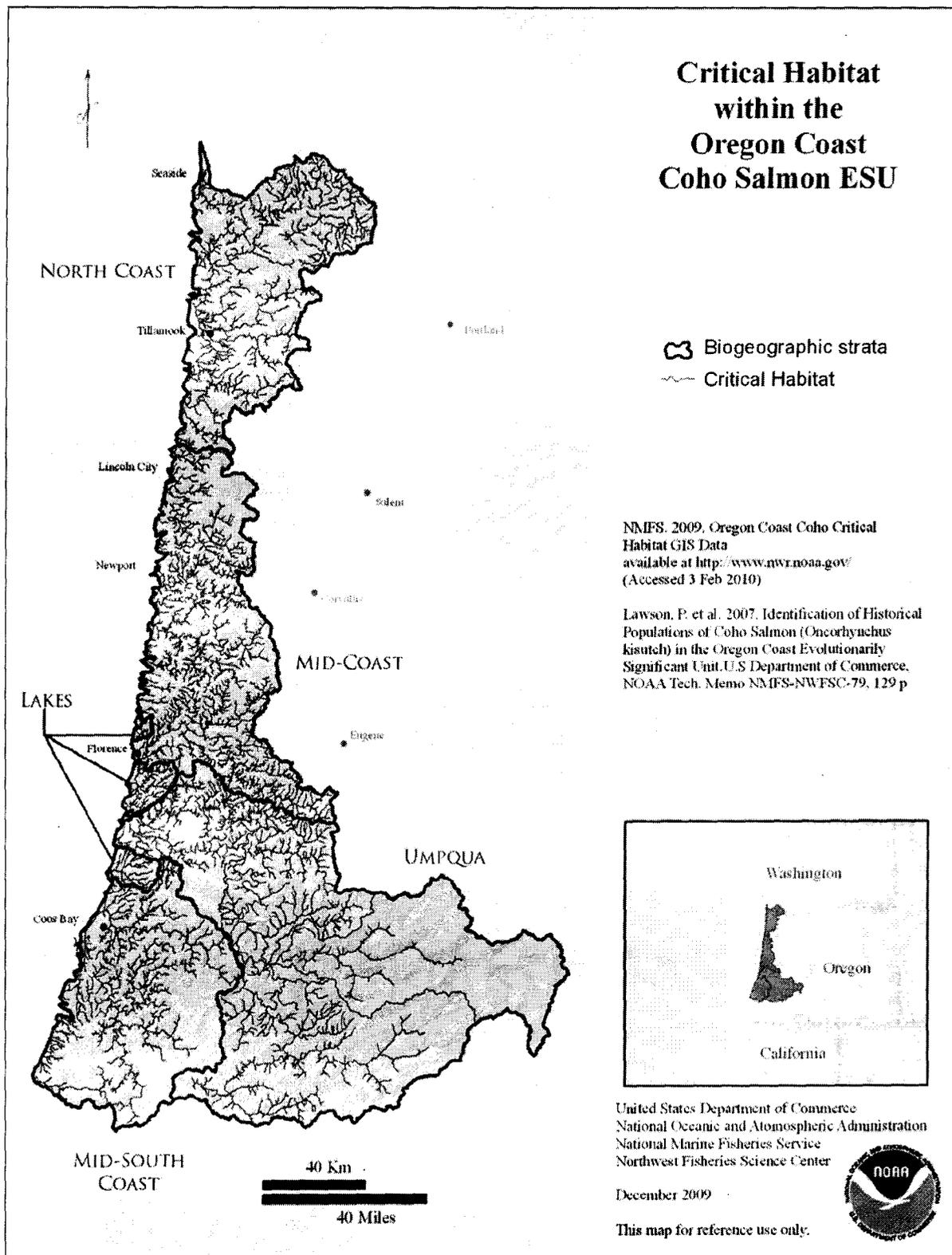


Figure 2. Critical Habitat Designation for Oregon Coast Coho Salmon ESU Feb. 2008.

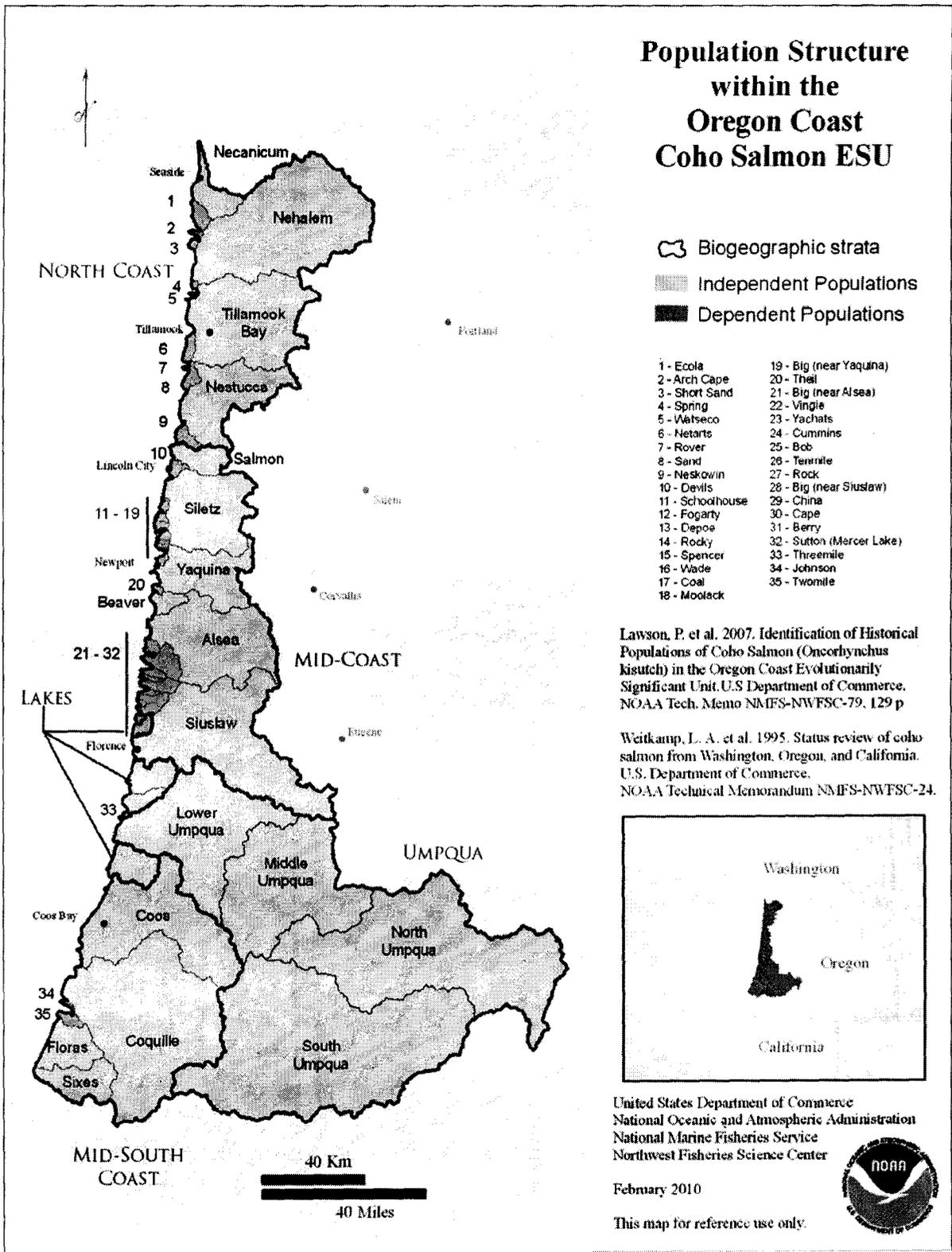


Figure 3. Historical populations and biogeographic strata for the OC Coho Salmon ESU (Lawson et al. 2007).

ESU and Stratum Totals

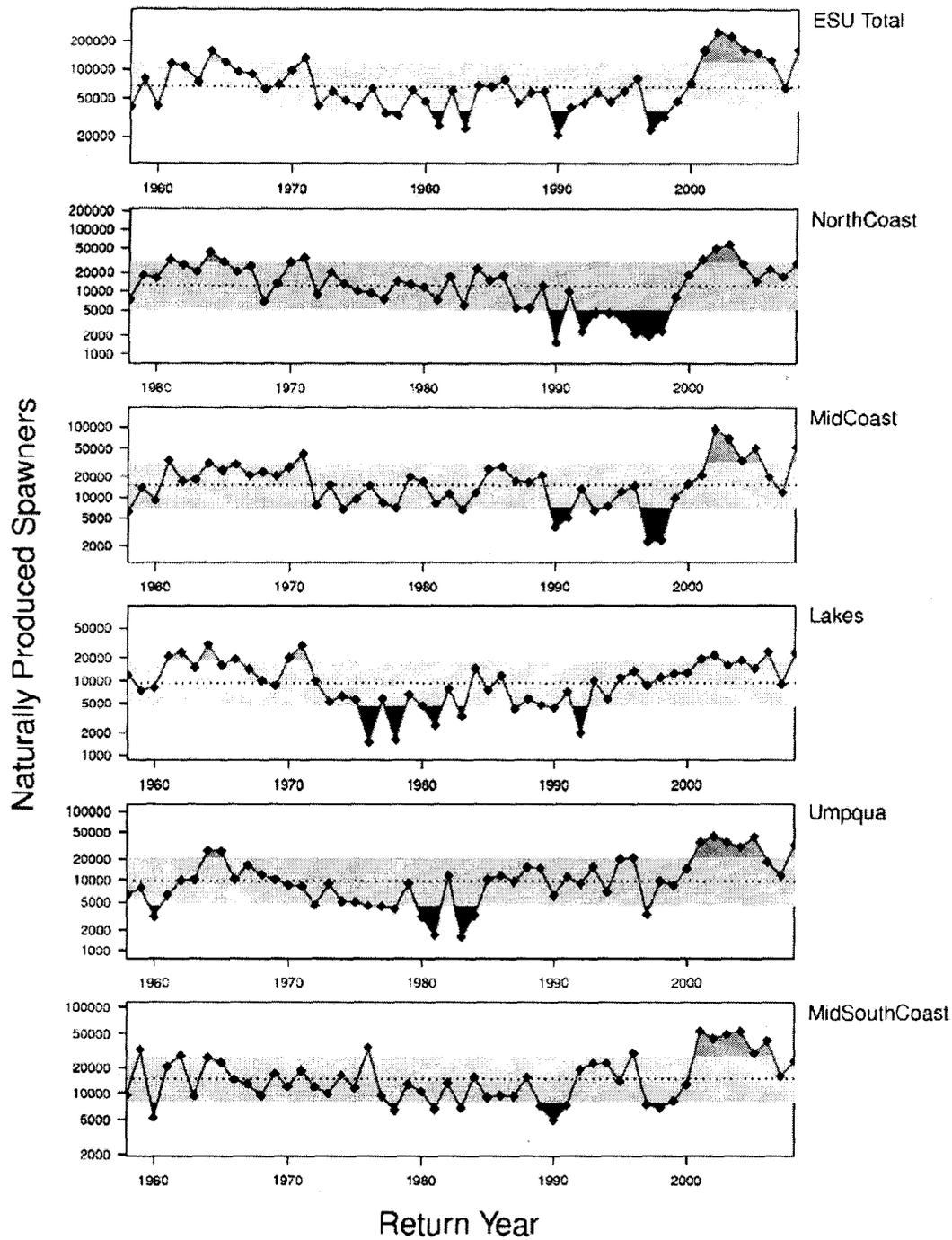


Figure 4. Trends in Natural Spawner Abundance for the whole ESU (top panel) and the five biogeographic strata (lower panels). The dashed line marks the long-term mean, and the green background spans the mean \pm 1 standard deviation (SD). Values that exceed the mean + 1 SD are highlighted in yellow, values more than 1 SD below the mean are highlighted in blue. Note the logarithmic scale. Data from Wainwright et al. 2008 and ODFW 2009a.

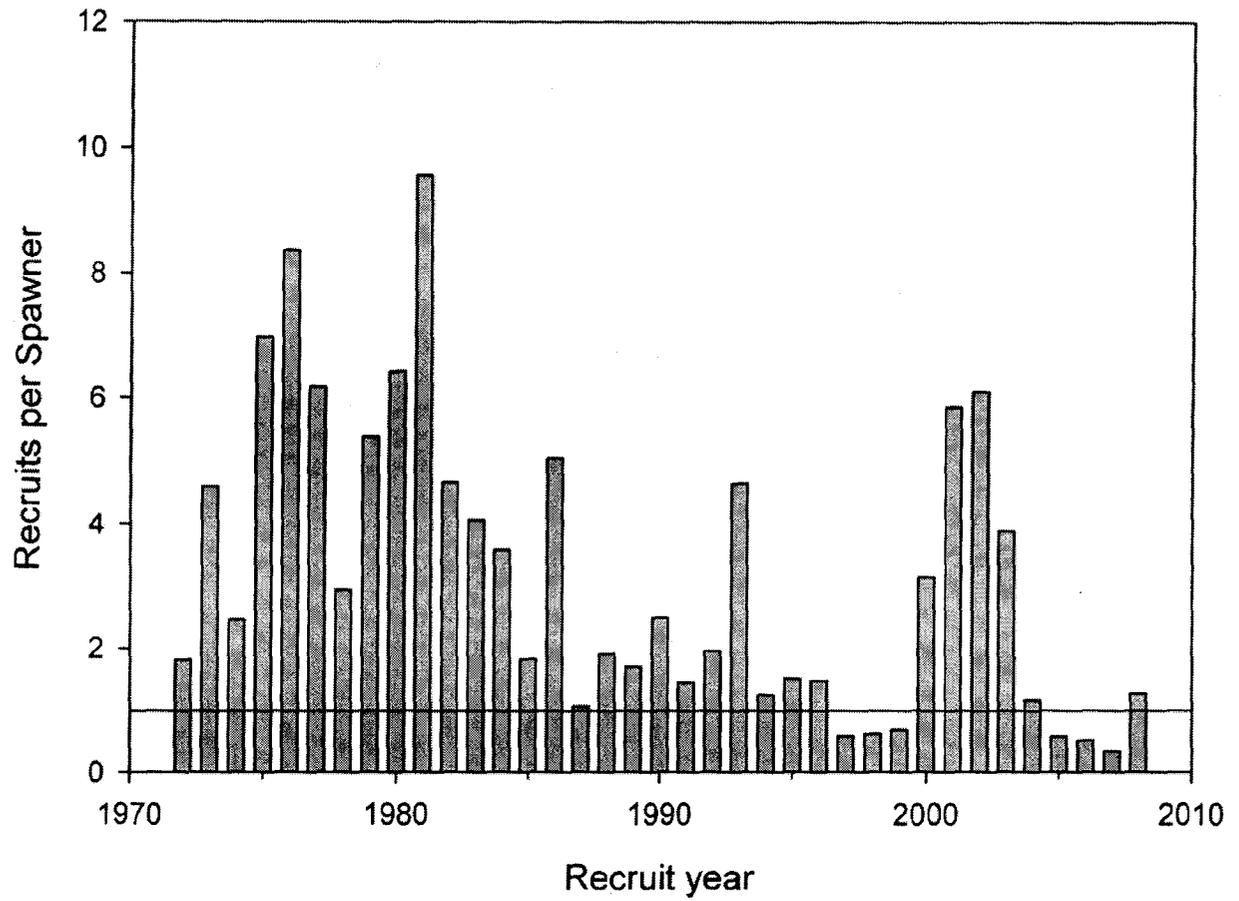


Figure 5. OC coho salmon naturally produced recruits per spawner (t-3), 1972 – 2008. Unity line is replacement (data from Table 2) (PFMC 2009).

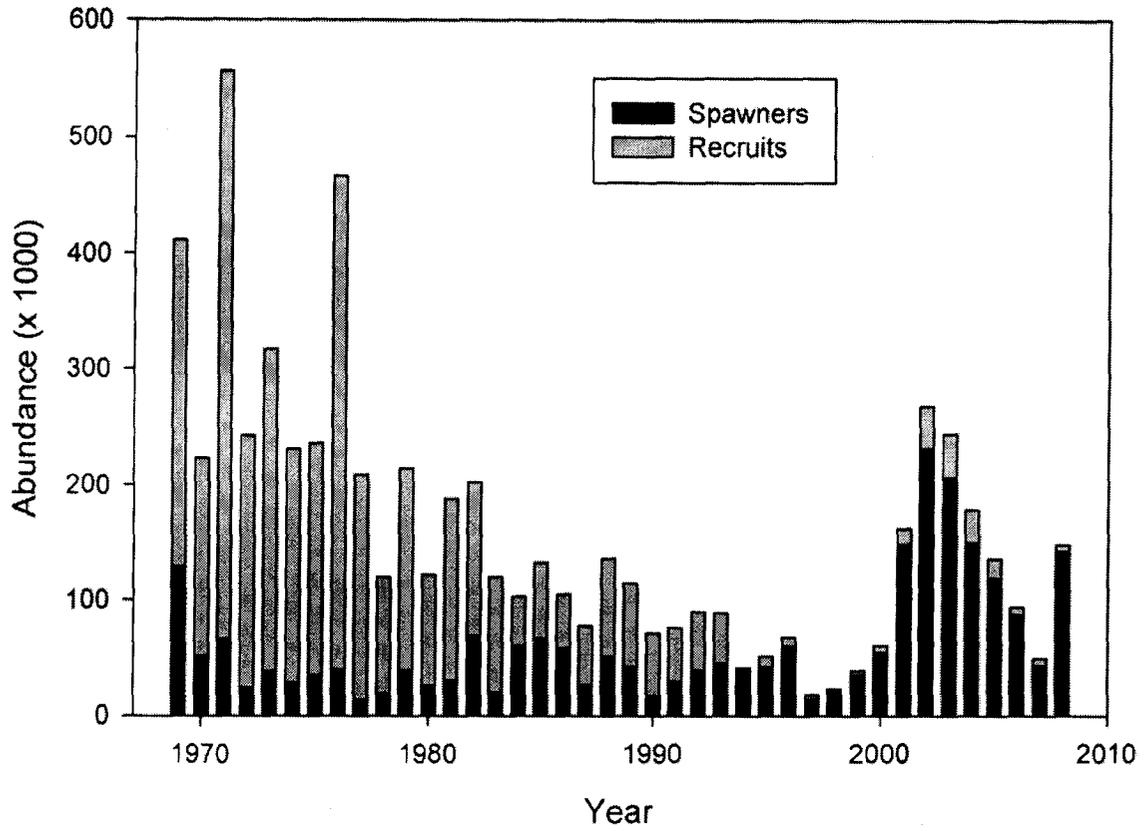


Figure 6. OC coho salmon naturally produced spawners and recruits, 1969 to 2008. Harvest was curtailed in 1994 (data from Table 2) (PFMC 2009).

ESU and Stratum Totals

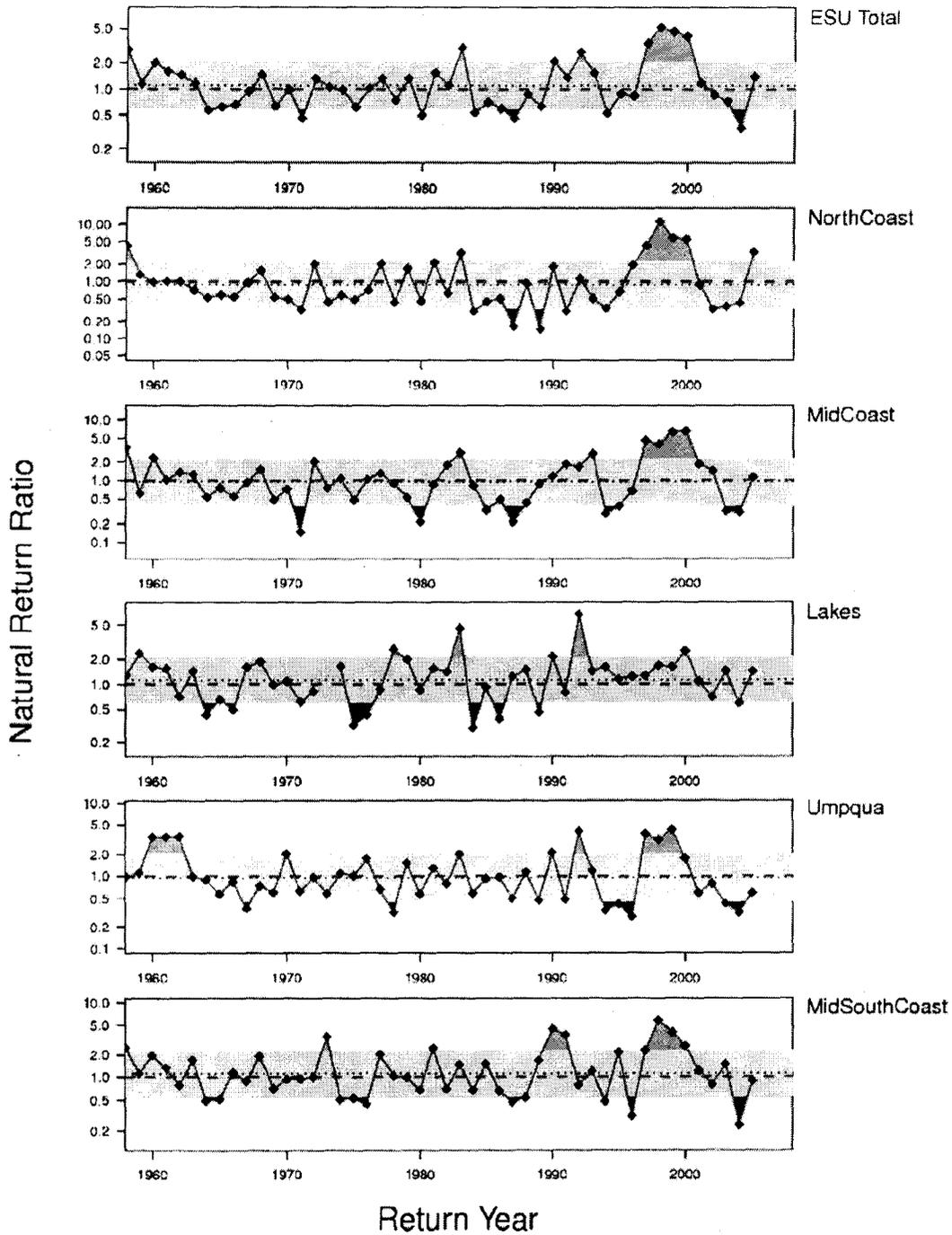


Figure 7. Trends in Natural Return Ratio for the whole ESU (top panel) and the five biogeographic strata (lower panels). The dashed line marks the long-term mean, and the green background spans the mean ± 1 standard deviation (SD). Values that exceed the mean + 1 SD are highlighted in yellow, values more than 1 SD below the mean are highlighted in blue. Note the logarithmic scale. Data from Wainwright et al. 2008 and ODFW 2009a.

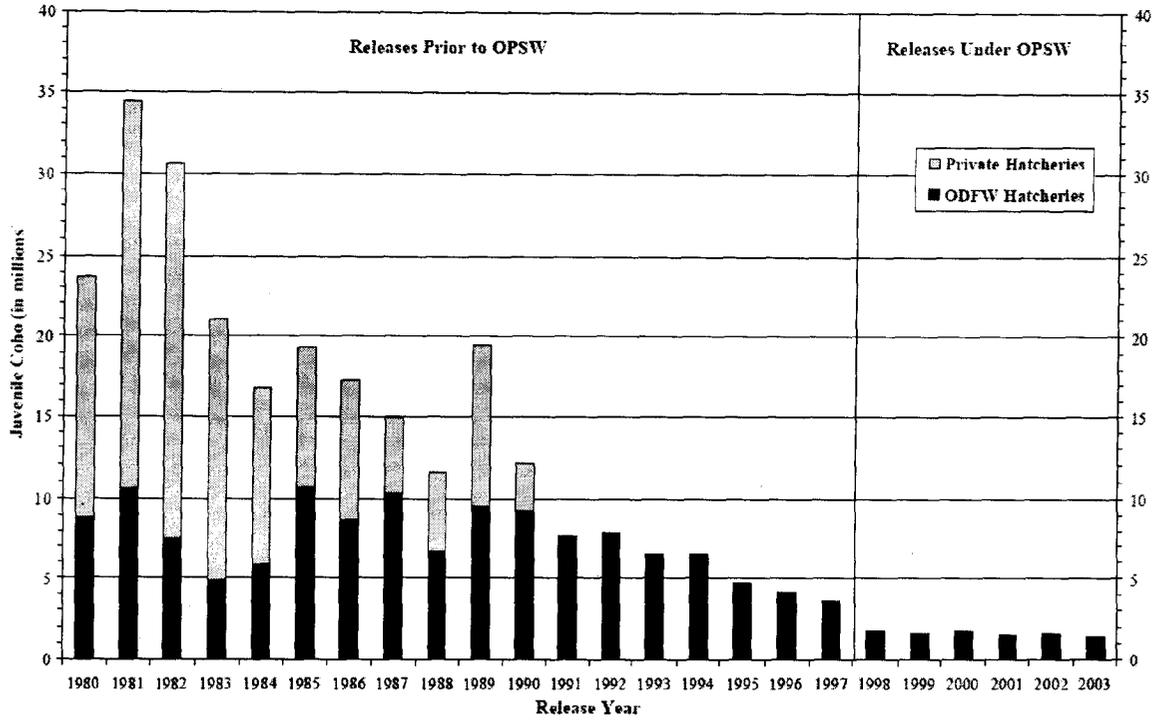


Figure 8. Releases of juvenile hatchery coho (all age classes) in the Oregon Coast Coho Salmon ESU, by hatchery type, from 1980 to 2003. The 1980 through 1984 release years are missing unfed fry release data. Further reductions occurred from 2004 to 2009, as described in text. Figure taken from Oregon (2005).

Trends in Hatchery Influence: Coastal Coho ESU 1994-2008

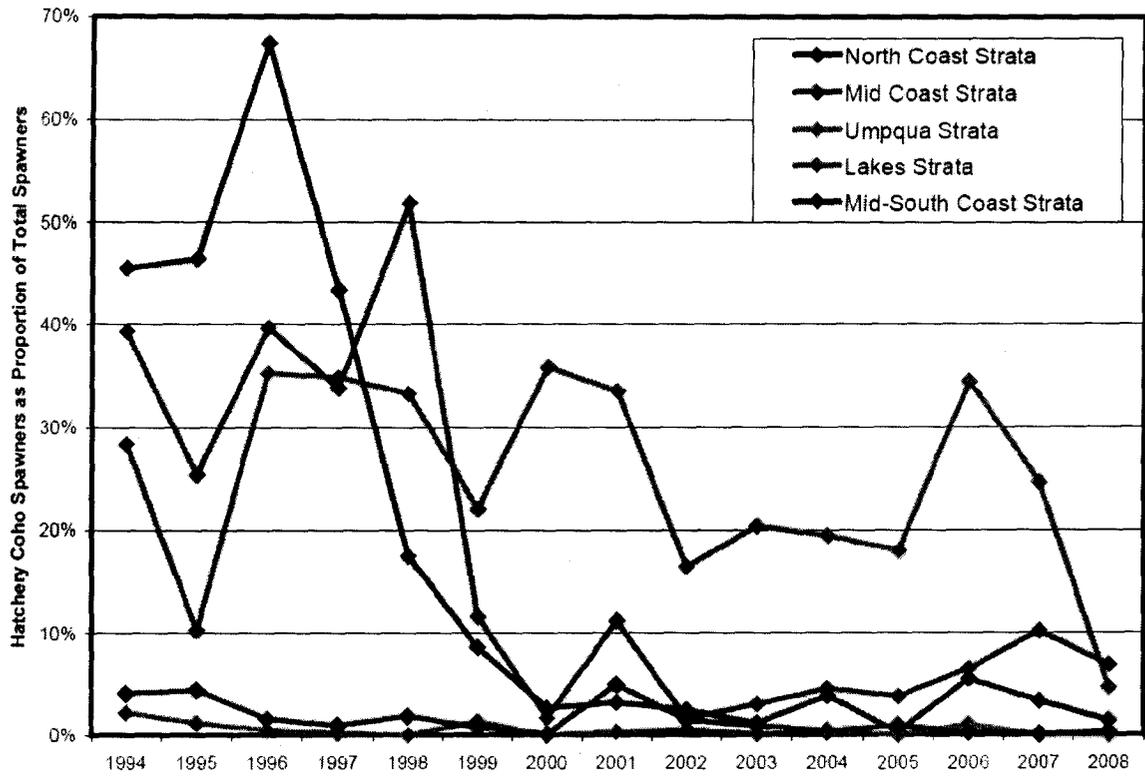


Figure 9. Proportion of hatchery origin coho salmon in each stratum of the Oregon Coast Coho ESU: 1994-2008. Figure taken from ODFW 2009a .

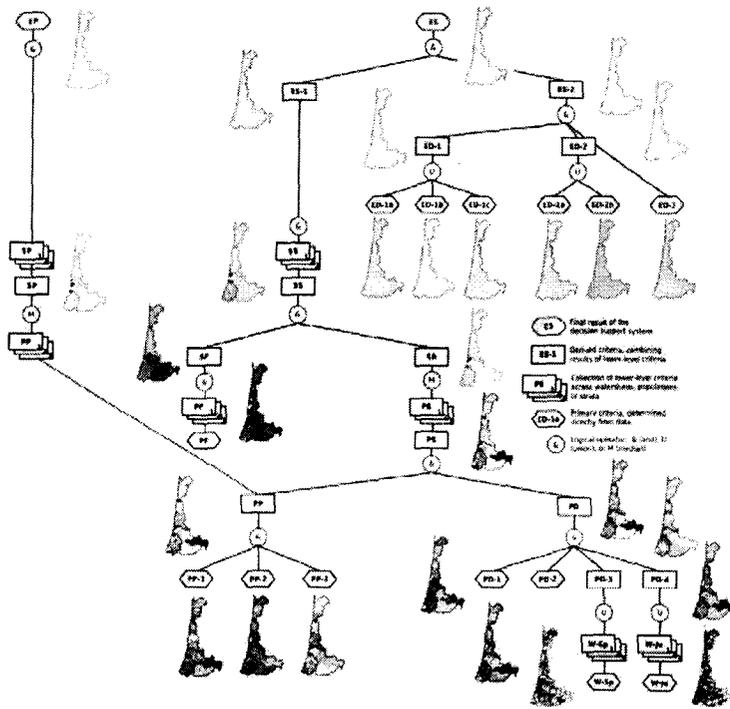


Figure 10. Decision tree for the biological recovery criteria. Flow lines show the logical connections from the primary criteria (blue hexagons) through intermediate levels (blue rectangles) to ESU-wide evaluations (Magenta ovals) for ESU persistence (EP) and sustainability (ES). Colored maps show results at each geographic scale, with dark red indicating poor conditions and dark green indicating good conditions. Criteria abbreviations are as in Table 5.

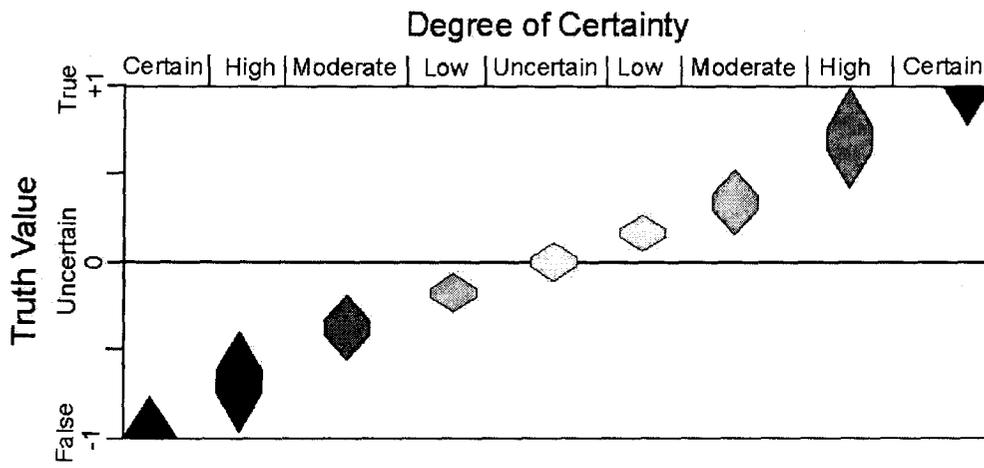
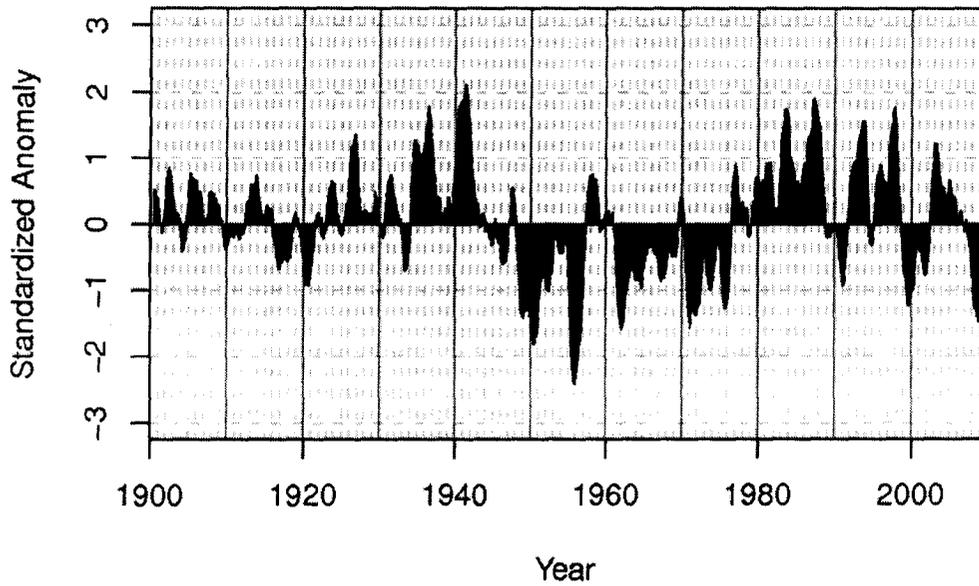


Figure 11. Truth values color degree of certainty interpretation.

Pacific Decadal Oscillation (PDO)



NOAA/NWFS/C/FED, Updated 12 Jan 2010

Figure 12. The Pacific Decadal Oscillation index from 1900 through 2009. Values shown are standardized deviations from the long-term (1900-1993) mean. A 12-month moving average was applied to eliminate short-term noise. Data from University of Washington (URL: <http://jisao.washington.edu/pdo/PDO.latest>).

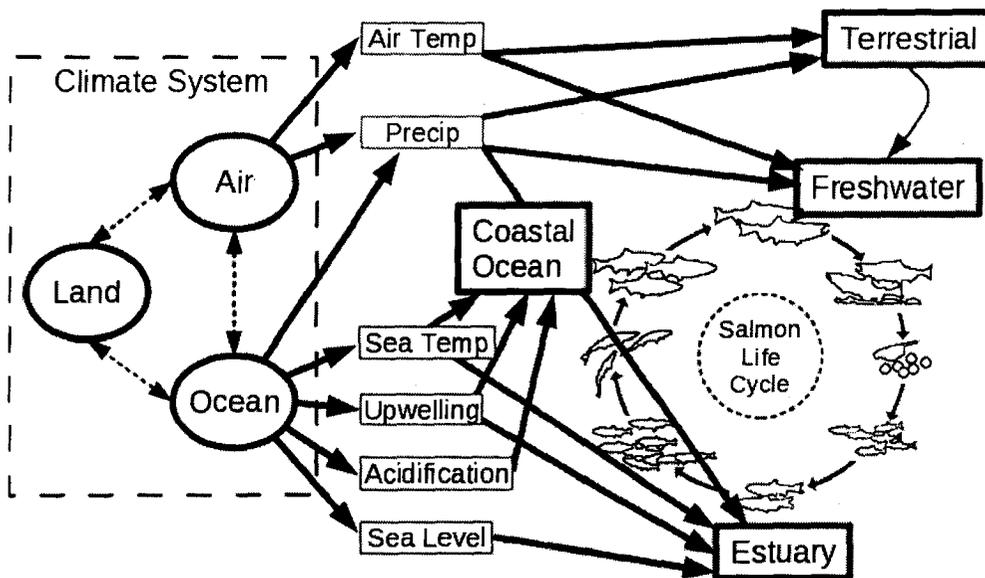


Fig. 13. Conceptual diagram of multiple pathways by which climate influences the salmon lifecycle. The climate system affects four habitats (terrestrial, freshwater, estuary, and coastal ocean) vital to salmon life stages, which in turn influence salmon reproduction, growth, and mortality.

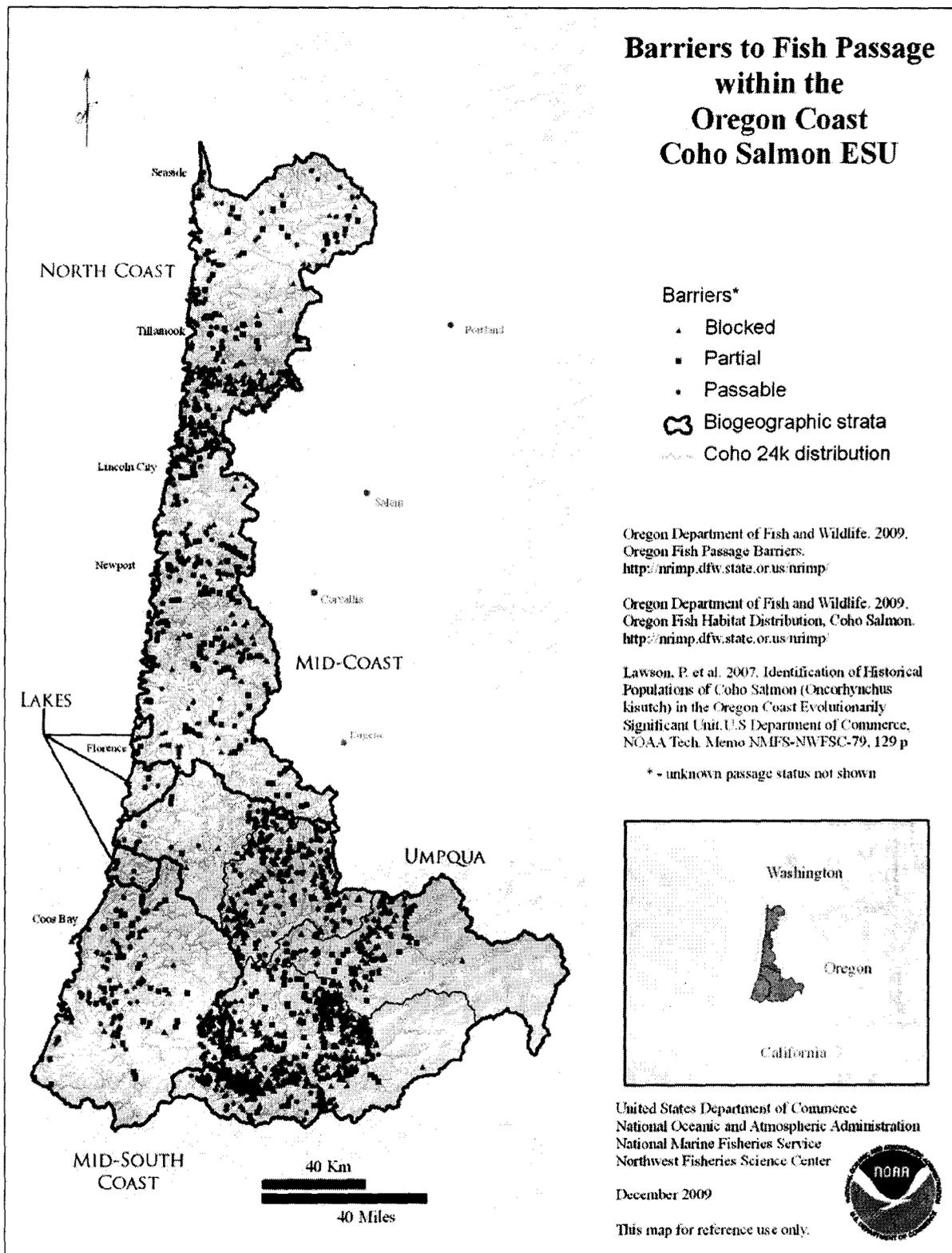


Figure 14. Barriers to Fish Passage (ODFW 2009).

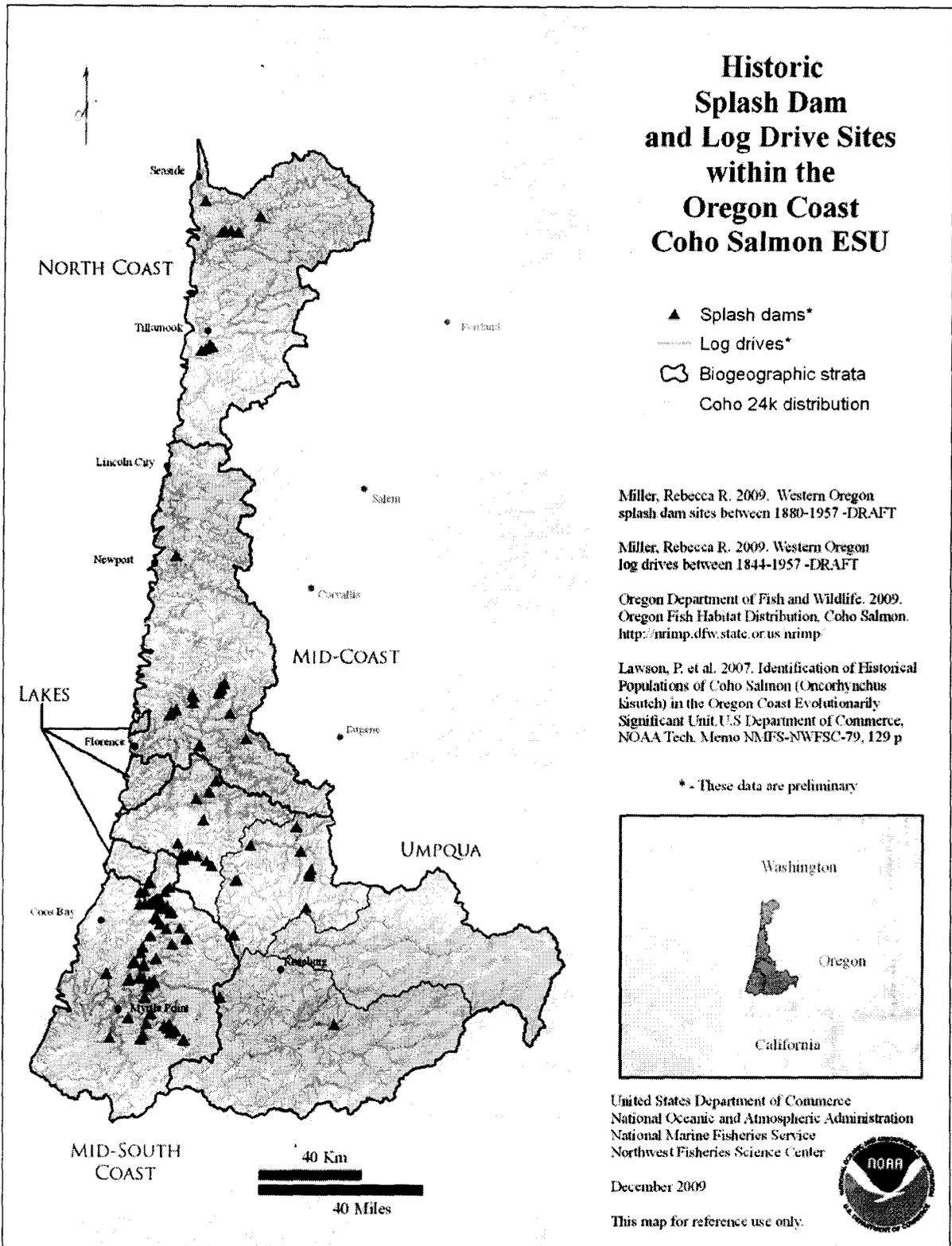


Figure 15. Splash dam and log driving locations in the OC Coho Salmon ESU.

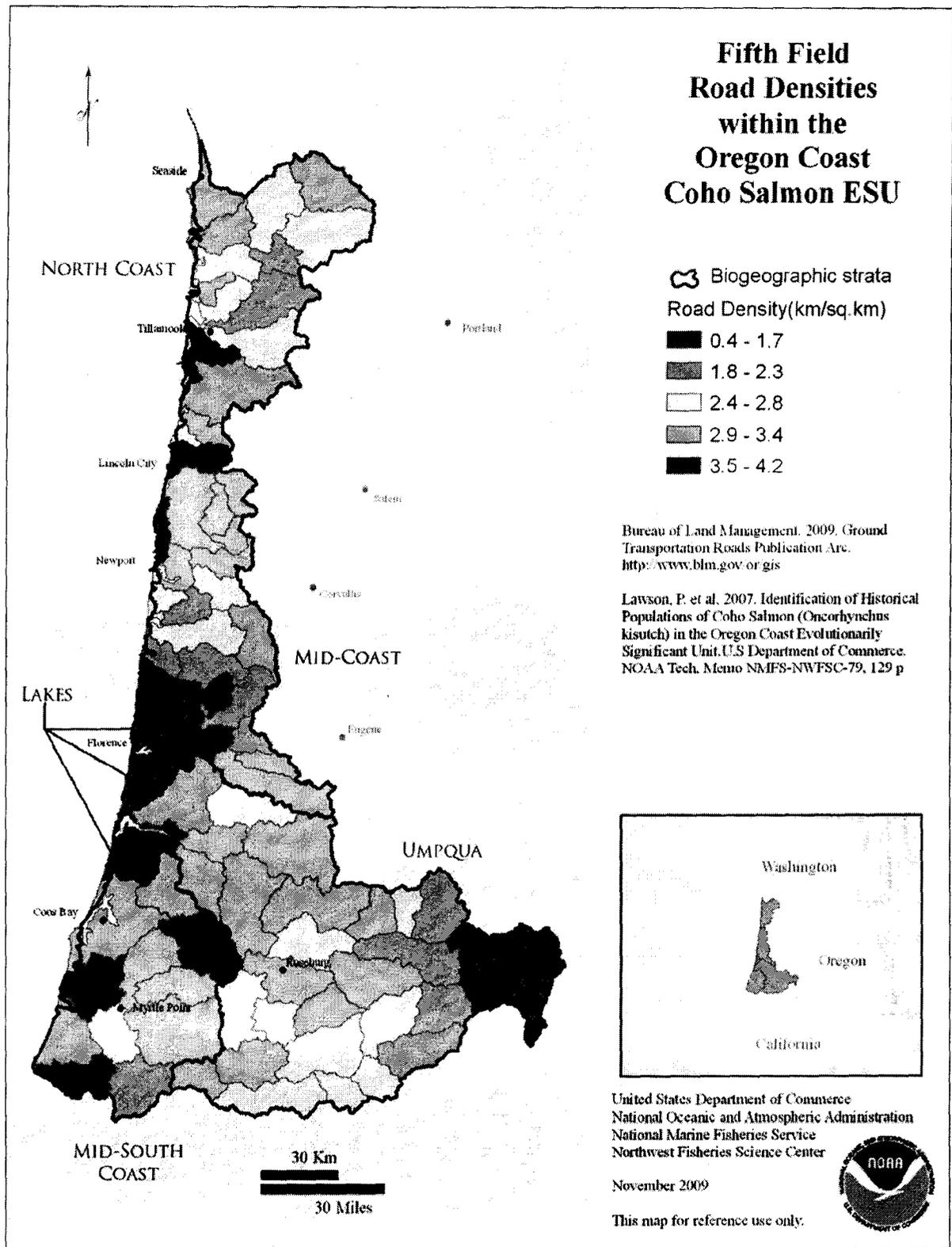


Figure 16. Road Densities by HUC-5 within the OC Coho Salmon ESU.

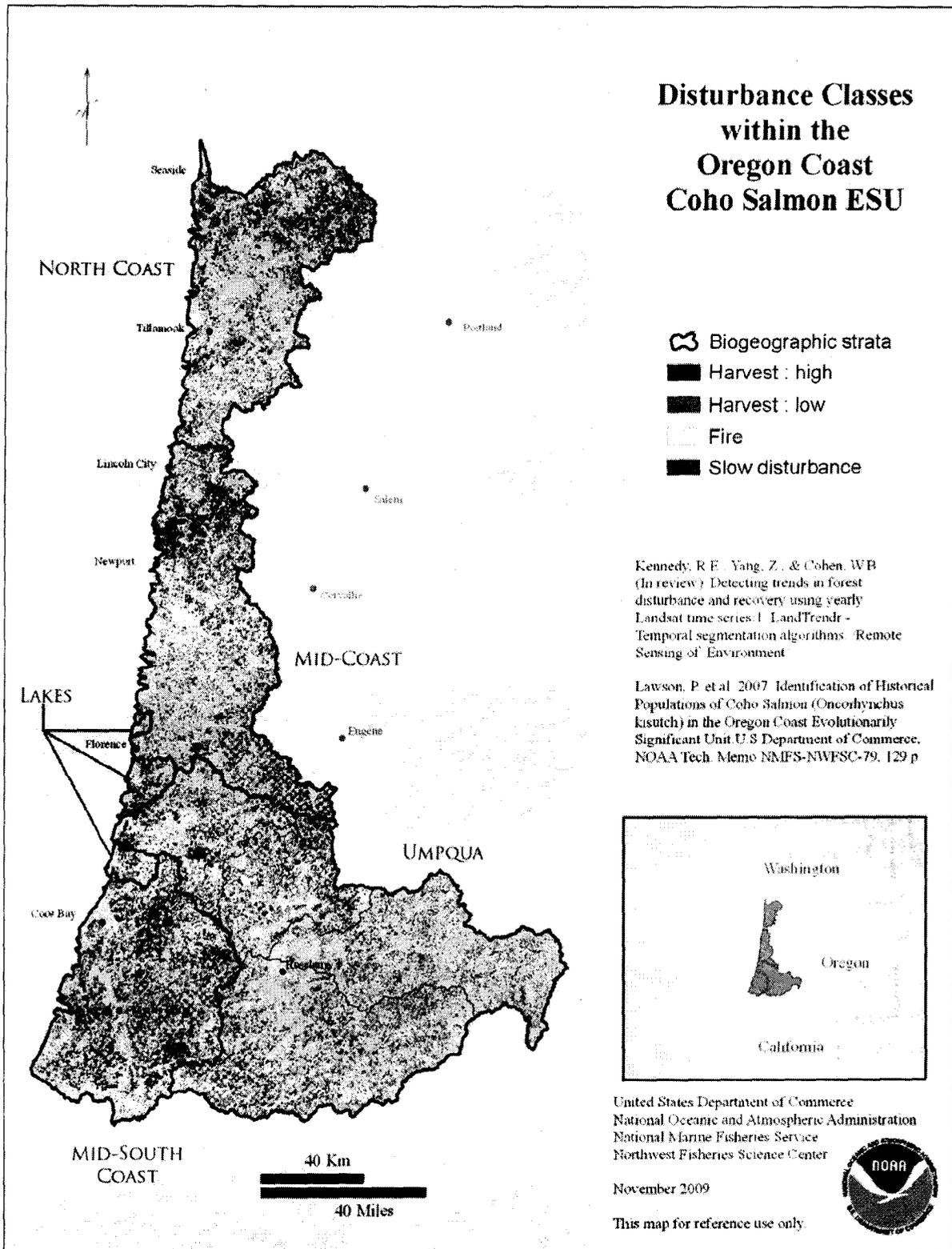


Figure 17. Distribution and intensity of vegetation disturbance for the OC coho salmon ESU from 1986 to 2008 based on analysis of Landsat imagery.

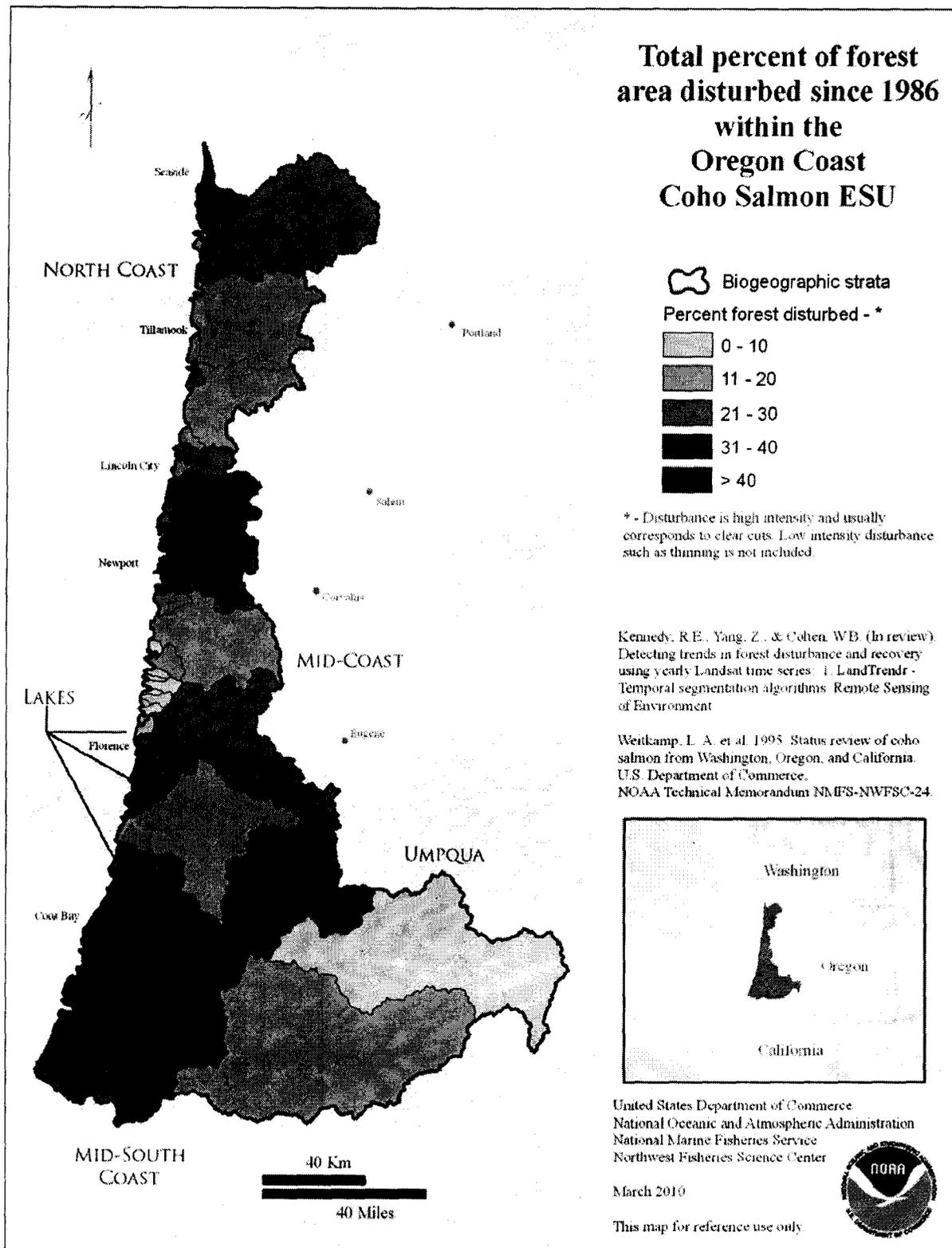


Figure 18. Ranking of river basins and the Umpqua sub-basins in the Coho Salmon ESU by cumulative percent vegetation disturbance (high= dark, low=light) from 1986 to 2008.

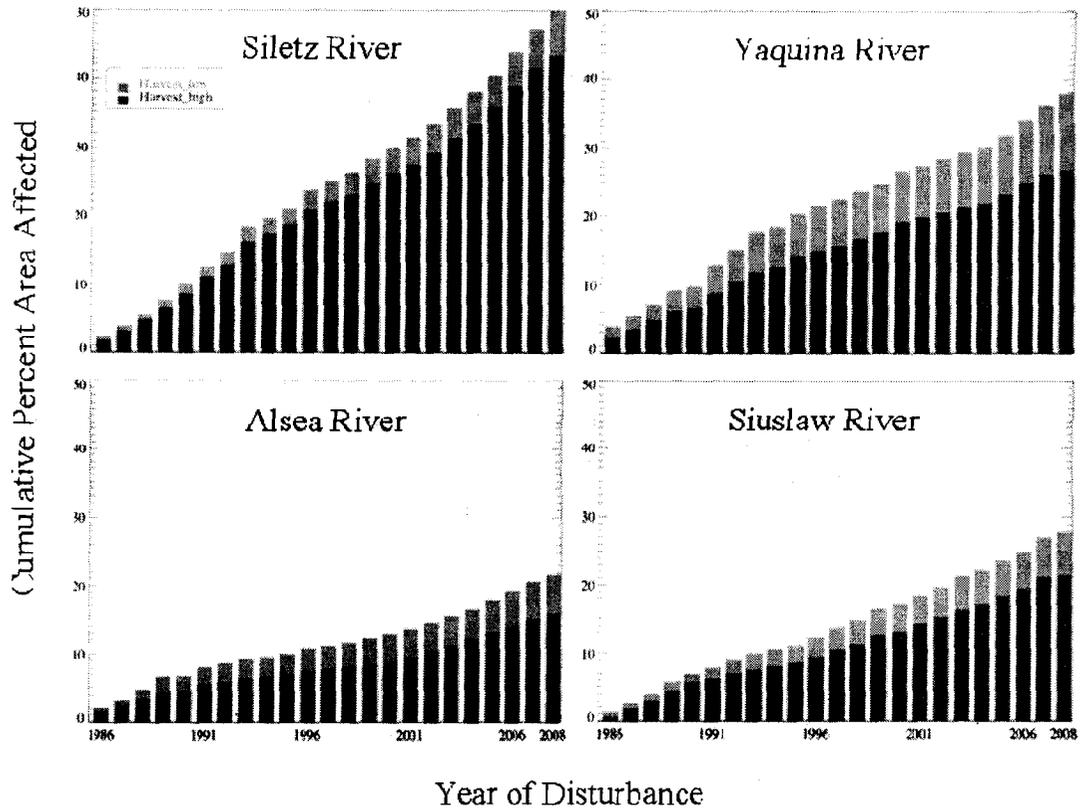


Figure 19. Time series of cumulative area of vegetation disturbance for four river basins in the Mid-Coast Stratum. High disturbance (dark gray) is usually clear cut logging, while low disturbance (light gray) is related to forest thinning

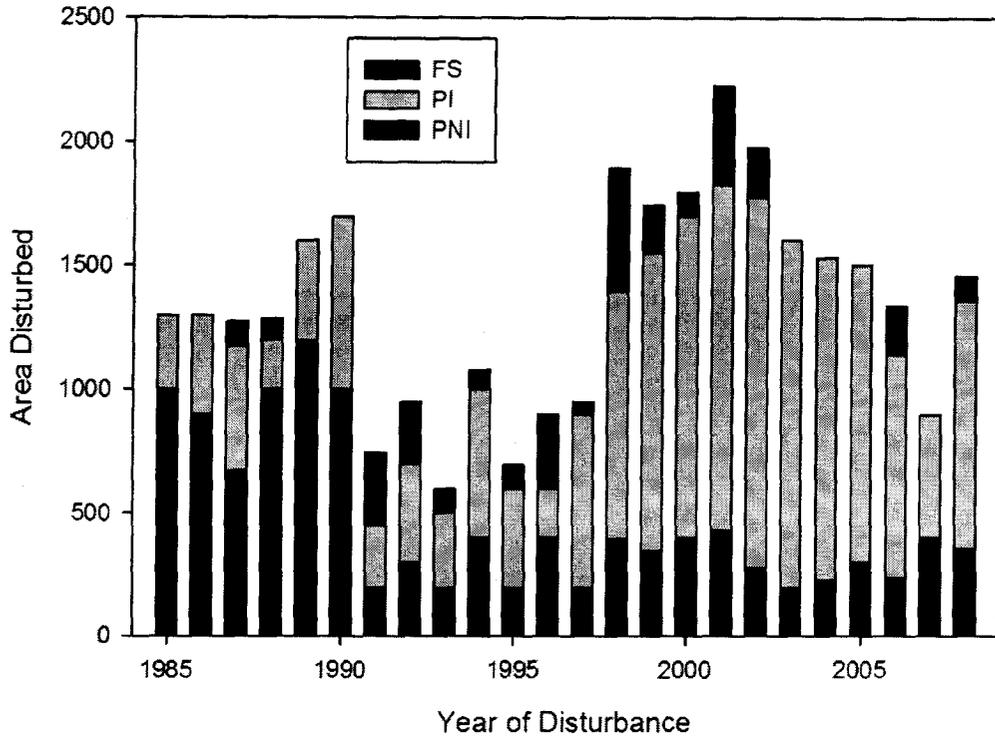


Figure 20. Total area (hectares) of vegetation disturbance in the Oregon Coast coho salmon ESU by three land ownership categories from 1986 to 2008. PNI; private non-industrial, PI; private industrial, FS; U.S. Forest Service

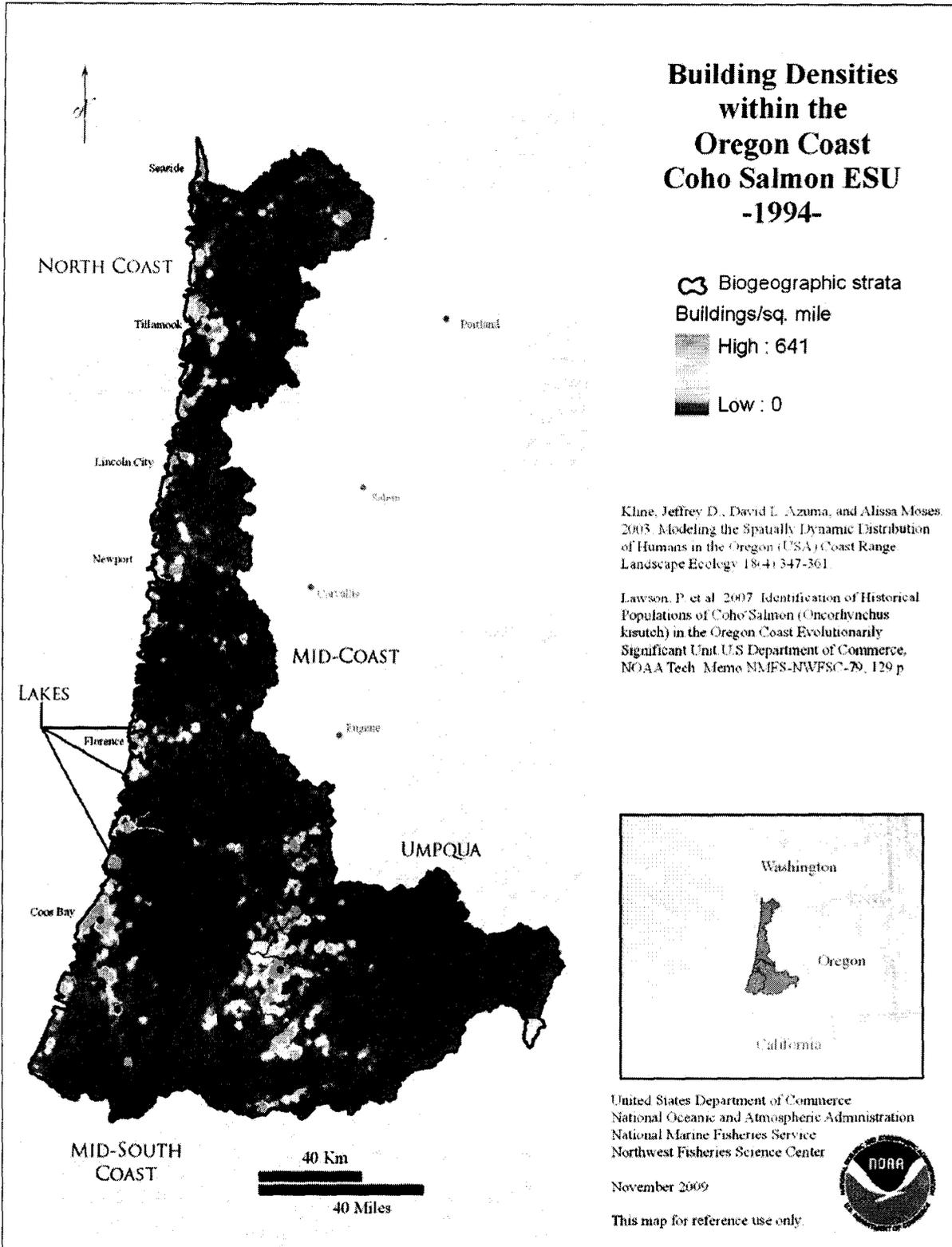


Figure 21. Projected building densities within the OC Coho Salmon ESU, 2044.

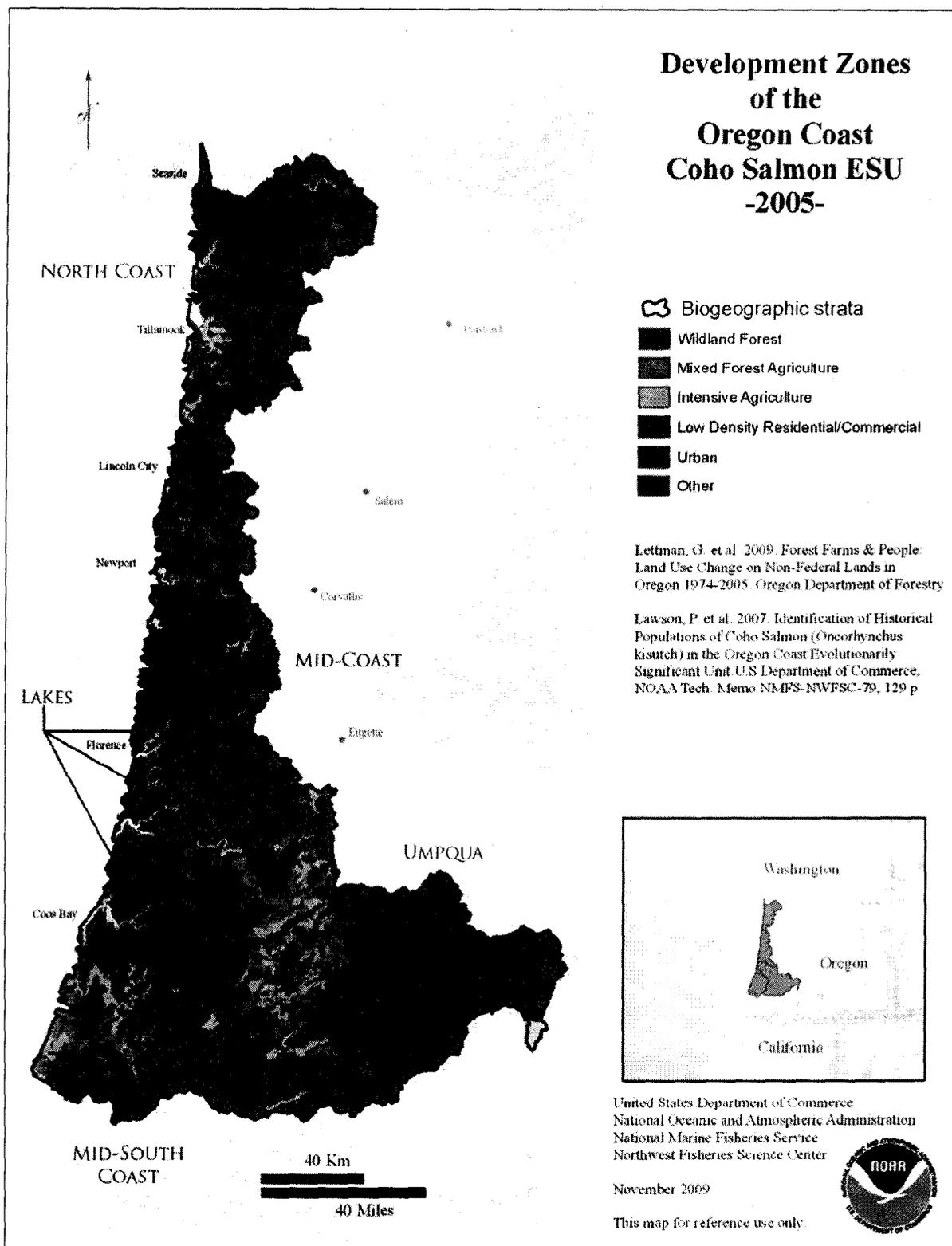


Figure 22. Development Zones of OC Coho Salmon ESU, 2005.

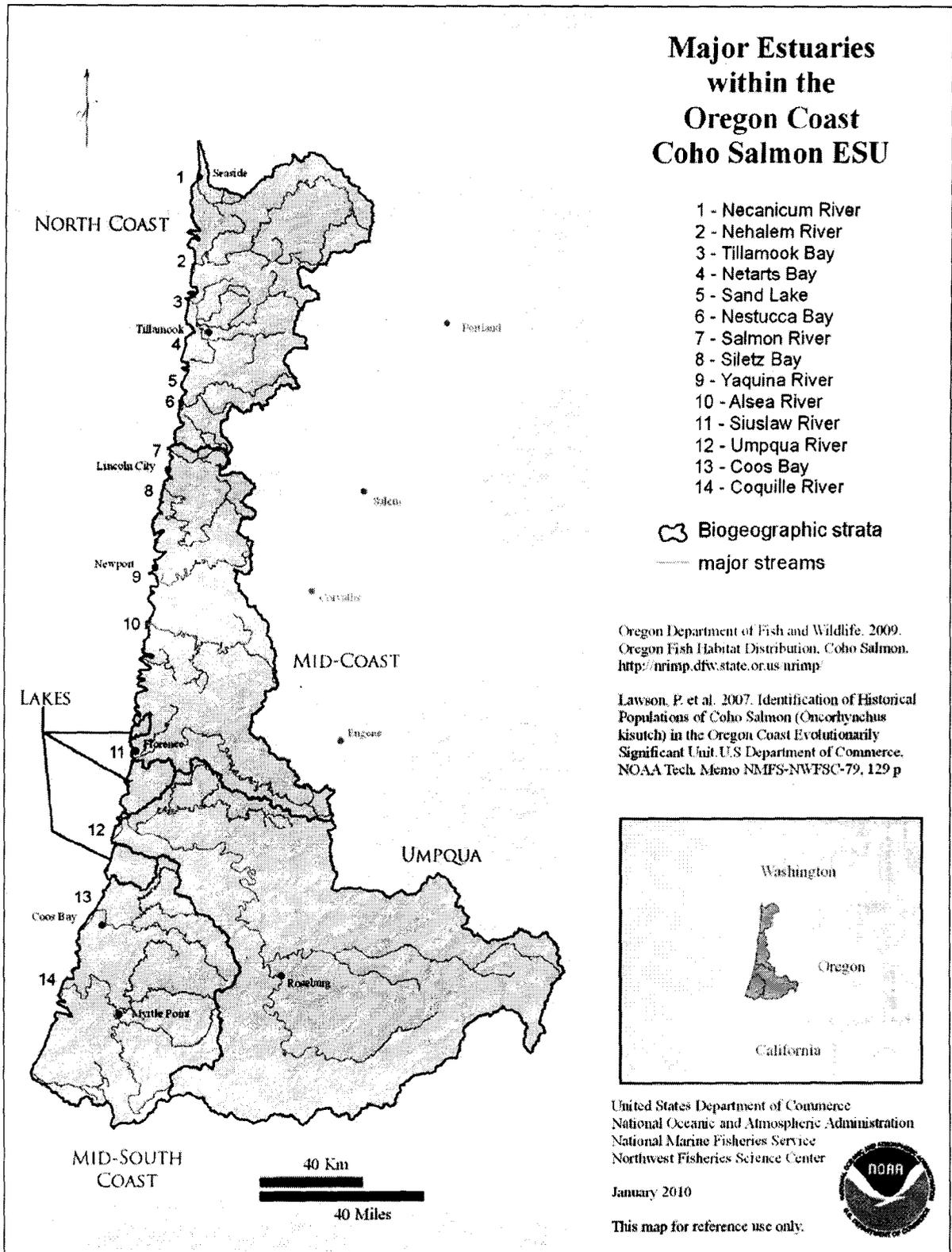


Figure 23. Major Estuaries within the OC Coho Salmon ESU.

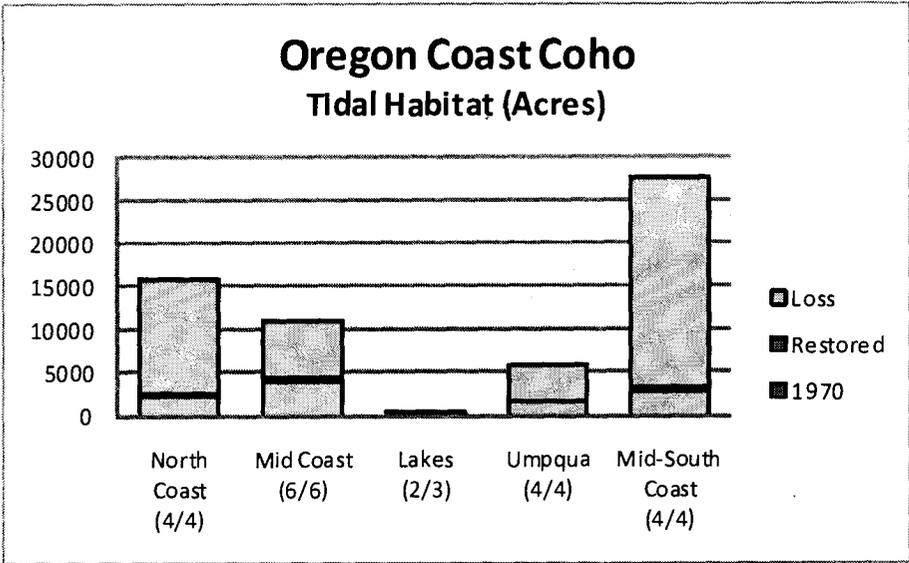
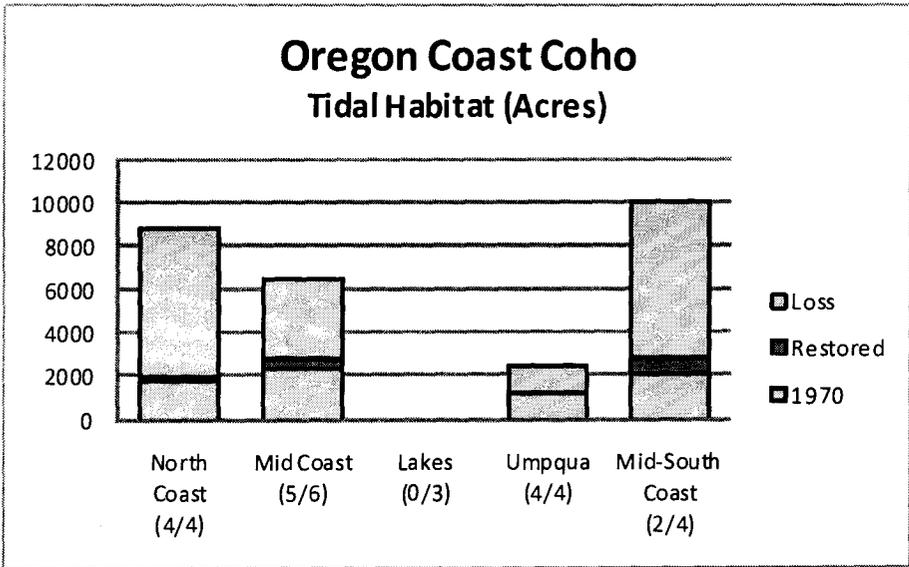


Figure 24. Tidal Estuary Gains in OC Coho Salmon ESU.

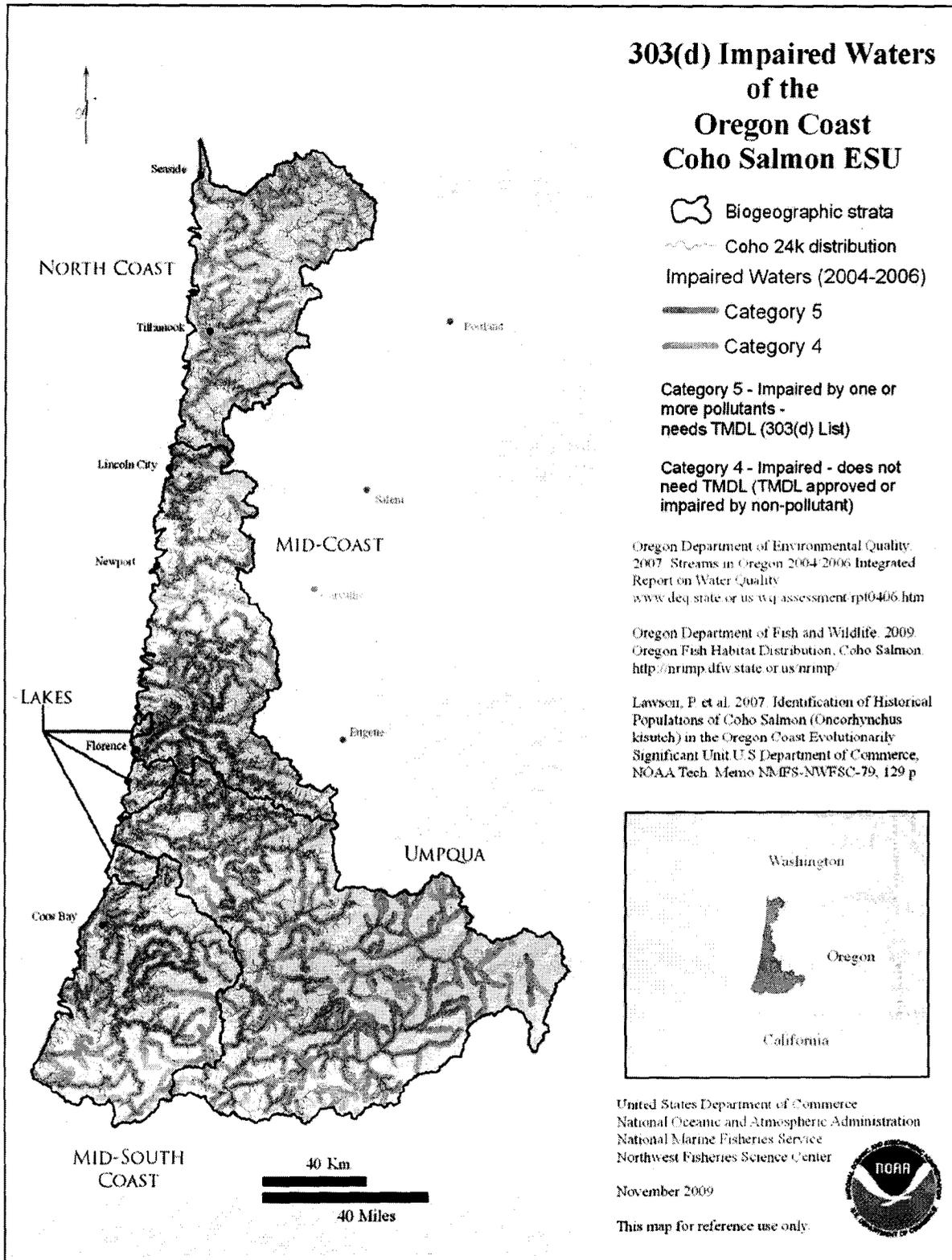


Figure 25. 303(d) Impaired Waters of the OC Coho Salmon ESU.

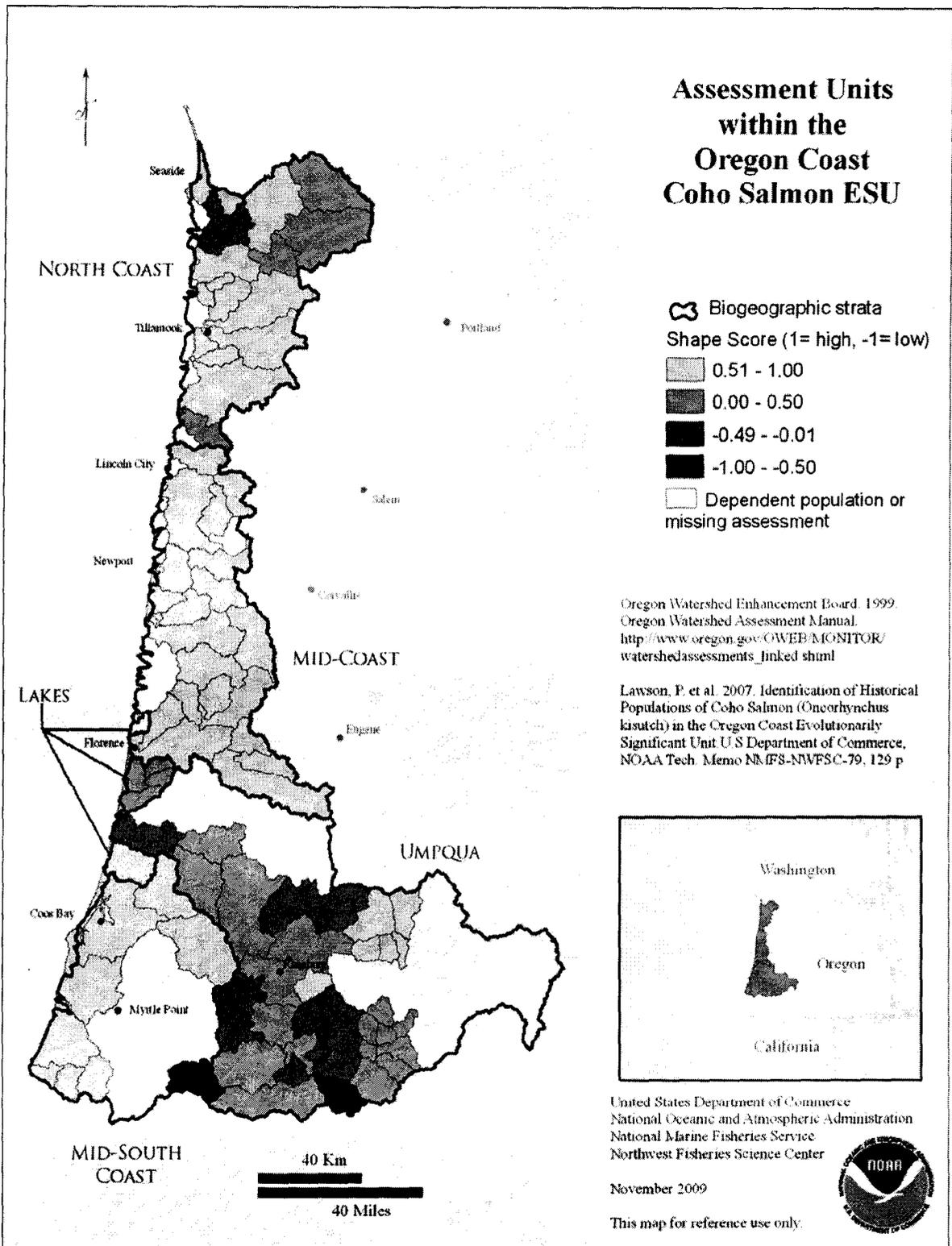


Figure 27. SHAPE scores for OC Coho Salmon Assessment Units.