Status review update for Pacific salmon and steelhead listed under the Endangered Species Act

Pacific Northwest[1]

Michael Ford (ed.), Tom Cooney, Paul McElhany, Norma Sands, Laurie Weitkamp, Jeffrey Hard, Michelle McClure, Robert Kope, Jim Myers, Andrew Albaugh, Katie Barnas, David Teel, Paul Moran and Jeff Cowen*

Northwest Fisheries Science Center
Conservation Biology Division
*Operations, Management and Information Division

December 10, 2010

Cite as: Ford MJ (ed.), Cooney T, McElhany P, Sands N, Weitkamp L, Hard J, McClure M, Kope R, Myers J, Albaugh A, Barnas K, Teel D, Moran P, Cowen J. 2010. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest. Draft U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NWFSC-XXX.

[1] An equivalent report for California is available: Williams, T.H., S.T. Lindley, B.C. Spence, and D.A. Boughton. Draft (December 2010). Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Southwest. Draft U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-SWFSC-XXX.

Table of Contents

Introduction and summary of conclusions

The Endangered Species Act (ESA) requires that the National Marine Fisheries Service (NMFS) review the status of listed species under its authority at least every five years and determine whether any species should be removed from the list or have its listing status changed. In June of 2005, NMFS issued final listing determinations for 16 Evolutionarily Significant Units (ESUs) of Pacific Salmon (*Oncorhynchus sp.*) and in January of 2006 NMFS issued final listing determinations for 10 Distinct Population Segments (DPS) of steelhead (*O. mykiss*, the anadromous form of rainbow trout)[2]. NMFS is therefore conducting a review in 2010 and early 2011 of 27 of the 28 currently listed Pacific salmonid ESUs/DPSs of West Coast Pacific salmon (FR 75:13082 – see http://www.nwr.noaa.gov/Publications/FR-Notices/2010/upload/75FR13082.pdf) [3].

The review is being conducting by the NMFS Northwest and Southwest Regions, and this report is in response to a 23 February 2010 request from the Regions to the Northwest and Southwest Fisheries Science Centers to provide a scientific summary of the risk status of the subject ESUs/DPSs. In the last formal status review (Good et al. 2005) the Biological Review Team (BRT) categorized each ESU as either "in danger of extinction", "likely to become endangered" or "not likely to become endangered", based on the ESU's abundance, productivity, spatial structure and diversity. In this report, for each listed ESU/DPS, we summarize whether there is new information since the 2005/2006 listings to indicate that an ESU is likely to have moved from one of the three biological risk categories to another. We focus in particular on 1) information on ESU/DPS boundaries, and 2) trends and status in abundance, productivity, spatial structure and diversity. The information in the report will be incorporated into the Regions' review, and the Regions will make final determinations about any proposed changes in listing status, taking into account not only biological information but also ongoing or planned protective efforts.

One of the notable differences between 2010/2011 and the last status review in 2005 (Good *et al.*, 2005) is the development of viability criteria for all listed salmon ESUs. NMFS initiated its salmon recovery planning in 2000, and the 2005 status review incorporated information that was available from the recovery planning process at that time. In particular, in 2000 NMFS published guidelines for developing viability (recovery) criteria for Pacific salmon (McElhany *et al.*, 2000) and launched a series of regional Technical Recovery Teams to develop viability

[2] For Pacific salmon, NMFS uses its 1991 ESU policy, that states that a population or group of populations will be considered a Distinct Population Segment if it is an Evolutionarily Significant Unit. The species *O. mykiss* is under the joint jurisdiction of the NMFS and the Fish and Wildlife Service, so in making its listing January 2006 determinations NMFS elected to use the 1996 Joint FWS-NMFS DPS policy for this species.

[3] The Oregon Coast coho salmon ESU was reviewed in 2010, and therefore is not included in this report.

criteria for each listed ESU/DPS (see http://www.nwfsc.noaa.gov/trt/index.cfm). However, at the time of 2005 status review, only one TRT (Puget Sound Chinook) had produced final viability criteria, and no formal recovery goals had been adopted for any ESU/DPS. In contrast, in 2010 all ESUs/DPSs have TRT-developed viability criteria and several have formal recovery goals (Table 1 and http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Draft-Plans.cfm). Where possible, therefore, this review summarizes current information with respect to both the viability criteria developed by the TRTs and the recovery goals identified in final recovery plans[4]. We also provide descriptions of spawning abundance and trends following the methods of the 2005 status review to allow direct comparison to that report.

In addition to summarizing ESU/DPS status, we also provide some information that will be useful for evaluating trends in threats. The original listings identified a range of factors that threatened the viability of listed salmon. Although the specific composition of threats varied among ESUs, in general most ESUs were threatened by some combination of the "four H's" – harvest, hydropower, habitat degradation and hatchery production. Some of these threats, such as harvest, are well monitored and relatively easy to quantify. Others, such as habitat degradation, are not monitored in a coordinated way across multiple jurisdictions making trend evaluation difficult. In this report, we summarize trends in harvest impacts and some simple aspects of hatchery impacts using readily available data. For habitat, we used recovery plans and databases of habitat restoration activities to summarize the habitat threats identified for ESU and the types of activities that have been conducted to address those threats. This analysis is under review, and will therefore be included in a subsequent report. In addition, we have initiated work that will use satellite imagery to summarize trends in land use for several ESUs. We do not summarize information related to hydropower, because this topic (particularly in the Columbia River) is already the subject of extensive review (see http://www.nwr.noaa.gov/Salmon-Hydropower/index.cfm). Global climate change potentially has far reaching impacts on Pacific salmonids, and we therefore provide a brief summary of new information on how climate change may affect ESA listed salmon and steelhead.

[4] The recovery plans based their goals upon the work of the TRTs, so the criteria in the recovery plans are similar to the TRT criteria. The TRT criteria were intended to be flexible, however, to allow for local control of recovery plan development. In some cases, therefore, the recovery plan criteria are not identical to the TRT criteria.

Table 1 –List of viability reports completed by Technical Recovery Teams. See http://www.nwfsc.noaa.gov/trt/pubs.cfm and http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=2242 for links to the reports.

Domain	Viability Criteria document name	Year completed
Puget Sound - Chinook	Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook salmon evolutionarily significant unit	2002
Puget Sound – Hood Canal Summer Chum	Determination of Independent Populations and Viability Criteria for the Hood Canal Summer Chum Salmon Evolutionarily Significant Unit	2009
Puget Sound – Lake Ozette Sockeye	Viability Criteria for the Lake Ozette Sockeye Salmon Evolutionarily Significant Unit	2009
Willamette/Lower Columbia	Revised viability criteria for salmon an steelhead in the Willamette and Lower Columbia Basins 2003 and 2006	2006
Oregon Coast	Biological recovery criteria for the Oregon Coast Coho Salmon Evolutionarily Significant Unit	2007
Interior Columbia Basin	Viability criteria for application to Interior Columbia Basin salmonid ESUs	2007
North Central California Coast	A framework for assessing the viability of threatened and endangered salmon and steelhead in North-Central California Coast recovery domain	2007
Southern Oregon Northern California Coast	Framework for assessing viability of threatened Coho salmon in the Southern Oregon/Northern California Coast Evolutionarily Significant Unit	2007
Southern-Central California Coast	Viability criteria for steelhead of the south-central and southern California coast	2007
California Central Valley	Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin	2007

A summary of our conclusions is presented in Table 2. Natural origin abundance of most ESUs/DPSs has increased since the original status reviews in the mid-1990s, but declined since the time of the last status review in 2005. Risks from harvest and hatchery production have improved considerably for many ESUs since the mid-1990s, and have remained largely stable since 2005. Analysis of trends in habitat was not included in this report. Overall, the information we reviewed does not suggest that a change in biological risk category is likely for any of the currently listed ESU/DPSs.

Table 2 – Current listing status and summary of conclusions

Species	ESU	2005 risk category	Listing status	Update indicates change in risk category?
Chinook	Upper Columbia spring	In danger of extinction	Endangered	No
	Snake River spring/summer	Likely to become endangered	Threatened	No
	Snake River fall	Likely to become endangered	Threatened	No
	Upper Willamette spring	Likely to become endangered	Threatened	No
	Lower Columbia	Likely to become endangered	Threatened	No
	Puget Sound	Likely to become endangered	Threatened	No
Coho	Lower Columbia	In danger of extinction	Threatened	No
	Puget Sound	Not likely to become endangered	Species of Concern	No
Sockeye	Snake River	In danger of extinction	Endangered	No
	Lake Ozette	Likely to become endangered	Threatened	No
Chum	Hood Canal summer	Likely to become endangered	Threatened	No
	Columbia River	Likely to become endangered	Threatened	No
Steelhead	Upper Columbia	In danger of extinction	Threatened	No
	Snake River	Likely to become endangered	Threatened	No
	Middle Columbia	Likely to become endangered	Threatened	No
	Upper Willamette	Likely to become endangered	Threatened	No
	Lower Columbia	Likely to become endangered	Threatened	No
	Puget Sound	Likely to become endangered	Threatened	No

Methods

This report includes both a set of common analyses conducted for each ESU/DPS as well as ESU/DPS specific analyses developed by the individual TRTs. Here, we describe only the common set of analysis; see the individual ESU/DPS sections a description of the analysis that pertain to specific ESUs/DPSs.

Abundance and trends – All of the Pacific Northwest TRTs spent considerable time and effort developing spawning abundance data for the populations they identified within ESUs. In almost all cases these estimates are derived from state, tribal or federal monitoring programs. The raw information upon which the spawning abundance estimates were developed consist of numerous types of data including redd counts, dam counts, carcass surveys, information on pre-spawning mortality, distribution within populations, etc, which the TRTs used to develop estimates of natural origin spawning abundance. It is important to recognize that spawning abundance estimates and related information such as the fraction of spawners that are natural origin are not 'facts' that are known with certainty. Rather, they are estimates based on a variety of sources of information, some known with greater precision or accuracy than others. Ideally, these estimates would be characterized by a known level of statistical uncertainty. However, for the most part such a statistical characterization is either not possible or has not been attempted. The spawning time series summarized here and references to the methods for their development are available from the Northwest Fisheries Science Center's Salmon Population Summary database:
https://www.webapps.nwfsc.noaa.gov/apex/f?p=238:home:0.

We used the abundance time series to calculate several summary statistics, following the methods described of the last major status review update in 2005 (Good et al. 2005). Recent abundance of natural spawners is reported as the geometric mean (and range) of the most recent data. Geometric means were calculated for the most recent 5 years. Zero values in the data set were replaced with a value of 1, and missing data values within a multiple year range were excluded from geometric mean calculations.

Short- and long-term trends were calculated from time series of the total number of adult spawners. Short-term trends were calculated using data from 1995 to the most recent year, with a minimum of 10 data points. Long-term trends were calculated using all data in a time series. Trend was calculated as the slope of the regression of the number of natural spawners (log-transformed) over the time series; to mediate for zero values, 1 was added to natural spawners before transforming the data. Trend was reported in the original units as exponentiated slope, such that a value greater than 1 indicates a population trending upward, and a value less than 1 indicates a population trending downward. The regression was calculated as: $\ln(N+1) = \beta_0 + \beta_1 X + \varepsilon$, where N is the natural spawner abundance, β_0 is the intercept, β_1 is the slope of the equation, and ε is the random error term. Confidence intervals (95%) for the slope, in their original units of abundance, were calculated as $\exp(\ln(b_1) - t_{0.05(2),df}\, s_{b1}) < \beta_1 < \exp(\ln(b_1) + t_{0.05(2),df}\, s_{b1})$, where b_1 is the estimate of the true slope, β_1, $t_{0.05(2)}$, df is the two-sided t-value for a confidence level of 0.95, *df* is equal to n – 2, *n* is the number of data points in the time series, and s_{b1} is the standard error of the estimate of the slope, b_1.

We also calculated short and long-term population growth rates, λ, following the methods described in Good et al. (2005) and implemented in the computer program SPAZ (http://www.nwfsc.noaa.gov/trt/wlc/spaz.cfm).

Hatchery releases – We plotted trends in hatcheries releases within the geographic boundaries of the spawning populations of each ESU. All data was obtained from the Regional Mark Information System (RMIS) database, maintained by the Regional Mark Processing Center (RMPC) as part of the Pacific States Marine Fisheries Commission (PSMFC -- http://www.rmpc.org/external/rmis-standard-reporting.html). Through interviews with individuals at PSC, WDFW, ODFW, USFWS, Tribes, and IDFG it was determined that all data, or nearly all data in the case of ODFW, has been submitted to the RMIS from the year 1990 to present. In the case of ODFW all releases from 2004 to present are in RMIS, and all CWT releases are in RMIS from 1990 to 2003 with an unknown amount of non-CWT submitted as well.

The following agencies, WDFW, ODFW, USFWS, NWIFC, CRITFC, and IDFG were queried in the states of WA, OR and ID to obtain all releases of all species in the RMIS and create a master dataset. Several attributes were then converted from code used within RMIS to a more intuitive nomenclature. All species that were not Chinook, Chum, Coho, Sockeye or Steelhead were removed.

RMIS reports release totals in 4 different categories, 'cwt_1st_mark_count', 'cwt_2nd_mark_count', 'non_cwt_1st_mark_count', and 'non_cwt_2nd_mark_count'. These were all summed to obtain a total release for each release event. Release age was calculated as release year - brood year - 1 for fall spawners (most salmon) and as release year – brood year for spring spawners (steelhead). Ages zero were considered sub-yearlings and age 1 or greater were considered yearlings.

Determining release location by ESU and Pacific Salmon Commission (PSC) basin was a multi-step process. All releases in RMIS are assigned a PSC Region and PSC Basin code. These codes were converted from code to full names. After obtaining GIS basin layer data from PSC it was determined that PSC Basins are larger than TRT defined salmon population boundaries, yet smaller than ESU boundaries. Through GIS mapping using the ESRI ArcMap software a list of ESUs and the PSC basins contained within them was created. From this list it was possible to sum all releases in all PSC basins that corresponded to each ESU. Some of the releases were not directly associated in the RMIS database to a specific PSC basin and were given a 'General location' label. Using release location comment fields, hatchery locations, and other investigative tools these 'General' releases were assigned a PSC basin.

Harvest – We compiled data on trends in the adult equivalent exploitation rate for each ESU/DPS. It is important to note that magnitude and trend of an exploitation rate cannot be interpreted uncritically as a trend in level of risk from harvest. Analyses relating exploitation rate to extinction risk or recovery probability have been conducted in a quantitative way for several ESUs (Ford *et al.*, 2007; NMFS, 2001; NWFSC, 2010) and qualitatively for others (NMFS, 2004). See specific ESU/DPS sections for details.

References

Ford M, Sands N, McElhany P, *et al.* (2007) Analyses to support a review of an ESA jeopardy consultation on fisheries impacting Lower Columbia River tule Chinook salmon. National Marine Fisheries Service Northwest Fisheries Science Center and Northwest Regional Office, Seattle, WA. October 5, 2007.

Good TP, Waples RS, 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., p. 598.

McElhany P, Ruckelshaus MH, Ford MJ, Wainwright TC, Bjorkstedt EP (2000) Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. *NOAA Technical Memorandum NMFS-NWFSC* **42**, 156p.

NMFS (2001) RAP -- A risk assessment procedure for evaluating harvest mortality on Pacific salmonids. National Marine Fisheries Service, Northwest Region, Sustainable Fisheries Division and Northwest Fisheries Science Center, Resource Utilization and Technology Division.

NMFS (2004) NOAA Fisheries' approach to making determinations pursuant to the Endangered Species Act about the effects of harvest actions on listed Pacific salmon and steelhead. National Marine Fisheries Service, Northwest Region, Sustainable Fisheries Division.

NWFSC (2010) Lower Columbia River Tule Chinook Salmon Life-cycle Modeling. June 1, 2010. Northwest Fisheries Science Center. .

Sources for harvest information:

CTC in prep. 2010 annual report of the exploitation rate analysis and model calibration. Pacific Salmon Commission, Chinook Technical Committee.

Puget Sound Indian Tribes and Washington Department of Fish and Wildlife. 2010.Puget Sound Steelhead Harvest Management Plan (draft). Submitted to NMFS NW Region, January 7, 2010.

TAC 2009. 2009 Joint Staff Report: stock status and fisheries for fall Chinook salmon, coho salmon, chum salmon, summer steelhead, and white sturgeon. Joint Columbia River Management Staff, Oregon Department of Fish & Wildlife, Washington Department of Fish and Wildlife. July 16, 2009. 57p.

TAC 2010. 2010 Joint Staff Report: stock status and fisheries for spring Chinook, summer Chinook, sockeye, steelhead, and other species, and miscellaneous regulations. Joint Columbia River Management Staff, Oregon Department of Fish & Wildlife, Washington Department of Fish and Wildlife. February 2, 2010. 89p.

ESU Boundaries[5]

ESU and DPS Definition – In establishing whether a petitioned biological entity can be listed under the U.S. Endangered Species Act (ESA) it must first be determined whether the entity can be considered a "species" under the ESA. The ESA allows listing not only of full taxonomic species, but also named subspecies and distinct populations segments (DPSs) of vertebrates. The ESA, as amended in 1978, however, provides no specific guidance for determining what constitutes a DPS. Waples (1991) developed the concept of Evolutionarily Significant Units (ESUs) for defining listable units under the ESA. This concept was adopted by NMFS in applying the ESA to anadromous salmonids species (NMFS 1991). The NMFS policy stipulates that a salmon populations or group of populations is considered a DPS if it represents an ESU of the biological species. An ESU is defined as a population or group of populations that 1) is substantially reproductively isolated from conspecific populations, and 2) represents and important component in the evolutionary legacy of the species. In 2006, the NMFS departed from its practice of applying the ESU Policy to *O. mykiss* populations, and instead applied the joint USFWS-NMFS DPS definition in determining "species" of *O. mykiss* for listing consideration (71 FR 834; January 5, 2006). This change was initiated because *O. mykiss* are jointly administered with the FWS and the FWS does not use the ESU policy in their listing decisions (71 FR 834; January 5, 2006). Under the joint U.S. Fish and Wildlife Service (FWS) and NMFS DPS policy a group of organisms is a DPS if it is both "discrete" and "significant" from other such populations. Evidence of discreteness can include being ''markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, and behavioral factors", and evidence of significance includes persistence in an unusual or unique ecological setting, evidence that a group's extinction would result in a significant gap in the range of the taxon, or markedly different genetic characteristics from other populations (see DPS Policy; 61 FR 4722 for details). The DPS policy was intended to be consistent with the ESU policy, and both policies utilize the same types of information. However, NMFS has concluded that under the DPS policy resident and anadromous forms of *O. mykiss* are discrete (and hence are different DPSs), whereas biological review teams have generally concluded that resident and anadromous *O. mykiss* within a common stream are part of the same ESU if there is no physical barrier to interbreeding (see Good et al. 2005 for an extensive discussion of this issue).

Information that can be useful in determining the degree of reproductive isolation includes incidence of straying, rates of recolonization, degree of genetic differentiation, and the existence of barriers to migration. Insight into evolutionary significance or discreteness can be provided by data on genetic and life history

[5] Section authors: Jim Myers, Laurie Weitkamp, David Teel

characteristics, habitat differences, and the effects of stocks transfers or supplementation efforts.

Life history characteristics that have been useful in establishing ESU and DPS boundaries include: juvenile emigration and adult return timing, age structure, ocean migration patterns, body size and morphology, and reproductive traits (i.e. egg size). Population genetic structure can be very informative for estimating the degree of reproductive isolation among populations. Similarly, mark/recapture studies provide information on the level of interpopulation migration, although "straying" does not necessarily result in successful introgression.

Habitat and ecological information has been extensively used to establish ESU and DPS boundaries, especially where there is little population specific information available. Given the high level of homing fidelity exhibited by salmonids and the associated degree of local adaptation in life history traits, habitat characteristics become a useful proxy for putative differences in life history traits. Similarly, biogeographic boundaries and the distribution and ESU structure of similar species have been used where information on the "species" in question is lacking.

In initially defining the structure of ESUs and DPSs the Biological Review Teams analyzed a variety of different data types of varying quality. At the time, the BRTs recognized that ESU boundaries would not necessarily be discrete, rather a transitional zone covering one or more basins might exist at the interface between putative ESUs. In some cases, especially where there was not a geographic feature to rely upon, there was some degree of uncertainty in the identification of ESU boundaries. Population specific information was frequently limited and in some cases natural populations in the transitional zone had been extirpated or modified by the transfer of fish between basins. Ultimately, the BRTs have used the best available information to assign transitional populations into an ESUs/DPSs with the understanding that if additional information became available the decisions regarding the boundaries could be revisited.

New Information – The majority of the ESUs and DPSs for Pacific salmon and steelhead were initially defined in the late 1990s as part of the coastwide status review process undertaken by the NMFS. In the intervening 15 years, the most marked change in population monitoring has arguably been in the analysis of genetic variation. Initially, the majority of the genetics information was developed using the starch-gel electrophoresis of allozymes. The utilization of DNA microsatellite technology in fisheries during the last 10 years has provided a wealth of additional genetic information. Overall, this technique has provided a finer level of discrimination than was possible with allozymes. Furthermore, since the initial listings there have been extensive monitoring efforts throughout the West Coast. Thus, the quality and quantity of genetic information available to address the issue of ESU and DPS delineation has improved considerably.

For a number of populations, monitoring efforts over that last 15 years have expanded the existing data bases on abundance, spawn timing, and migratory patterns. Additionally, the mass-marking of hatchery-origin juveniles has improved the quality of the data collected, especially regarding the life-history data of naturally-produced fish.

Information of all types, from published and unpublished sources, was reviewed in order to assess whether sufficient data existed to justify a reconsideration of the ESU boundary. Much of the relevant information had already been summarized by the Technical Recovery Teams (TRTs) in their identification of populations within listed ESUs and DPSs (Table 3). This review will not explicitly discuss all of the information that was considered, but rather focuses on information pertaining to ESUs and DPSs that would potentially justify further investigation regarding changes in boundaries.

Table 3 -- Technical Recovery Team reports on population structure within listed Pacific Northwest Evolutionarily Significant Units (ESUs) and Distinct Population Segments (DPSs). See http://www.nwfsc.noaa.gov/trt/pubs.cfm for copies of these reports.

Domain	Population structure document name	Year completed
Puget Sound - Chinook	Independent Populations of Chinook Salmon in Puget Sound	2006
Puget Sound – Hood Canal Summer Chum	Determination of Independent Populations and Viability Criteria for the Hood Canal Summer Chum Salmon Evolutionarily Significant Unit	2009
Puget Sound – Lake Ozette Sockeye	Identification of an Independent Population of Sockeye Salmon in Lake Ozette, Washington	2009
Willamette/Lower Columbia	Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins	2006
Oregon Coast	Identification of Historical Populations of Coho Salmon (*Oncorhynchus kisutch*) in the Oregon Coast Evolutionarily Significant Unit	2007
Interior Columbia Basin	Independent Populations of Chinook, Steelhead, and Sockeye for Listed Evolutionarily Significant Units Within the Interior Columbia River Domain	2003

Coho salmon -- Puget Sound and Washington Coast ESUs[6]

Evolutionarily significant units (ESUs) for West Coast coho salmon were originally delineated in 1995 (Weitkamp et al. 1995). At that time, six ESUs were identified: 1) Central California Coast, 2) Northern California/Southern Oregon Coasts, 3) Oregon Coast, 4) Columbia River/Southwest Washington, 5) Olympic Peninsula, and 6) Puget Sound/Strait of Georgia (Figure 1). In 2005, NMFS determined that the Columbia River/Southwest Washington ESU should be split and

[6] Compiled by Laurie Weitkamp, David Teel, and Heather Stout. Northwest Fisheries Science Center.

the Columbia River portion was listed under the U.S. ESA, leaving the status of southwest Washington coho salmon populations in question.

Since the original status review, new genetic and life history information has become available that provides further insight into how coho salmon are likely adapted to habitats throughout their range, resulting in reproductive isolation and phenotypic variation. This new information has yet to be considered for those coho salmon ESUs which have not been evaluated since the original status review. Accordingly, this analysis will focus on coho salmon populations that occupy freshwater habitats along the Washington Coast, Strait of Juan de Fuca, Puget Sound, and southern British Columbia. Possible changes to ESU boundaries have previously been considered for coho salmon from northern California and Oregon and were found to be consistent with the best scientific information and therefore will not be discussed here (Stout et al. 2010).

Information related to the original delineation of coho ESU boundaries in the Washington State and Southern British Columbia

Geographic and Ecological Characteristics

Freshwater habitats along the Washington Coast, Strait of Juan de Fuca, Puget Sound, and southern British Columbia are largely influenced by elevation and rainfall and fall into two ecoregions at low elevations (Omernik 1987): the Coastal Range, which extends from the Olympic Peninsula to roughly San Francisco Bay, and Puget Lowland, which encompasses the eastern Strait of Juan de Fuca and lowlands of Puget Sound. Across the border in British Columbia, the “Georgia Depression” ecoregion is essentially the northern extension of the Puget Lowland ecoregion, and covers most of the Strait of Georgia (Demarchi 1996).

The Washington Coast is typified by a broad habitat gradient from the low elevation Willapa Hills in the south to the higher elevation Olympic Mountains in the north. Dominant vegetation throughout this area is Sitka spruce and western hemlock and rainfall is considerable. At the south end of this range, there are extensive mud- or sandflats within the Columbia River estuary, Willapa Bay, and Grays Harbor; due to the shared geology of the Willapa Hills area (WDNR 2003) and the transportation of Columbia River sediments northward along the Washington coast.

Because of their higher elevations and associated greater rainfall, rivers draining the Olympic Peninsula are characterized by high levels of precipitation and colder, glacially influenced, headwaters, high average flows with a relatively long duration of peak flows, including a second summer peak resulting from snow melt. The Chehalis River displays characteristics of both parts of the Washington coast--tributaries draining the north side of the Chehalis River Basin share the same hydrology, topography, and climate as Olympic Peninsula Rivers, while southern tributaries have more in common with the southwest Washington coast.

The eastern boundary of the Olympic Peninsula overlays an extended transition zone between the extremely wet Olympic Peninsula and the much drier Puget Sound/Salish Sea. The transition point between the wet Olympic Peninsula and the rainshadow farther east is thought to occur east of the Elwha River. However, the Elwha River is physically more similar to the Dungeness River than to those basins farther west. The Elwha and Dungeness Rivers are both relatively long and begin in alpine areas of the Olympic Mountains, while rivers west of the Elwha River are much shorter, draining the low ridge that separates the Sol Duc River from the Strait of Juan de Fuca (Weitkamp et al. 1995).

Drainages entering the Salish Sea from both sides share many of the physical and environmental features that characterize the Puget Sound area. This region is drier than the rainforest area of the western Olympic Peninsula and the west side of Vancouver Island and is dominated by western hemlock forests. Streams are similar to those of the Olympic Peninsula, being characterized by cold water, high average flows, a relatively long duration of peak flows, and a second snow-melt peak, although flow levels per basin area are much lower than in the Olympic Peninsula (Weitkamp et al. 1995).

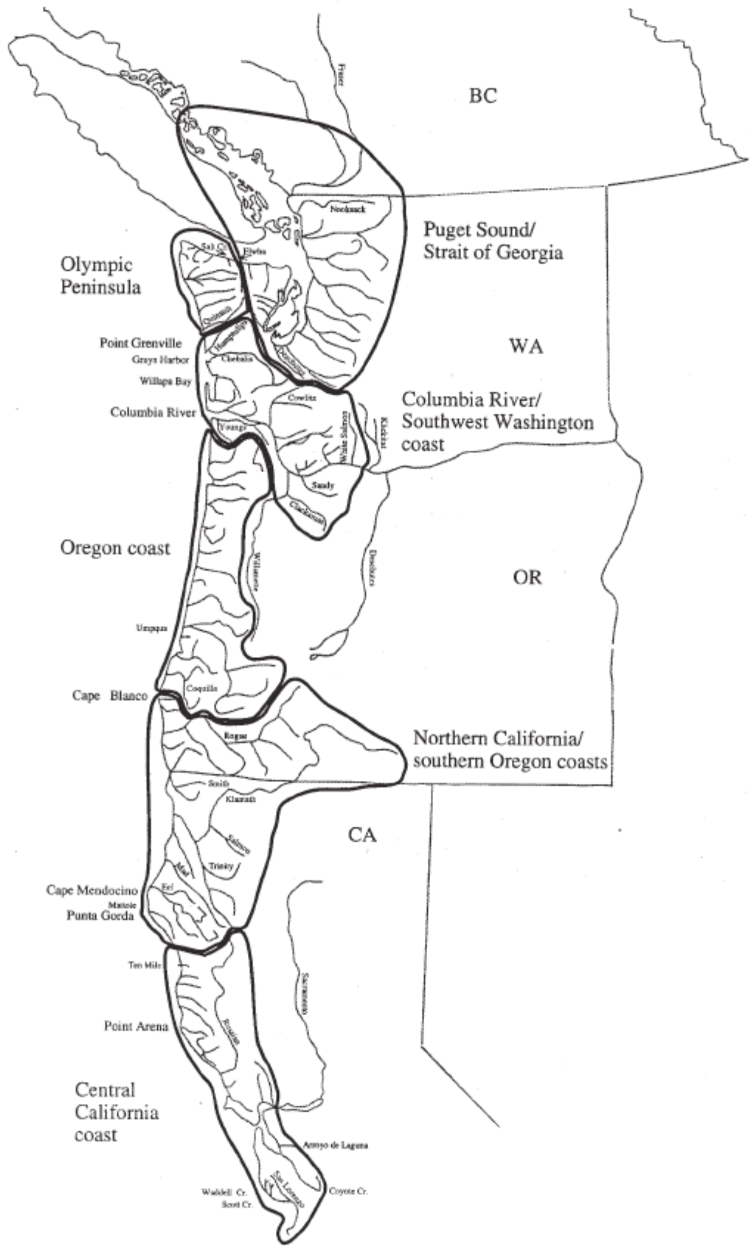


Figure 1 -- Evolutionarily significant units for coho salmon proposed in 1995. Since 2005, Lower Columbia coho form their ESU. Reproduced from Weitkamp et al. (1995).

Life History and Genetical Characteristics

Life history characteristics. Weitkamp et al. (1995) considered a variety of coho salmon life history information in order to determine how salmon were responding to the variation in habitats discussed above, and therefore indicate likely locations for ESUs boundaries. A thorough review of coho salmon populations characteristics concluded that coho salmon exhibit considerably less variation in traits such as age at maturity or timing of adult returns compared with other salmonid species for which ESUs had been delineated at that time (primarily Columbia River Chinook salmon and sockeye salmon and steelhead). In essence, coho salmon appeared to have a "one size fits all" model for life history variation, which greatly limited the use of these traits in establishing ESU boundaries.

One life history trait that did show considerable variation was marine distribution pattern based on recoveries of coded wire tags in marine fisheries, grouped by state or province of recovery. Based on the recovery of 1.9 million coho salmon originating from 66 hatcheries over a 20 year period, Weitkamp et al. (1995) found that coho salmon originating from a particular freshwater region shared a common marine recovery pattern, which differed from that of adjacent region with very little transition in patterns. Based on this analysis, eight recovery patterns were identified coastwide, including four in Washington State and southern British Columbia consisting of 1) Columbia River, 2) Washington Coast, 3) Puget Sound, Hood Canal, and Strait of Juan de Fuca, and 4) southern British Columbia. Most of these fish were recovered in Washington and British Columbia marine waters, although the relative proportion varied by release region, leading to detectable differences between regions.

Genetical characteristics. As part of the coho salmon status review in 1994, Weitkamp et al. (1995) reviewed genetic studies of coho salmon in California, Oregon, Washington, British Columbia, and Alaska. Nearly all of the genetic studies focused on particular geographic regions and except for two mitochondrial DNA studies of coho salmon in Oregon and in the Columbia River, all were allozyme studies employing few polymorphic loci and mostly based on small numbers of samples. Weitkamp et al. (1995) also compiled a new allozymes dataset of 53 polymorphic loci and 101 population samples ranging from California to Alaska, with a primary focus on Oregon, Washington, and southern British Columbia. Principal components analysis (PCA) and an analysis of genetic distances identified seven major genetic clusters (Figure 2).

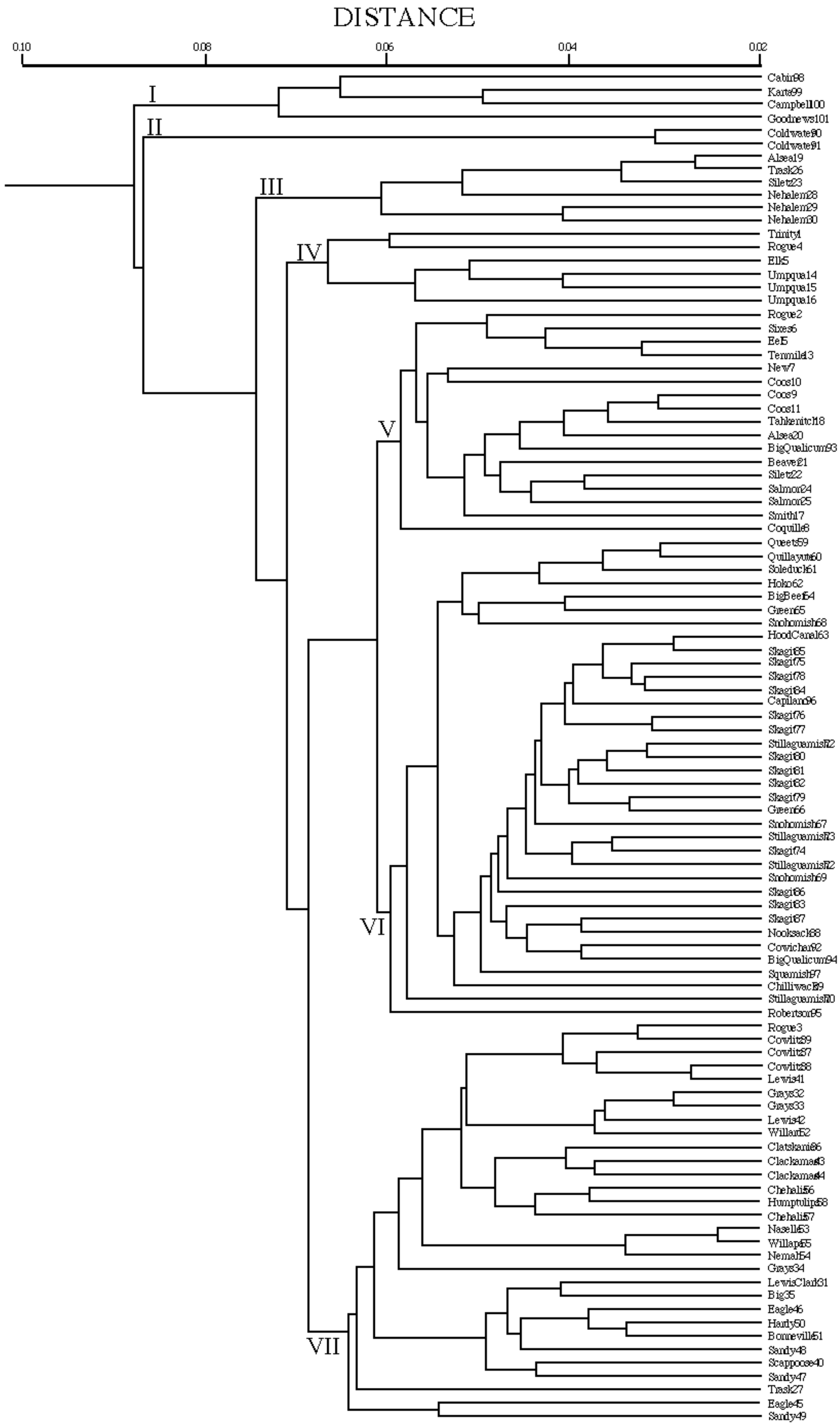


Figure 2 -- Dendrogram using 53 polymorphic allozymes loci and based on pariwise genetic distance values (CSE chord distance) between 101 samples of coho salmon from the Pacific Northwest. Cluster VI includes populations from the northern Washington coast, Strait of Juan de Fuca, Puget Sound, and southern British Columbia. Populations from the southwest Washington coast and the Columbia River are in cluster VII. Reproduced from Weitkamp et al. (1995).

Populations from Puget Sound and southern British Columbia generally clustered together and were distinct from populations in the interior Fraser River. The single population in the Strait of Juan de Fuca (Hoko River) and those along the northern Washington coast clustered together and were most genetically similar to the Puget Sound/southern British Columbia cluster. Samples from populations along the southern Washington coast and from the Columbia River formed another of the major clusters and were distinct from both more northern and southern populations. Weitkamp et al. (1995) noted that the allozyme data also revealed high levels of genetic heterogeneity within the greater Olympic Peninsula/Puget Sound/Strait of Georgia area indicating fairly high reproductive isolation of individual populations or groups of populations.

Subsequent to the analysis conducted by Weitkamp et al. (1995), genetic relationships among coho populations in southwest Washington and the lower Columbia River were investigated as part of an examination of historical population structure of Pacific salmonids in the region (Myers et al. 2006). Myers et al. (2006) reviewed a study conducted by geneticists at the Canadian Department of Fisheries and Oceans that used four microsatellite DNA loci and one histocompatibility locus (Shaklee et al. 1999). Although the Shaklee et al. (1999) dataset included only two lower Columbia River (Cowlitz and Lewis rivers), those samples formed a cluster that was distinct from two samples from the southwest Washington coast which were genetically similar to several samples from the northern Washington coast. Myers et al. (2006) also analyzed an allozyme dataset that included new data not available during the 1994 status review (Teel et al. 2003). In that analysis, samples from Columbia River and southwest Washington coho salmon populations also formed separate clusters (Figure 3).

New Information on Washington State and Southern British Columbia ESUs

Life History and Genetical Characteristics

<u>Life history characteristics</u>. As described above, one line of life history evidence that indicated major changes coastwide was the marine distributions of coho salmon based on recoveries of coded wire tagged (CWT) hatchery fish. Weitkamp and Neely (2002) redid this analysis, using the same coded wire tag (CWT) database but including more hatcheries (90 vs. 60) and smaller and therefore more numerous recovery areas to help understand how marine distributions varied between hatcheries and regions. They also included 36 wild populations in their analysis to evaluate the influence of hatchery effects on marine distributions. Like the earlier analysis, they found that wild and hatchery salmon from the same freshwater region shared a common recovery pattern, and that the recovery patterns abruptly changed across regions, with little or no transition between regions.

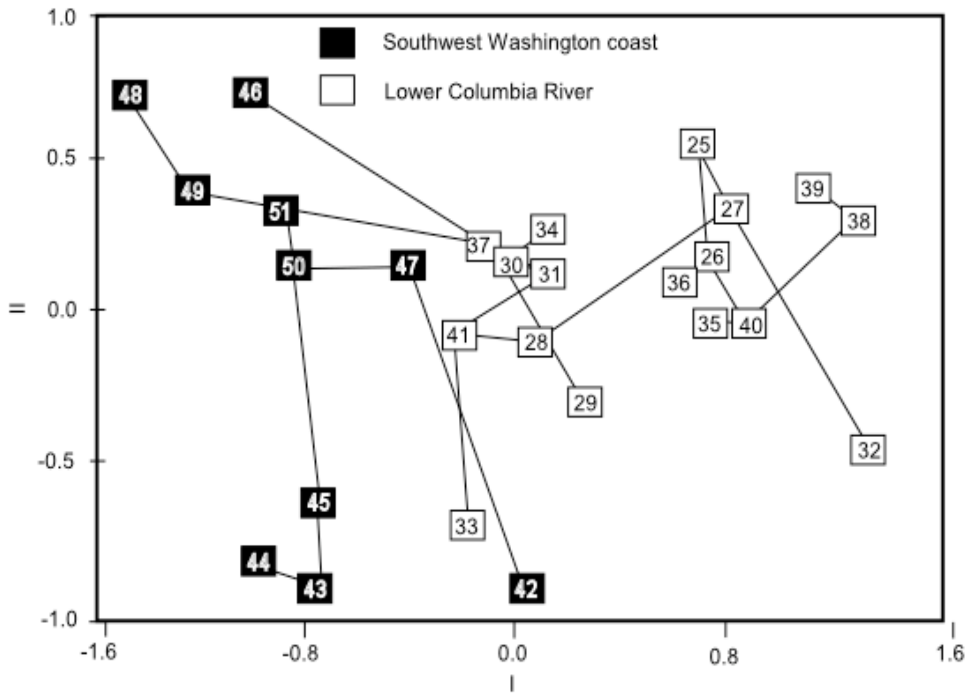


Figure 3 -- Figure 3. (Myers et al. 2006) Multidimensional scaling and minimum spanning tree of pairwise chord distance values (Cavalli-Sforza and Edwards 1967) among 27 samples of coho salmon from lower Columbia River and southwest Washington coast. Analysis was based on data for 61 gene loci. Samples from lower Columbia River populations are identified by white squares; those from southwest Washington are identified by black squares. Numeric codes correspond to those in Table 1 of Myers et al. (2006).

For coho salmon from Washington and southern British Columbia, the analysis indicated several discrete groups based on geographic location of the populations (Figure 4). Whether only hatchery populations were considered or both hatchery and wild, the patterns were similar. In particular, hatchery and wild coho salmon populations from Strait of Georgia (cluster F in Figure 4), Puget Sound and eastern Strait of Juan de Fuca (cluster H), Washington Coast and western Strait of Juan de Fuca (cluster I) and lower Columbia River (cluster J) each formed well separated clusters. The dividing line between clusters H and I (Puget Sound and Washington coast) occurred between the Dungeness and Elwha hatcheries (hatcheries 55 and 56, respectively, in Figure 4).

Genetic Review for Coho Salmon

<u>Genetical characteristics</u>. The DNA dataset for British Columbia coho salmon reported by Shaklee et al. (1999) and the subsequent analyses of those data by Beacham et al. (2001) included several samples from the Washington coast, Strait of Juan de Fuca, and Puget Sound. In their analyses, Washington samples were genetically distinct from British Columbia samples. Within the Washington cluster, coastal populations clustered separately from a cluster that included populations in

Puget Sound, Hood Canal, and Juan de Fuca (Dungeness and Elwha). Another recent genetic study of coho salmon analyzed 11 microsatellite DNA loci in samples ranging from California to southern British Columbia including 29 populations in coastal Washington and Puget Sound and 11 in the lower Columbia River (Van Doornik et al. 2007). Their analysis revealed six major clusters of populations including a Columbia River cluster, a Washington coast cluster, a cluster of Puget Sound and Hood Canal populations and a southern British Columbia cluster (Van Doornik et al. 2007, Figure 5). The Columbia River population group had

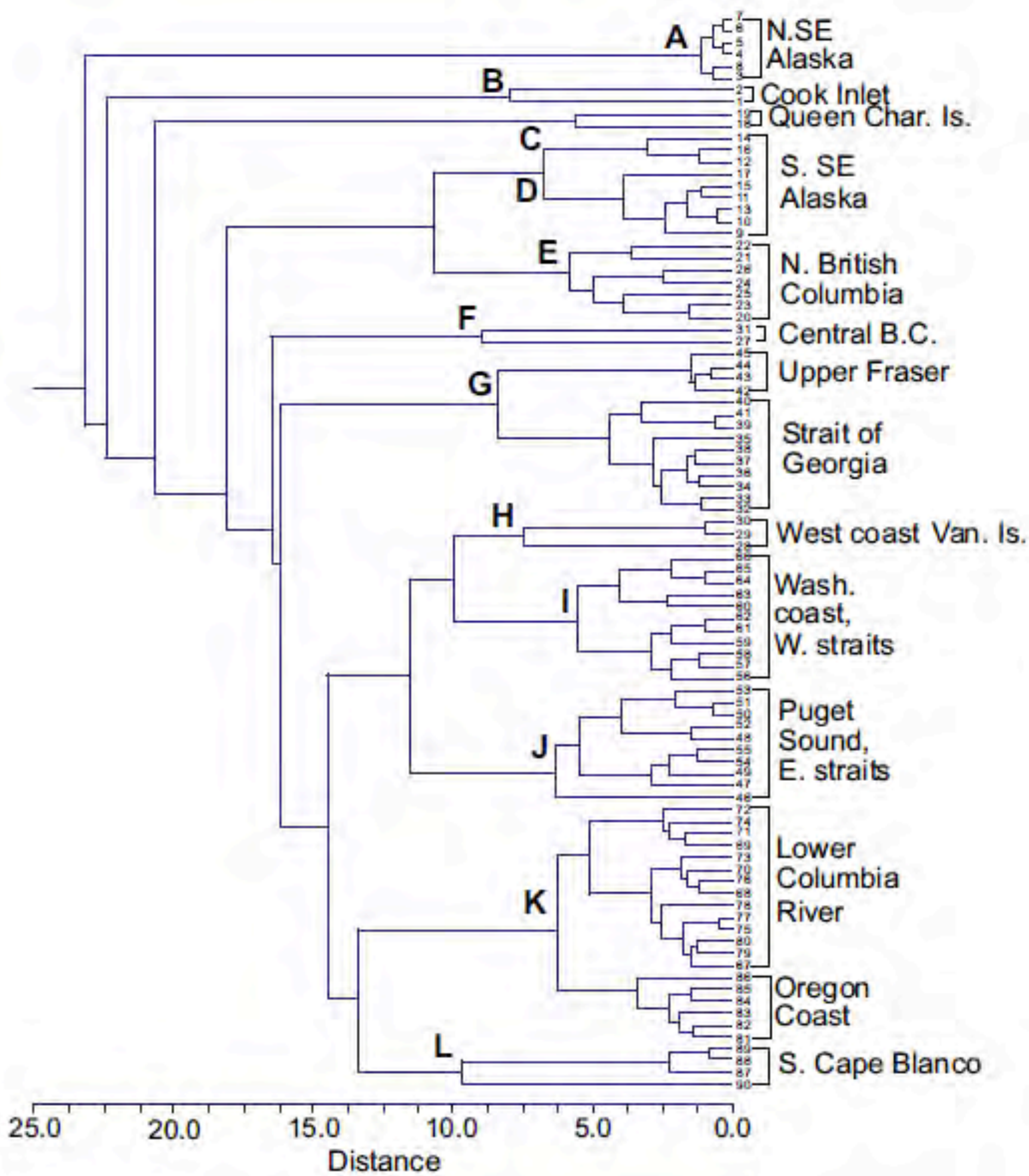


Figure 4 -- Dendogram based on marine recovery patterns of 90 hatchery and 36 wild coho salmon population. Names indicate the freshwater release region. Reproduced from Weitkamp and Neely (2002).

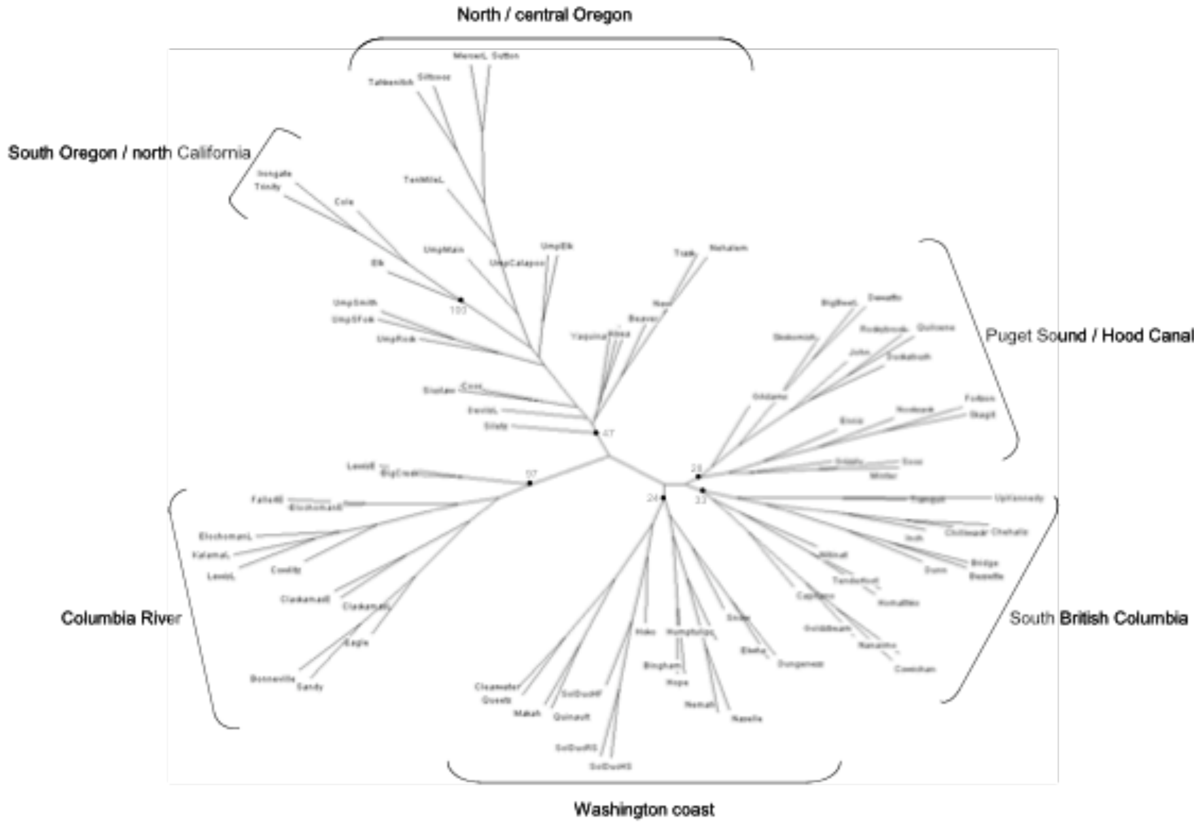


Figure 5 -- Neighbor-joining dendrogram generated from Cavalli-Sforza and Edwards' (1967) chord distances for 84 coho salmon samples collected within six regions of the Pacific coast. Bootstrap values (%) for the regions are shown. Reproduced from Van Doornik et al. (2007).

the highest bootstrap value among the clusters (97%) illustrating strong support for genetic differentiation from coastal populations. Lower bootstrap values were associated with the Washington coast (24%), Puget Sound/Hood Canal (28%) and southern British Columbia (33%) clusters. Van Doornik et al. (2007) discussed their findings relative to ESU determinations and to the population structuring reported in previous studies. They observed a general concurrence with earlier coho salmon genetic studies, including relatively weak geographic population structure overall. Additionally, concurring with Beacham et al. (2001), they found that Puget Sound populations and those in British Columbia were closely related, but clustered separately. Van Doornik et al. (2007) also noted that in contrast to Beacham et al. (2001), they found that samples from the Strait of Juan de Fuca (Hoko, Elwha and Dungeness rivers and Snow Creek) were genetically more similar to Washington coastal populations than those in Puget Sound.

A recent genetic study of Pacific salmon in the Elwha River included microsatellite DNA data for several coho salmon populations in Juan de Fuca (Winans et al. 2008). We used these new data combined with the data of Van Doornik et al. (2007) to evaluate genetic relationships within and among regional groups of hatchery and naturally produced coho salmon in the Pacific Northwest (Table 4).

Table 4 -- Mean pairwise Fst values between regional groupings of Pacific Northwest coho salmon populations. Values were computed using 11 microsatellite DNA loci and comparisons were conducted between individual populations in each region. Bold values are comparisons within each region. Data are from Van Doornik et al. (2007) and Winans et al. (2008).

	Population or Region	1	2	3	4	5	6	7	8
1	East Vancouver Island	0.023	0.028	0.038	0.027	0.028	0.041	0.034	0.058
2	Southern BC mainland		0.010	0.028	0.021	0.023	0.034	0.031	0.052
3	Lower Fraser River			0.018	0.026	0.030	0.036	0.038	0.051
4	Puget Sound/Hood Canal				0.013	0.019	0.028	0.023	0.048
5	Juan de Fuca					0.017	0.025	0.020	0.041
6	Northern Washington coast						0.021	0.027	0.041
7	Southern Washington coast							0.014	0.045
8	Columbia River								0.017

Average Fst values (a metric indicating the amount of genetic differentiation) in comparisons of populations within regions were mostly smaller than values in among-region comparisons (range = 0.010 – 0.023). The largest within-region Fst value was for east Vancouver Island (0.023) largely due to the divergence effect of the Goldstream Hatchery population. The second largest within-region Fst was the northern Washington coast group (0.021) primarily because the of the natural and hatchery summer-run coho salmon populations in the Sol Duc River, which were genetic outliers. Among-region comparisons showed that Columbia River populations were the most genetically distinct group of populations in the analysis (0.041 – 0.058). Moderate levels of differentiation were evident for comparisons of Puget Sound / Hood Canal populations with Strait of Georgia populations (0.021 – 0.027) and with northern Washington coastal populations (0.028). The values for both of these among-region comparisons were larger than the within-Puget Sound / Hood Canal comparisons (0.019). Average values for Juan de Fuca populations in comparisons with Puget Sound / Hood Canal (0.019) were smaller than in comparisons with northern Washington coastal populations (0.025). The difference in these two sets of comparisons was largely due to comparisons involving Sol Duc summer run samples. When those samples were not included in the analysis, Juan de Fuca populations had the same average Fst values in comparisons with the northern Washington coast as with Puget Sound / Hood Canal.

Other information. Because coho salmon were the first Pacific salmon species for which coast-wide ESUs were delineated, boundaries for other Pacific salmon ESUs were not available for comparison. This biogeographic information is useful because it indicates how other Pacific salmon species respond to the same suite of environmental conditions that coho salmon interact with. West Coast ESUs have been delineated for pink (Hard et al. 1996), chum (Johnson et al. 1997), sockeye (Gustafson et al. 1997), and Chinook salmon (Myers et al. 1998), and steelhead (Busby et al. 1996). Each native sockeye salmon population is considered an ESU, so the pattern of sockeye salmon ESUs provides little insight to coho salmon.

For species with multiple populations per ESU, ESU configurations in Washington State (excluding the Columbia River) and southern British Columbia are somewhat variable although most have several breakpoints in common. For example, within the Salish Sea, ESUs for two species (Chinook salmon, steelhead) did not cross the border into Canada but more or less stopped at the border (the North Fork of the Nooksack River being the northern-most stream). By contrast, odd year pink and fall chum salmon ESUs, like coho salmon, included both Puget Sound and the Strait of Georgia. Whether Salish Sea ESUs did or did not include Canadian populations, however, in all cases the Elwha River was included in the Puget Sound ESU, rather than in the Olympic Peninsula or Washington Coast ESU.

For Washington Coast ESUs, there was considerable diversity in ESU configurations. Chinook salmon have a single Washington Coast ESU, which stretches from just west of the Elwha River to (but not including) the lower Columbia River. Chum salmon have a similar ESU configuration to Chinook salmon, except that it also includes the Oregon Coast to the southern end of the species range (also excluding the lower Columbia River) and was appropriately named the Pacific Coast ESU. Steelhead, like the original coho salmon configuration, have two ESUs on the Washington Coast: an Olympic Peninsula ESU and a Washington Coast ESU which includes the Columbia River downstream of the Cowlitz River.

Finally, conservation units (CUs) have been tentatively designed for Pacific salmon populations in British Columbia (Holtby and Ciruna 2007). Although not identical to ESUs, the foundation of Conservation Units is similar in that they are based on habitat, life history and genetic diversity, and are intended to capture the major blocks of diversity exhibited by Pacific salmon within British Columbia.

For coho salmon, 43 CUs have been identified, including 5 within the Canadian portion of the Puget Sound/Strait of Georgia ESUs. These CUs are: Lower Fraser A, Lower Fraser B, Howe-Burrard (immediately north of the Fraser River), Boundary Bay (immediately south of the Fraser River), Georgia Strait Mainland, and Georgia Strait East Coast of Vancouver Island.

Conclusions

Based on the new genetic and life history information presented here, it appears that there is new information that indicates that the current ESU configuration for Washington Coast, Strait of Juan de Fuca, Puget Sound, and Strait of Georgia coho salmon populations would benefit from additional review. Both genetic and life history (marine distribution) information suggest that there is geographically-based diversity within the Puget Sound/Strait of Georgia ESU which warrants further examination. Doing so may result in a Puget Sound ESU that, like Chinook and steelhead ESUs, does not include Canadian populations. For Washington coast populations, the new information also indicates that a single Washington coast ESU may be most consistent with the data. However, where the boundary for it and the Puget Sound ESU should be placed will need further consideration.

Lower Columbia River and Middle Columbia River Boundaries[7]

This section reviews new information regarding the boundaries between the Lower Columbia River Chinook salmon ESU and the Middle Columbia River Chinook salmon spring run ESU, between the Lower Columbia River steelhead DPS and the Middle Columbia River steelhead DPS (Figure 6). These boundaries have been uncertain due to limited or ambiguous data. Here, we have review new genetic information that may help clarify these boundaries. Specifically, new analyses have utilized microsatellite DNA based measures of genetic variation rather than the less sensitive allozyme based methods used in earlier reviews. In some cases new samples have been added to the analysis, but the majority of the samples are the same ones used in the initial BRT assessments.

[7] Section authors: Jim Myers, Jon Hess, Melanie Paquin, and Paul Moran.

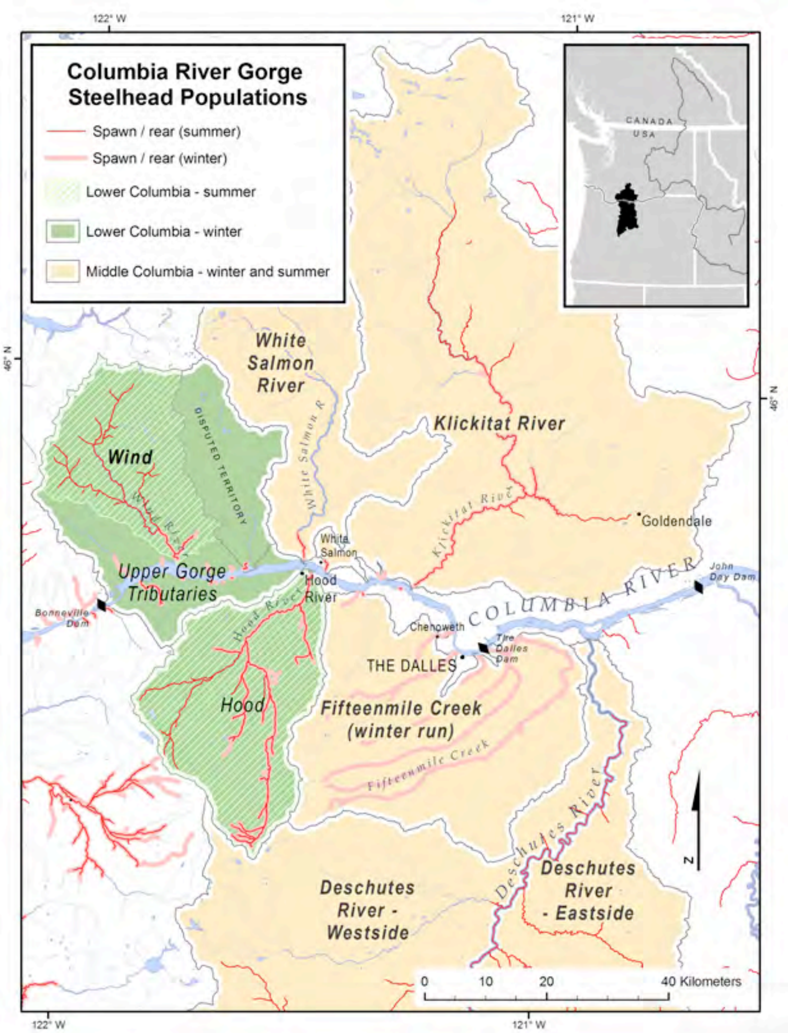


Figure 6 – Current boundaries between the Lower and Middle Columbia River steelhead DPSs. The current boundary between the Lower and Middle Columbia River Chinook salmon ESUs runs between the White Salmon and the Klickitat Rivers and the Hood and Deschutes Rivers.

Information related to the original delineation of steelhead DPS boundaries in the Columbia River

Busby et al (1996) reviewed biological and geographic information on steelhead populations in the Columbia River. In the identification of DPS (then ESU) boundary between the Lower Columbia and Middle Columbia River DPSs, the characteristics of the Big White Salmon River and Klickitat River steelhead populations were found to be intermediate to the two DPS, or sharing some characteristics with either of the DPS. Fifteenmile Creek, which is upstream of the Hood and Klickitat Rivers at RKm 309 (but below the historical location of Celilo Falls), contains only winter-run steelhead. Oregon Department of Fish and Wildlife includes several small tributaries, Mosier, Mill, and Fifteenmile creeks in their Mid-Columbia Gene Conservation Group (Kostow 1995).

Despite the fact that Fifteenmile Creek contains only winter-run steelhead, Busby et al (1996) assigned this population to the Middle Columbia River DPS based primarily on genetic similarity to Interior Columbia River Basin steelhead. Alternatively, allozyme analysis by Shreck et al. (1984) found that Fifteenmile Creek loosely grouped with Lower Columbia River populations, although the dendrogram clustered Fifteenmile Creek with Skamania hatchery populations and some Snake River populations.

Subsequent analysis by Currens (1997) indicated that steelhead from Fifteenmile Creek are intermediate to Coastal and Interior Columbia Basin steelhead populations with an affinity to Interior populations (Figure 7). Phelps et al. (1997) grouped adult steelhead and juvenile *O. mykiss* from the Big White, Little Klickitat, and Klickitat rivers with the Inland Major Ancestral Lineage (MAL) for steelhead. Samples from these rivers formed their own dendrogram cluster relative to other Inland steelhead samples. Later analysis by Phelps et al. (2000) indicated that the *O. mykiss* from the Yakima and Klickitat rivers were distinct from each other. Additionally, Phelps et al. (2000) observed that there appeared to be little introgression by hatchery (Skamania Hatchery) summer run steelhead on presumptive "native" summer steelhead samples. Alternatively, Rawding (1995) in a letter to the BRT suggested that the eastern boundary of the Coastal *O. mykiss* should be at the Klickitat River. Rawding suggested that the run timing, age structure, and life history of Klickitat River steelhead was more similar to coastal forms.

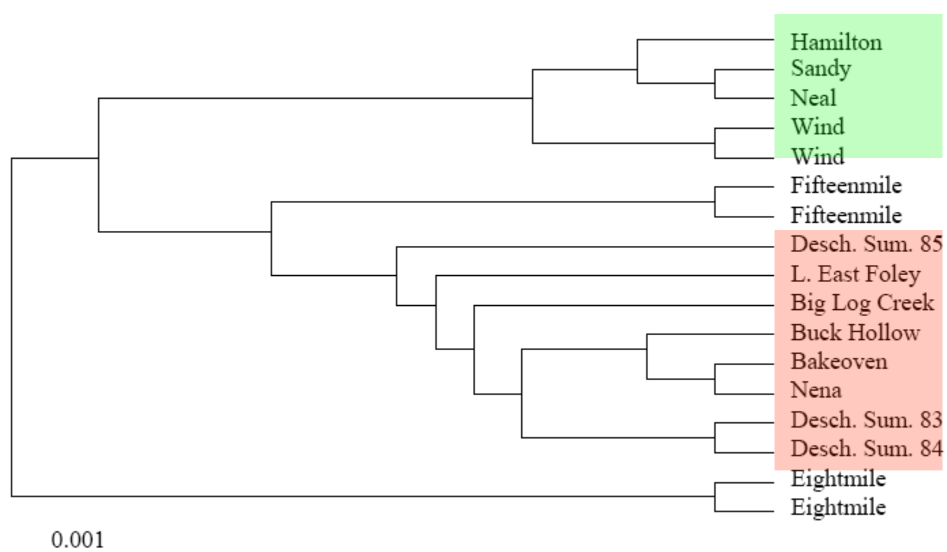


Figure 7 -- Figure 6. UPGMA dendrogram of Lower Columbia and Deschutes River steelhead based on CSE chord distances. Data from Currens (1997). Graph from McClure et al. (2003). Lower Columbia populations are in green, Interior Columbia populations are in red. Eightmile Creek *O. mykiss* are thought to be resident rainbow trout (Currens 1997).

Geographic and Ecological Characteristics

In contrast to the other steelhead populations in the Middle Columbia Steelhead DPS, the Big White Salmon and Klickitat rivers and Fifteenmile Creek are located downstream from the Dalles Dam, near the historical location of Celilo Falls (RKm 320), an important historical migration obstacle, which now lies submerged under Celilo Lake following the construction of the Dalles Dam in 1957. Celilo Falls also lies near the Cascade Crest, which demarks the transition between the wetter western Cascade slopes and the drier interior Columbia River Basin. The Big White Salmon and Klickitat River basins also lie in the within the Eastern Cascade Ecoregion rather than the Columbia Basin Ecoregion that lies immediately to the east of the Klickitat River. Fifteenmile Creek lies in the Columbia Basin Ecoregion. The Big White Salmon River enters the Columbia River at RKm 270, downstream of the mouth of the Hood River, RKm 272 (winter and summer steelhead from the Hood River were designated as being part of the Lower Columbia River DPS), while the Klickitat River enters the Columbia River at RKm 289. Shreck et al. (1984) determined that environmental conditions in the Klickitat and Hood Rivers were most similar to Fifteenmile Creek using parameters such as gradient, precipitation, land form category, geological category, vegetation type, soil type, elevation, and distance to the mouth of the Columbia River.

Life History and Genetical Characteristics

Most Middle Columbia River steelhead smolt at 2 years of age and spend 1 to 2 years in salt water prior to re-entering fresh water. Within the Middle Columbia River Steelhead DPS, the Klickitat River is unusual in that it produces both summer and winter steelhead, and the summer steelhead are dominated by 2-ocean steelhead, whereas other rivers in this region produce about equal numbers of both age-1- and 2-oceam steelhead (Table 5). Busby et al. (1995) noted that the BRT considered different scenarios for the composition of the Middle Columbia River DPS with respect to the downstream and upstream boundaries. Life history information for Klickitat River steelhead is more similar to Lower Columbia River Steelhead than to other populations with within the Middle Columbia River DPS; additionally, Schreck et al. (1986) placed Klickitat River steelhead in the coastal steelhead based on genetic, morphometric, meristic and life history characteristics. However, as was described above, other genetic analyses (Phelps et al. 1994, Leider et al. 1995) suggest a closer affinity for Klickitat River steelhead with the inland steelhead group. Busby et al. (1996) indicated that there was considerable variability in the relative relationship between different samples from the Klickitat River, suggesting that temporal samples might represent fish from different native, resident, or hatchery populations.

Table 5 -- Ocean age frequency for selected steelhead populations. Data are from adult steelhead and indicate age at the first spawning migration. Table is adapted from Busby et al. 1996. Data from Howell et al. (1985) except where indicated.

Population	Run-type	0	1	2	3	4	N

Cowlitz R.	O	--	--	**0.64**	0.34	0.02	56
Kalama R.	O	--	0.04	**0.76**	0.20	--	1363
Kalama R.	S	--	0.20	**0.74**	0.06	--	909
Washougal R.	O	--	0.14	**0.71**	0.14	--	141
Wind R.	S	--	0.05	**0.68**	0.26	--	19
Hood R.	O	--	0.06	**0.73**	0.21	--	*
Hood R.	S	--	0.08	**0.77**	0.15	--	*
Klickitat R.	S	--	0.16	**0.79**	0.05	--	148
Deschutes R.	S	--	**0.53**	0.47	--	--	100
John Day R.	S	--	**0.51**	0.44	0.04	--	115

* Data from Kostow 2003

New Information on Lower Columbia and Middle Columbia River Steelhead.

In 1998, the West Coast Steelhead BRT reviewed information regarding the Upper Willamette and Middle Columbia River DPSs (Busby et al 1999). In response to the initial findings of the BRT, ODFW suggested that the Middle Columbia River DPS be adjusted so that the winter-run populations (e.g. Fifteenmile Creek) be included in the Lower Columbia River DPS. At the time, there was no new biological information available to justify the redelineation of the DPS boundaries. The BRT did acknowledge the there was considerable uncertainty regarding the DPS boundaries and that a more intensive review of existing genetic and ecological, environmental and life history information was warranted.

The relationship between steelhead populations in the White Salmon, Klickitat, Hood rivers, and Fifteenmile Creek and Coastal and Inland lineages remained topical outside of the BRT discussions. *O. mykiss* populations along the Cascade Crest were identified as a transitional zone between coastal and inland resident and anadromous form (Benhke 2002).

Since the initial delineation of the DPS boundaries substantial new genetic information has become available. In some cases previously analyzed samples have been reanalyzed using microsatellite DNA markers instead of allozyme markers. In general, microsatellite DNA is more variable and therefore may provide a finer level of resolution in population analysis. Additionally, new genetic samples have been acquired from presumptive populations in area of the Cascade Crest. A study by Winans et al. (2004) indicated that steelhead samples from the Klickitat River were distinct from steelhead in the Middle and Upper Columbia River as well as the Snake River; however, there were no Lower Columbia River samples included in the analysis and the majority of the samples were collected in the early 1990s, a period when the marking of hatchery steelhead was not commonplace. There was considerable variability in the relationships among the four sample sites in the Klickitat River: Lower Klickitat River, Bowman Creek, Upper Klickitat River, and Little Klickitat River, suggesting that different source populations were being sampled (including possible hatchery-origin summer run). A more recent study by Narum et al. (2006) using DNA microsatellite analysis, indicated that there had been minimal integration between naturally-produced and hatchery origin (Skamania

Hatchery) summer run steelhead. Unfortunately, there were no out-of-basin populations included in the analysis and the relationship between natural populations in the Klickitat River and those in the Lower Columbia and Middle Columbia steelhead DPSs was not assessed.

Kostow (2003) indicated that Fifteenmile Creek was the eastern most basin in the Columbia River that contained coastal cutthroat trout (*O. clarki*). This would further underscore the historical importance of Celilo Falls as a biological boundary between coastal and inland assemblages.

A study by Hess et al. (2008) reanalyzed samples from the Klickitat and White Salmon Rivers (including both anadromous and resident *O. mykiss*). In this comparison the White Salmon and Klickitat River samples were intermediate between coastal and interior populations, with samples from 8 and 15 Mile creeks clearly lying in the Interior cluster of steelhead populations (Figure 8). Outliers in the White Salmon River were resident fish located above long standing natural barriers (although there was some suggestion that rainbow trout may also have been stocked in these headwater regions).

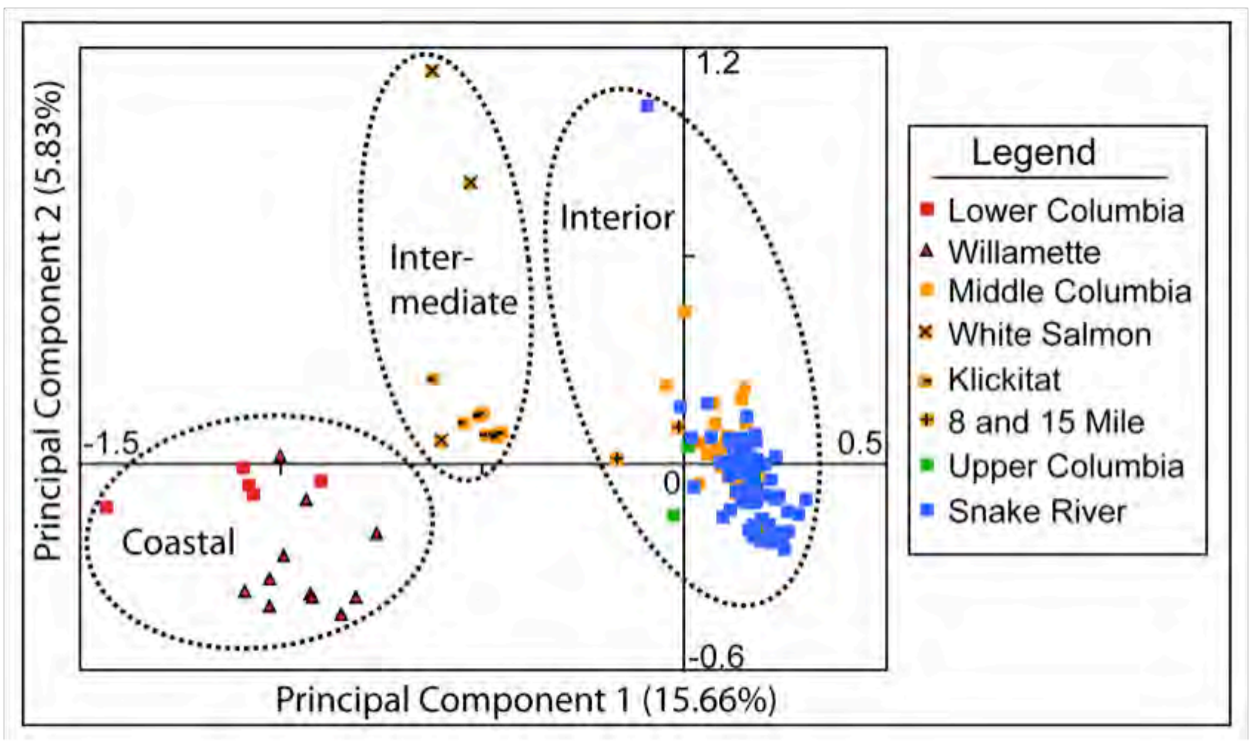


Figure 8 – Principal components analysis of allele frequency data for steelhead population in the Columbia River Basin. The analysis is based on allele frequencies at 12 microsatellite loci. Each symbol represents a population sample, and the distance between symbols is proportional to the genetic differences between the respective populations. Colors correspond to four DPS: the Lower, Middle and Upper Columbia River, and the Snake River. Reproduced from Hess et al. (2008).

Information related to the original delineation of Chinook DPS boundaries in the Columbia River

The coastwide Chinook salmon BRT (Myers et al. 1998) initially reviewed biological and geographic information on Chinook populations in California, Idaho, Oregon, and Washington. In the identification of the boundary between the Lower Columbia and Middle Columbia River ESUs, available life history characteristics were reviewed. The construction of Condit Dam (RKm 4) on the Big White Salmon River in 1913 eliminated anadromous access to the majority of the basin. There is little historical documentation available regarding the characteristics of the spring and fall-run Chinook that existed in the Big White Salmon River other than the existence of those runs. Fall-run fish from the Big White Salmon were used to establish the U.S. Bureau of Fisheries Spring Creek Hatchery, later the Spring Creek NFH, in 1901. The Spring Creek NFH fall-run population has become the de facto representative sample for the historical White Salmon River populations.

Geographic and Ecological Characteristics -- The Middle Columbia spring-run Chinook salmon ESU includes one population located downstream from the Dalles Dam (Celilo Falls), the Klickitat River spring run. Celilo Falls also was historically located near the Cascade Crest, which demarks the transition between the wetter western Cascade slopes and the drier interior Columbia River Basin. The Big White Salmon and Klickitat River basins also lie within the Eastern Cascade Ecoregion rather than the Columbia Basin Ecoregion that lies immediately to the east of the Klickitat River. The Big White Salmon River enters the Columbia River at RKm 270, downstream of the mouth of the Hood River, RKm 272 (winter and summer steelhead from the Hood River were designated as being part of the Lower Columbia River DPS and Hood River spring and fall-run Chinook salmon are part of the Lower Columbia River ESU), while the Klickitat River enters the Columbia River at RKm 289.

Life History and Genetical Characteristics -- Historically, only spring-run Chinook salmon were present in the Klickitat River. Lyle Falls, actually a series of falls and cascades near the mouth of the Klickitat River (RKm 2), was apparently a barrier to fall-run Chinook salmon (these fish would have returned during low flow conditions at the falls). Rawding (1998) suggests that fall-run Chinook salmon may have spawned in kilometer or two of river that existed below the falls. Much of this fall-run habitat was inundated with the filling of the Bonneville Pool in the 1930s. There is some discussion in the Chinook Salmon Status Review (Myers et al. 1998) regarding the status of the Klickitat River. Marshall et al. (1995) reported that the spring run in the Klickitat River has some genetic and life-history similarities to Lower Columbia River spring runs (Figure 9). WDFW included the Klickitat River spring-run in their Lower Columbia River major ancestral lineage (MAL). Genetic analysis of Chinook salmon in the Columbia River, run as part of the coastwide status review, indicated that Klickitat River spring run fish were intermediate between Lower Columbia River ocean-type Chinook salmon and Mid-Columbia River stream-type Chinook salmon

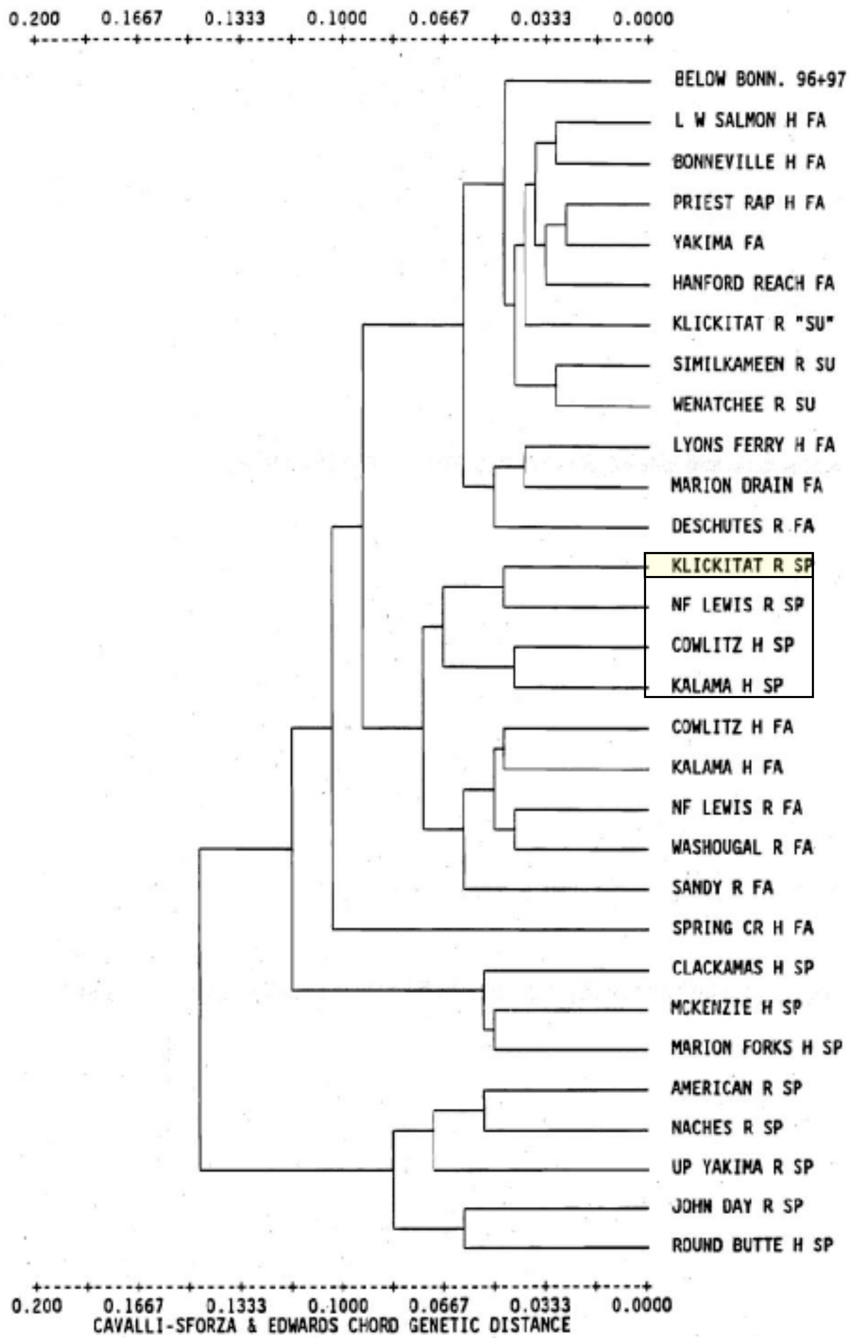


Figure 9 -- Dendrogram of Lower Columbia River Chinook Salmon populations. Reproduced from Marshall 1998.

(Figure 10) (Myers et al. 1998). Marshall (1998) in a later analysis of Lower and Mid- Columbia River Chinook salmon samples found that the Klickitat River spring run Chinook sample clustered most closely with the NF Lewis River, Cowlitz River, and Kalama River spring-run Chinook salmon samples.

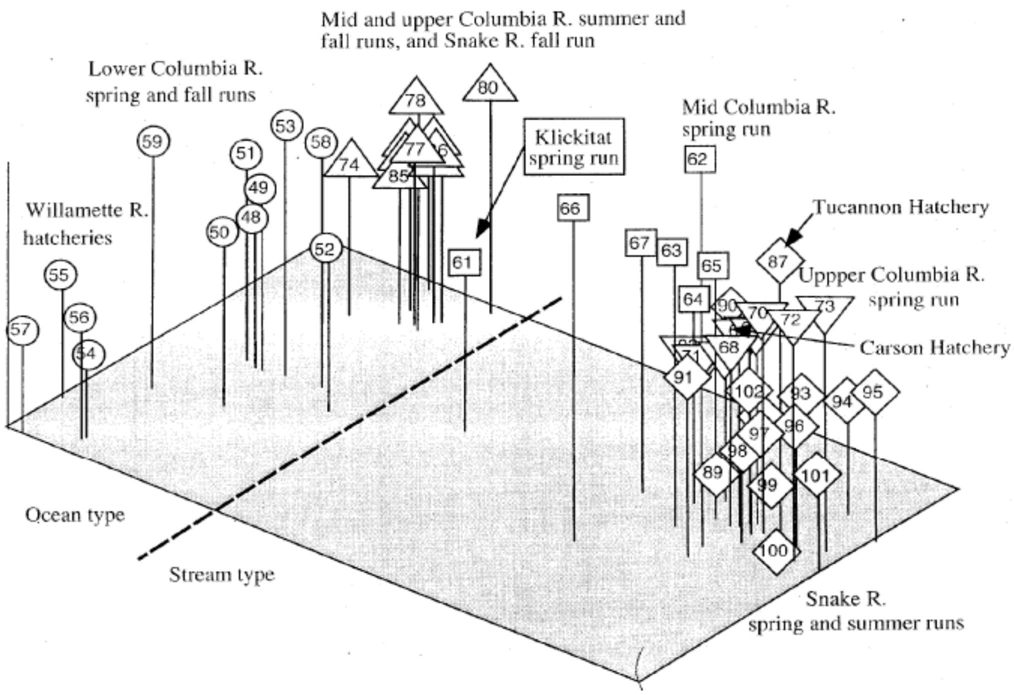


Figure 10 -- Multidimensional scaling (MDS) of Cavalli-Sforza and Edwards (1967) chord distances based on 31 allozyme loci between 55 composite samples of Chinook salmon from populations in the Columbia River drainage. The Ocean/Stream line was added subsequent to the decision to place Klickitat spring run in the Middle Columbia River spring run ESU.

Based on the recoveries from hatchery origin CWT marked fish, very few fish were recovered from coastal fisheries, a characteristic associated with stream-type fish. Age data taken from scales during the early 1900s indicated that Klickitat River spring run fish outmigrated as yearlings (Rich 1920). Finally, vertebral counts from Klickitat River spring-run fish clustered with interior Columbia River Basin stream-type Chinook populations (Schreck et al. 1986). Using an index of genetic, morphometric, and ecological information, Schreck et al. (1986) concluded that the Klickitat River spring run did not cluster with either lower or upper Columbia River Chinook salmon populations. The results of the studies done prior to the 1998 Status Review were thought to be confounded by the release of Chinook salmon from both lower (Cowlitz and Willamette River) and upper (Carson NFH) river sources (Myers et al. 1998).

New Information on Lower Columbia and Middle Columbia River Chinook salmon ESUs.

As with the steelhead populations in the Columbia River Basin, a basin wide Chinook salmon microsatellite baseline has been recently developed. CWT recoveries from Klickitat Hatchery spring run Chinook salmon from 1997 to 2007 were similar to those examined by the BRT in the 1990s; a few spring run Chinook salmon were recovered in the coastal fisheries (from California to Alaska). Whether these recoveries are indicative of the transitional nature of the population (from ocean to stream type) or simply random recoveries remains unclear.

Reanalysis of Columbia River Chinook salmon using microsatellite DNA variability presents a complicated picture of population structure within the Klickitat River (Hess et al. 2010). The Klickitat Hatchery sample is more aligned with Interior (Stream-type) spring run populations, while the naturally spawning spring run Chinook salmon appear to be a mixture between Coastal and Interior lineages (Figure 11). It is also not clear to what degree out-of-basin introductions into the Klickitat Hatchery have influenced the present genetic structure, or whether fall-run Chinook salmon (provided access to the upper river via a fish ladder built in the 1950s) may have interbred with spring run Chinook on the natural spawning grounds.

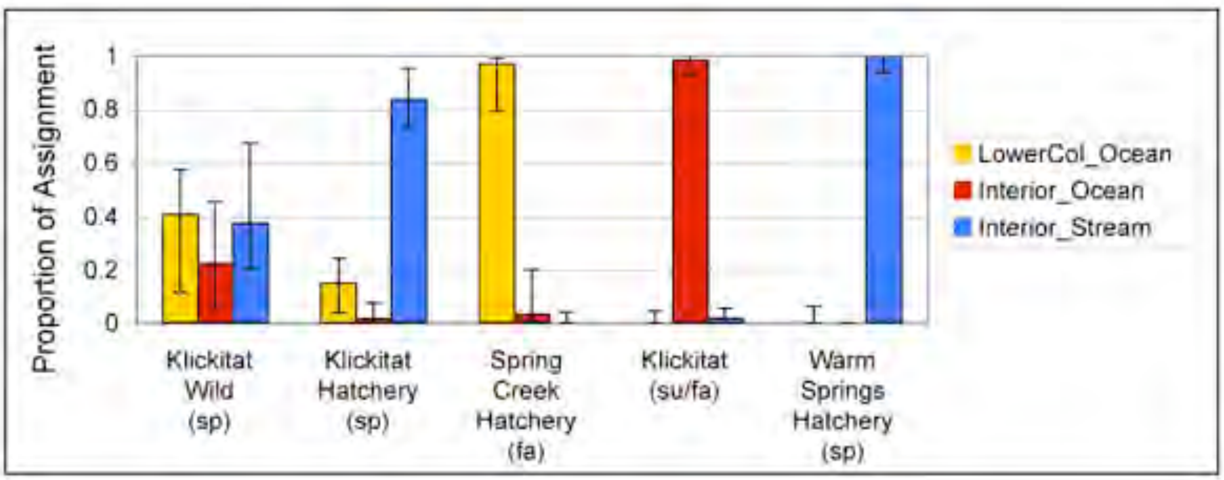


Figure 11 -- Proportion of sample that assigned to three major Columbia River Chinook lineages. Reproduced from Hess et al. (2010).

Conclusions

The boundary between coastal and interior populations of Chinook salmon, coho salmon and steelhead coincides with a major biogeographic barrier that lies along the Cascade Crest, and for aquatic species may have been delineated by Celilo Falls. Life history, genetic, and ecological information indicate that the Big White Salmon and Klickitat River basins form part of a transitional zone between the two regions. At the time of the coastwide status reviews in the mid-1990s, there was considerable disagreement on the placement of populations within this transitional zone. New information, primarily DNA microsatellite variation, underscores the transitional nature of populations in this area. The extirpation and potential alternation (via hatchery transfers) of some populations further clouds the issue of population assignment. Within the transition zone it is relatively clear that the Hood River steelhead are associated with Lower Columbia River populations (based on previous and current studies) and given the relative locations of the mouths of the Hood, Big White, and Klickitat rivers, the lack of definitive genetic information, and some life-history information suggestions connections with the Lower River, it may be reasonable to assign the Big White and Klicktat River steelhead to the Lower Columbia River DPS. The 15-mile Creek population, however, appears to be clearly associated with the Interior Columbia steelhead lineage.

Given the transitional nature of the Klickitat River Chinook salmon population it might be reasonable to assign that population to the Lower Columbia River Chinook salmon ESU. As coho populations in the gorge and interior Columbia regions have been largely extirpated, genetic analyses have not been conducted of coho in this region. The original Lower Columbia coho ESU boundary was assigned based largely on extrapolation from information about the boundaries for Chinook and steelhead. It may therefore reasonable to assign the Klickitat population to the Lower Columbia coho ESU. This would establish a common boundary for Chinook salmon, coho salmon, chum salmon, and steelhead at the Celilo Falls (Dalles Dam).

References

Beacham, T. D., J. R. Candy, K. J. Supernault, T. Ming, B. Deale, A. Schulze, D. Tuck, K. H. Kaukauna, J. R. Irvine, K. M. Miller, and R. E. Wither. 2001. Evaluation and application of microsatellite and major histocompatibility complex variation for stock identification of coho salmon in British Columbia. Transactions of the American Fisheries Society 130:1116-1149.

Benhke, R.J. 2002. Trout and salmon of North America. Free Press, New York.

Bjorkstedt, E.P., B.C. Spence, J.C. Garza, D.G. Hankin, D. Fuller, W. E. Jones, J.J. Smith, and R. Macedo. 2005. An Analysis of historical population structure for evolutionarily significant units of Chinook salmon, coho salmon, and steelhead in the North-Central California Coast Recovery Domain. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-382. 231 p.

Boughton, D.A., H. Fish, K. Pipal, J. Goin, F. Watson, J. Cadagrande, J. Cadagrande, and M. Stoecker. 2005. Contraction of the southern range limit for anadromous *Oncorhynchus mykiss*. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-380. 29 p.

Boughton, D.A., P. B. Adams, E. Anderson, C. Fusaro, E. Keller, E. Kelley, L. Lentsch, J. Nielsen, K. Perry, H. Regan, J. Smith, C. Swift, L. Thompson, and F. Watson. 2006. Steelhead of the South-Central/Southern California Coast: population characterization for recovery planning. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-394. 123 p.

Boughton, D. A., P. B. Adams, E. Anderson, C. Fusaro, E. Keller, E. Kelley, L. Lentsch, J. Nielsen, K. Perry, H. Regan, J. Smith, C. Swift, L. Thompson, and F. Watson. 2007. Viability criteria for steelhead of the south-central and southern California coast. NOAA Technical Memorandum NMFS-SWFSC-407.

Boughton, D. A., Fish, H., Pope, J., Holt, G. 2009. Spatial patterning of habitat for *Oncorhynchus mykiss* in a system of intermittent and perennial streams. Ecology of Freshwater Fish 1892-105.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-27.

Busby, P., R. Gustafson, G. Matthews, J. Myers, M. Ruckelshaus, T. Wainwright, R. Waples, J. Willliams, P. Adams, G. Bryant, and C. Wingert. 1999. Updated review of the status of the Upper Willamette River and Middle Columbia River ESUs [sic] of steelhead (*Oncorhychus mykiss).* West Coast Steelhead Biological Review Team report 36 p.

Clemento, A. J., E. C. Anderson, D. Boughton, D. Girman, and J. C. Garza. In press (2009). Population genetic structure and ancestry of Oncorhynchus mykiss populations above and below dams in south-central California. Conservation Genetics.

Garza, J .C., S. M. Blankenship, C. Lemaire, and G. Charrier. (2008) Genetic population structure of Chinook salmon (Oncorhynchus tshawytscha) in California's Central Valley. 82p.

Garza, J. C., and D. E. Pearse. 2008. Population genetic structure of Oncorhynchus mykiss in the California Central Valley. Final report for California Department of Fish and Game Contract #PO485303 with University of California, Santa Cruz and NOAA Southwest Fisheries Science Center, 110 Shaffer Rd. Santa Cruz, CA 95060. 54 p.

Hess, J.E., Paquin, M., Moran, P., and Myers, J. 2008. Phylogeography and genetic characterization of inland and coastal steelhead lineages in the Columbia River Basin. Poster prestned at the 2008 Coastwide Salmon Genetics Symposium.

Hess, J.E., Myers, J., and Moran, P. 2010. Examination of the phylogenetic relationships among collections of Columbia River Basin Chinook, *Oncorhynchus tshawytscha*, and evolutionary processes that reduced genetic diversity of stream-type compared to ocean-type lineages. NWFSC Report, dated August 31, 2010.

Kostow, K. 2003. Evolutionarily significant unit boundaries and status assessment in a highly polymorphic species, Oncorhynchus mykiss, in the Columbia Basin. 18 August 2003 draft rep. NOAA Fisheries Service and Oregon Dept. Fish and Wildlife. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Kostow, K. 1995. Biennial report on the status of wild fish in Oregon. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

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.

Lindley, S.T., R. Schick, B.P. May, J.J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson, and J. G. Williams. 2004. Population structure of threatened and endangered Chinook salmon ESUs in Califrornia's Central Valley Basin. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-360. 56 p.

Lindley, S. T., R. S. Schick, A. Agrawal, M. Goslin, T. E. Pearson, E. Mora, J. J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2006. Historical population structure of Central Valley steelhead and its alteration by dams. San Francisco Estuary and Watershed Science 4(1):Article 3

Lindley, S. T., R. S. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. R. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science 5(1): Article 4.

Marshall, A. 1998. Genetic analysis of mainstem Columbia River, below Bonneville Dam, Chinook spawners. Letter to K. Harlan (WDFW) from Anne Marshall (WDFW). 2p.

McClure M, R. Carmichael, T. Cooney, P. Hassemer, P. Howell, D. McCullough, C. Petrosky, H. Schaller, P. Spruell, and F. Utter. 2003. Independent Populations of Chinook, Steelhead and Sockeye for Listed Evolutionarily Significant Units within the Interior Columbia River Domain. Interior Columbia Basin Technical Recovery Team. 171 p.

Myers, J., C. Busack, D. Rawding, A. Marshall, D. Teel, D. M. Van Doornik, and M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-73. Online at http://www.nwfsc.noaa.gov/publications/index.cfm

Narum, S., M.S. Powell, R. Evenson, B. Sharp, and A.J. Talbot. 2006. Macrosatellites reveal population substructure of Klickitat River native steelhead and genetic divergence from and introduced stock. N. Amer. J. Fish. Man. 26: 147-155.

Narum, S.R., M. Banks, T.D. Beacham, R. Bellinger, M. Campbell, J. DeKoning, A. Elz, C. Guthrie, C. Kozfkay, K.M. Miller, P. Moran, R. Phillips, L. Seeb, C. T. Smith, K. Warheit, S. Young, and J.C. Garza (2008) Differentiating populations at broad and fine geographic scales with microsatellites and SNPs. Molecular Ecology 17: 3464-3477.

Phelps, S., S. A. Leider, P. L. Hulett, B.M. Baker, and T. Johnson. 1997. Genetic analyses of Washington steelhead: Preliminary results incorporating 36 new collections from 1995 and 1996. Progress Report. WDFW. 30 pp.

Phelps, S., B.M. Baker, and C.A. Busack. 2000. Genetic relationships and stock of structure of Yakima River basin and Klickitat River basin steelhead poulations. WDFW. 19 pp.

Rawding, Dan, 1995. Where is the boundary between coastal and inland steelhead? Letter to Peggy Busby (NWFSC) from Thom Johnson (WDFW) March 31, 2995. 7 p.

Ruckelshaus, M.H., K.P. Currens, W.H. Graeber, R.R. Fuerstenberg, K. Rawson, N.J. Sands, and J.B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-78, 125 p.

Schick, R.S., A. L. Edsall, and S.T. Lindley. 2005. Historical and current distribution of Pacific salmonids in the Central Valley, CA. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-369. 30 p.

Schreck, C. B., H. W. Li, C. S. Sharpe, K. P. Currens, P. L. Hulett, S. L. Stone, and S. B. Yamada. 1986. Stock identification of Columbia River Chinook salmon and steelhead trout. Project No. 83-45. U.S. Dept. Energy, Bonneville Power Administration, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Seeb, L. W., A. Antonovich, M. A. Banks, T. D. Beacham, M. R. Bellinger, M. Campbell, N. A. Decovich, J. C. Garza, C. M. Guthrie III, P. Moran, S. R. Narum, J. J. Stephenson, K. J. Supernault, D. J. Teel, W. D. Templin, J. K. Wenburg, S. F. Young, and C. T. Smith. (2007) Development of a standardized DNA database for Chinook salmon. Fisheries. 32: 540-552.

Shaklee, J.B., T.D. Beacham, L. Seeb, and B.A. White. 1999. Managing fisheries using genetic data: Case studies of four species of Pacific Salmon. Fisheries Research. 43:45-78.

Spence, B. C., E. P. Bjorkstedt, J. C. Garza, J. J. Smith, D. G. Hankin, D. Fuller, W. E. Jones, R. Macedo, T. H. Williams, and E. Mora. 2008. A framework for assessing the viability of threatened and endangered salmon and steelhead in the North-Central California Coast Recovery Domain. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-423.

Teel, D.J., D.M. Van Doornik, D.R. Kuligowski, and W.S. Grant. 2003. Genetic analysis of juvenile coho salmon (Oncorhynchus kisutch) off Oregon and Washington reveals few Columbia River wild fish. Fish. Bull. 101:640-652.

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 (*Oncorhynchus kisutch*) off the coasts of Washington and Oregon. North American Journal of Fisheries Management. 27:220-237.

Waples, R. 1991. Pacific salmon, *Oncorhynchus spp.*, and the definition of "species" under the Endangered Species Act. Marine Fisheries Review 53:11-22.

Weitkamp, L.A., T.C. Wainright, 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. Dep. Commer. NOAA Tech. Memo. NMFS-NWFSC-24, 258 p.

Williams, T.H., E.P. Bjorkstedt, W.G. Duffy, D. Hillemeier, G. Kautsky, T.E. Lisle, M. Mccain, M. Rode, R.G. Szerlong, R.S. Schick, M.N. Goslin, And A. Agrawal. 2006. Historical population structure of coho salmon in the Southern Oregon/Northern California coasts evolutionarily significant unit. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-390. xxx p.

Winans, G.A., M.M. Paquin, D.M. Van Doornik, B.M. Baker, P. Thornton, D. Rawding, A. Marshall, P. Moran, and S. Kalinowski. 2004. Genetic stock identification of steelhead in the Columbia River Basin: an evaluation of different molecular markers. North American Journal of Fish. Management. 24:672-685.

Winans, G. A., M. L. McHenry, J. Baker, A. Elz, A. Goodbla, E. Iwamoto, D. Kuligowski, K.M. Miller, M. P. Small, P. Spruell, and D. Van Doornik. 2008. Genetic Inventory of Anadromous Pacific Salmonids of the Elwha River Prior to Dam Removal. Northwest Science. 82:128-14

ESU status summaries

Upper Columbia River spring-run Chinook salmon[8]

The Upper Columbia Spring-Run Chinook Salmon ESU includes naturally spawning spring-run Chinook salmon in the major tributaries entering the Columbia River upstream of Rock Island Dam and the associated hatchery programs (70FR37160). The ESU was listed as Endangered under the ESA in 1998 (affirmed in 2005).

Summary of previous BRT conclusions

The previous BRT status review of the Upper Columbia River Spring-Run Chinook Salmon ESU was reported in Good et al. (2005). A slight majority (53%) of the cumulative votes cast by the BRT members placed this ESU in the "danger of extinction" category, with the next category, "likely to become endangered", receiving a substantial number of votes as well (45%). The 2005 BRT review noted that Upper Columbia Spring Chinook populations had "rebounded somewhat from the critically low levels" observed in the 1998 review. Although the BRT considered this an encouraging sign, they noted that the increase was largely driven by returns in the two most recent spawning years available at the time of the review. The BRT ratings were also influenced by the fact that two out of the three extant populations in this ESU were subject to extreme hatchery intervention measures in response to the extreme downturn in returns during the 1990s. Good et al. (2005) stated that these measures were "...a strong indication of the ongoing risks to this ESU, although the associated hatchery programs may ultimately play a role in helping to restore naturally self-sustaining populations."

Brief Review of Recovery Planning

The Interior Columbia Basin Technical Recovery Team has identified three extant populations within this ESU (ICTRT, 2003). Populations were identified based on genetic analysis and the distribution of spawning reaches vs. a dispersal curve derived from cwt recoveries from returning supplementation releases. The three extant populations represent natural production originating from spawning areas in the upper sections of the Wenatchee River, Entiat River and Methow River. The lower mainstem sections of each of these rivers also support production of Summer Run Chinook from a separate Chinook Salmon ESU. One other Upper Columbia drainage that remains accessible to anadromous fish, the Okanogan River, may have historically supported an additional spring Chinook population. The ICTRT classified the extant populations as a single Major Population Group (the North Cascades MPG). Two large mainstem Columbia River dams (Chief Joseph Dam and Grand Coulee Dam) block anadromous access to historical tributary habitats upstream of the extant populations. The ICTRT concluded that it is likely that additional populations of Upper Columbia Spring Chinook Salmon occupied tributary habitats upstream of these blockages. Based on the amount and distribution of habitat that would have been historically suited to stream type Chinook production, up to six additional populations may have existed historically upstream of the current blockages. The ICTRT recognized that there is some

---

[8] Section author: Tom Cooney

uncertainty as whether some of these areas were occupied by spring Chinook vs. summer Chinook.

TRT and Recovery Plan Criteria

NOAA Fisheries (National Marine Fisheries Service adopted a recovery plan for Upper Columbia Spring Chinook and steelhead in 2007 (FR 72 #194. 57303-57307). The Plan was developed by the Upper Columbia Salmon Recovery Board (UCSRB) and is available through their website (http://www.ucsrb.com/). The Upper Columbia Salmon Recovery Plan's overall goal is "...to achieve recovery and delisting of spring Chinook salmon and steelhead by ensuring the long-term persistence of viable populations of naturally produced fish distributed across their native range."

Two incremental levels of recovery objectives are specifically incorporated into the Upper Columbia Salmon Recovery Plan. Increasing natural production sufficiently to upgrade each Upper Columbia River ESU from "endangered" to "threatened" status is stated as an initial objective in the Plan. The Plan includes three specific quantitative reclassification criteria expressed relative to population viability curves (ICTRT, 2007). Abundance and productivity of naturally produced Spring Chinook within each of the extant Upper Columbia populations, measured as 8-year geometric means (representing approximately two generations), must fall above the viability curve representing the minimum combinations projecting to a 10% risk of extinction over 100 years. The plan also incorporates explicit criteria for spatial structure and diversity adopted from the ICTRT viability report. The mean score for the three metrics representing natural rates and spatially mediated processes should result in a moderate or lower risk in each of the three populations and all threats defined as high risk must be addressed. In addition, the mean score for the eight ICTRT metrics tracking natural levels of variation should result in a moderate or lower risk score at the population level.

Achieving recovery (delisting) of each ESU via sufficient improvement in the abundance, productivity, spatial structure and diversity is the longer-term goal of the UCSRB Plan. The Plan includes two specific quantitative criteria for assessing the status of the Spring Chinook ESU against the recovery objective; "The 12-year geometric mean (representing approximately three generations) of abundance and productivity of naturally produced spring Chinook within the Wenatchee, Entiat and Methow populations must reach a level that would have not less than a 5% extinction-risk (viability) over a 100 year period" and "at a minimum, the Upper Columbia Spring Chinook ESU will maintain at least 4,500 naturally produced spawners and a spawner:spawner ratio greater than 1:1 distributed among the three populations". The minimum number of naturally produced spawners (expressed as 12 year geometric means) should exceed 2,000 each for the Wenatchee and Methow River populations and 500 within the Entiat River. Minimum productivity thresholds were also established in the Plan. The 12 year geometric mean productivity should exceed 1.2 spawners per parent spawner for the two larger populations (Wenatchee and Methow Rivers), and 1.4 for the smaller Entiat River population. The ICTRT had recommended that at least two of the three extant populations be targeted for highly viable status (less than 1% risk of extinction over 100 years) because of the relatively low number of extant populations remaining in the ESU. The UC Plan adopted an alternative approach for addressing the the limited number of populations in the ESU – 5% or less risk of extinction for all three extant populations.

The Upper Columbia Salmon Recovery Plan also calls for '..restoring the distribution of naturally produced spring chinook salmon and steelhead to previously occupied areas where practical; and conserving their genetic and phenotypic diversity." Specific criteria included in the UCSRB Plan reflect a combination of the specific criteria recommended by the ICTRT (ICTRT, 2007) and in the earlier QAR effort (Ford et al. 2001). The Plan incorporates spatial structure criteria specific to each Spring Chinook population in Section 4.4.1. For the Wenatchee River population, the criteria call for observed natural spawning in four of the five major spawning areas as well as in at least one of the minor spawning areas downstream of Tumwater Dam. In the Methow River, natural spawning should be observed in three major spawning areas. In each case, the major spawning areas should include a minimum of 5% of the total return to the system or 20 redds, whichever is greater. The Entiat River Spring Chinook population includes a single historical major spawning area.

The Plan calls for meeting or exceeding the same basic spatial structure and diversity criteria adopted from the ICTRT viability report for recovery as for reclassification (see above).

New Data and Updated Analyses

Annual abundance estimates for each of the extant populations in this ESU are generated based on expansions from redd surveys and carcass sampling. Index area redd counts have been conducted in these river systems since the late 1950's. Multiple pass surveys in index areas complemented by supplemental surveys covering the majority of spawning reaches have been conducted since the mid 1980's. For more recent years, estimates of annual returns to the Wenatchee River population also reflect counts and sampling data obtained at a trap at the Tumwater Dam on the mainstem river downstream of spring chinook spawning areas. The previous BRT review of this ESU (reported in Good et al., 2005) considered returns through the 2001 spawning year. The ICTRT compiled status reviews for Upper Columbia Spring Chinook based on data covering up to the 2003 return year (ICTRT, 2009). Estimates are now available up through the 2008 spawning year. In addition, Rocky Reach and Wells Dam counts of adult spring Chinook passage are available through the current return year (2010). These counts are aggregates including natural production, returns from directed supplementation programs and returns of non-ESU hatchery Chinook.

<u>Standard abundance and trends</u>

Recent year geometric mean spawning abundance estimates for each of the three extant Upper Columbia spring Chinook populations are summarized in Table 6. Total spawning abundance, including both natural origin and hatchery fish, has increased relative to the levels reported in the previous BRT review. The geometric mean abundances of both natural origin and hatchery spawners are higher for each population relative to the previous review and to the levels just prior to listing. The relative increase in hatchery origin spawners in the Wenatchee and Methow River populations has been disproportionately high reflecting the large increase in releases from the directed supplementation programs in those two drainages. There is no direct hatchery supplementation program in the Entiat River basin. Hatchery origin spawners in the Entiat River system are predominately strays from the Entiat National Fish Hatchery releases. The Entiat NFH spring Chinook release program was discontinued in 2007. Given the 3-6 year life span of Upper Columbia spring Chinook stocks, the number of hatchery fish on the spawning grounds in the Entiat River should decline substantially over the next few years.

Table 6. Estimated spawning abundance (total spawners, natural origin spawners, percent natural origin) for Upper Columbia spring chinook populations.

Population	**Natural Spawning Areas**								
	Total Spawners (5 year geometric mean, *range*)			**Natural Origin** (5 year geometric mean)			**% Natural Origin** (5 year average)		
	Listing ***(1991-1996)***	***Prior*** ***(1997-2001)***	**Current** **(2003-2008)**	***Listing*** ***(1991-1996)***	***Prior*** ***(1997-2001)***	**Current** **(2003-2008)**	***Listing*** ***(1991-1996)***	***Prior*** ***(1997-2001)***	**Current** **(2003-2008)**
Wenatchee River	*167*	*470 (119-4,446)*	**1,554** ***(936-2,119)***	*NA*	*274*	**489**	*69%*	*58%*	**31%**
Entiat River	*89*	*111 (53-444)*	**253** ***(207-317)***	*NA*	*65*	**111**	*82%*	*58%*	**46%**
Methow River	*325*	*680 (79-9,904)*	**1,327** ***(984-1,801)***	*NA*	*282*	**402**	*78%*	*41%*	**29%**

Annual spawning escapements for all three of the extant Upper Columbia Spring Chinook populations showed steep declines during the late 1980s and early 1990s, leading to extremely low abundance levels in the mid-1990s (Figure 12).

The steep downward trend reflects the extremely low return rates for natural production from the 1990-94 brood years (Figure 13). Prior to the early 1980s, brood year return-per-spawner estimates were generally above replacement at low to moderate parent escapement levels. Brood year replacement rates were consistently below 1.0 even at low parent spawner levels throughout the 1990s. Steeply declining trends across indices of total spawner abundance were a major consideration in the 1997 BRT risk assessment prior to formal listing of the ESU. The short term trend assessment developed for the previous BRT analysis (Good et al. 2005) was slightly positive or neutral across the populations. The trend in total spawners since 1995 has been positive for all three populations, with a relatively low probability that the true values are below 1.0 (Table 7).

Table 7. Short term trend (expressed as slope of logs of annual natural origin spawner abundance 1995-2009. Expressed as 5 year geometric means (95% CI, probability the trend exceeds 1.0).)

Population		**Short-term trend**		
		1998 BRT (1987-97)	Previous (1990-2001)	1998 BRT (1987-97)
Wenatchee River	**Estimate** **(CI)** ***Prob>1.0***	0.88	0.99 0.82-1.18) *0.43*	**1.16** **(1.04-1.30)** ***0.994***
Entiat River	**Estimate**	0.801	1.01	**1.16**

	(CI) ***Prob>1.0***		(0.87-1.16) *0.53*	**(1.05-1.28)** ***0.996***
Methow River	**Estimate** **(CI)** ***Prob>1.0***	0.85	1.2 (0.62-1.28) *0.25*	**1.2** **(1.03-1.40)** ***0.988***

The short term indices of population growth rate indicate that natural origin returns have trended upwards since 1995 at a higher average rate than during the period leading up to the 2005 BRT review (Table 8). Estimated population growth rates assuming that hatchery origin spawners and natural origin spawners are contributing to natural production at the same rate are below replacement for all three populations. Possible contributing factors would include density dependent effects, differences in spawning distribution relative to habitat quality and reduced fitness of hatchery origin spawners.

Table 8. Short term population growth rate estimates for Upper Columbia Spring Chinook populations.

Population	**Short-term Lambda**					
	Hatchery effectiveness= 0			**Hatchery effectiveness= 1.0**		
		2005 BRT (1990-2001)	**Current** **(1995-2008)**		2005 BRT (1990-2001)	**Current** **(1995-2008)**
Wenatchee River		0.91 (0.05-16.5) *0.37*	**1.11** **(0.18-7.06)** ***0.70***		0.83 (0.05-12.84) *0.28*	**0.92** **(0.12-7.14)** ***0.36***
Entiat River		0.94 (0.13-7.00) *0.39*	**1.12** **(0.18-7.14)** ***0.71***		0.89 (0.14-5.58) *0.29*	**0.995** **(0.14-6.87)** ***0.49***
Methow River		0.92 (0.03-24.6) *0.40*	**1.15** **(0.08-16.12)** ***0.69***		0.84 (0.04-18.8) *0.30*	**0.85** **(0.04-20.4)** ***0.32***

Current abundance estimates for all three Upper Columbia Spring Chinook populations are well below the levels observed in the 1960s (Figure 12). Expressed as an average annual decline, total spawning abundance has declined the equivalent of 2%-4% per year (Table 9). Indices of population growth rate have shown a similar average decline, with relatively low probabilities that the actual growth rates exceeded 1.0.

Table 9. Long term trend metrics for Upper Columbia Spring Chinook populations.

Population	**Years**	**Trend in total Spawners Estimate (CI)**	**Lambda (HF=0) Estimate (CI)**	**Prob>1**	**Lambda(HF=1) Estimate (CI)**	**Prob>1**
Wenatchee	1960 - 2008	0.94 (0.92 - 0.95)	0.96 (0.83 - 1.10)	0.26	0.91(0.80 - 1.04)	0.08
Entiat	1960 - 2008	0.96 (0.94 - 0.97)	0.98 (0.87 - 1.10)	0.33	0.94 (0.85 - 1.05)	0.12
Methow	1960 - 2008	0.94 (0.92 - 0.96)	0.96 (0.82 - 1.13)	0.31	0.90 (0.76 - 1.06)	0.08

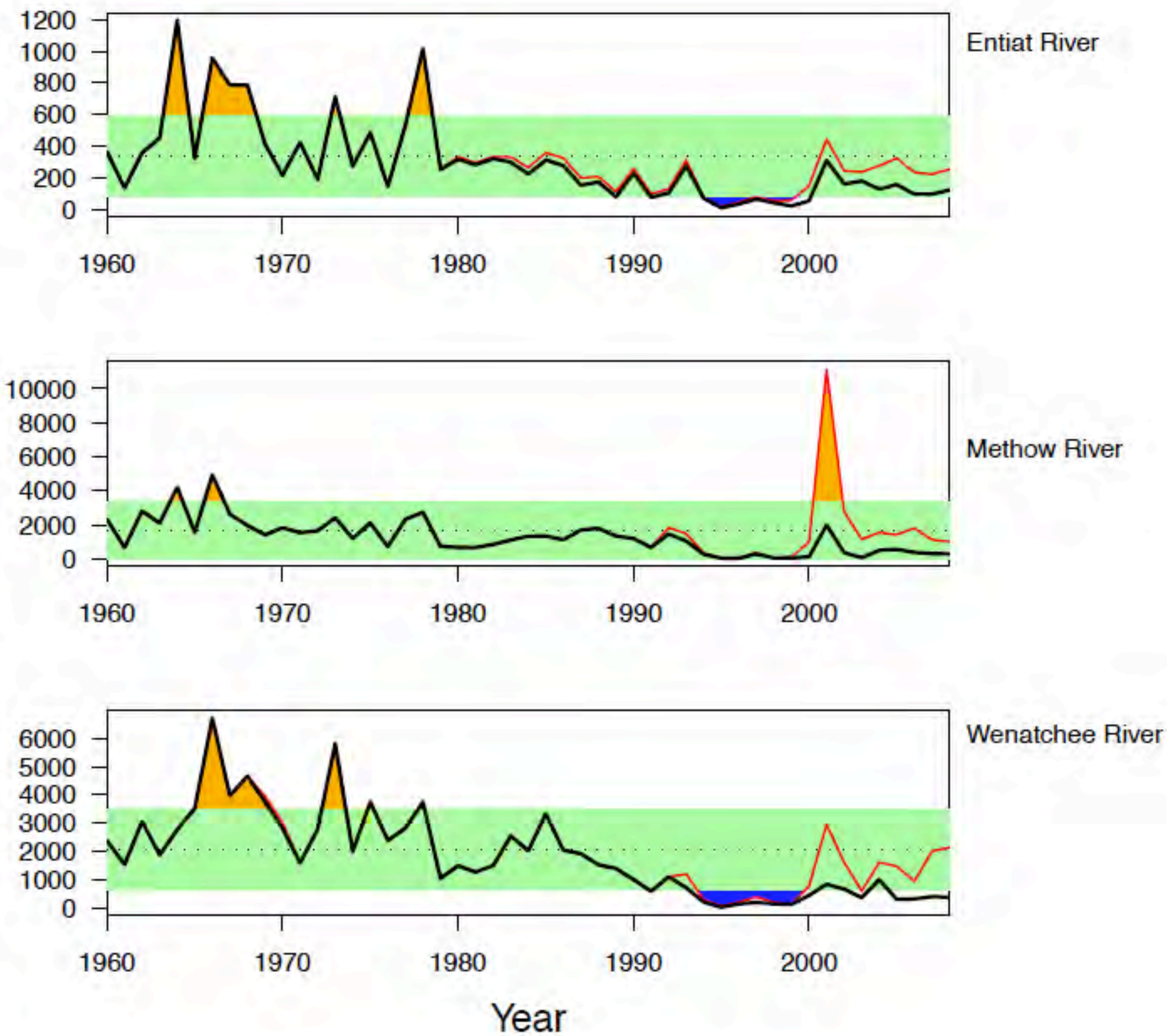


Figure 12 -- Updated spawning abundance for Upper Columbia Spring Chinook populations. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

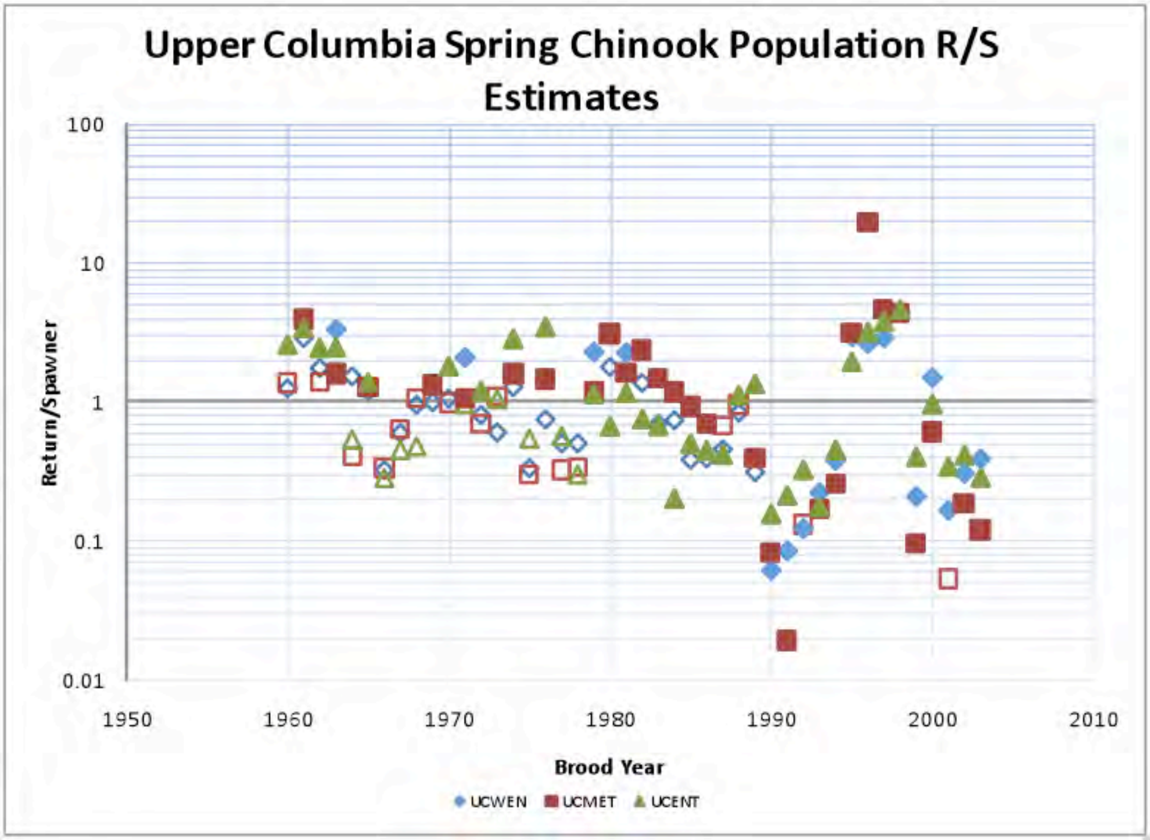


Figure 13 – Trend of broodyear spawner to spawner return rate estimates for the Upper Columbia River spring Chinook salmon ESU populations. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.

<u>Other data</u>

The ICTRT current productivity metric incorporates a relative adjustment for annual SAR estimates to reduce the impact of short term climate variability (ICTRT, 2007, ICTRT, 2010). The SAR index used for all three Upper Columbia River Spring Chinook population data series uses natural origin smolt to adult estimates derived from smolt and adult monitoring of production from the Chiwawa River along with a longer data series of smolt to adult return survival estimates for Leavenworth Hatchery releases. The indices represent cumulative out of basin survivals (downstream passage, ocean life stages, upstream passage including harvest escapement rates). The SAR series used by the ICTRT to evaluate population status ended with the 2001 brood year (2003 outmigration year). Four additional years of SAR estimates are now available for both series (Figure 14). SAR estimates for the 2002-2004 brood outmigrants were lower than the relatively high SARs associated with the 1995 through 1998 brood years, but well above the extremely low survivals observed for the 1990 and 1991 broods.

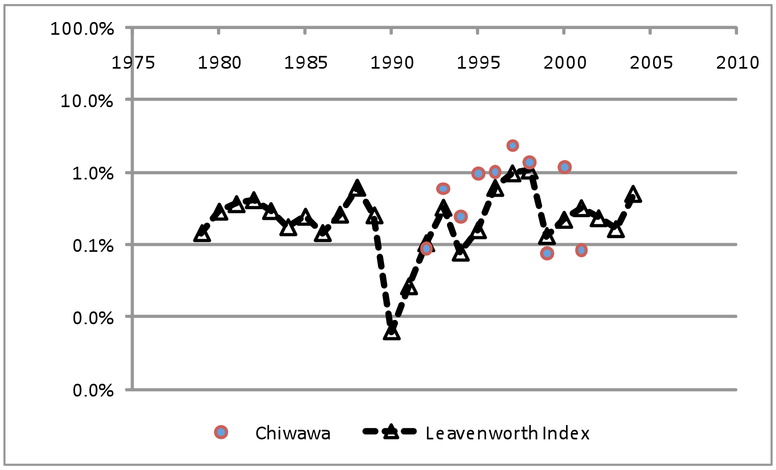


Figure 14 -- Smolt to adult return rate estimates. Chiwawa River natural production SAR: brood year adult returns to the Wenatchee River divided by estimated smolts produced. Leavenworth Hatchery Spring Chinook SAR: brood year adult returns divided by smolt release.

Smolt Production

Natural production of spring Chinook from the Chiwawa River tributary to the Wenatchee River has been monitored since 1991 (Hillman et al, 2010). Smolt traps at the mouth of the Chiwawa River and in the downstream Wenatchee River mainstem allow for generating annual estimates of total smolt production resulting from spawning in the Chiwawa River. Most of the smolts leaving the Wenatchee River from production in the Chiwawa River emigrate as yearlings in the spring of their second year of life. A portion of Chiwawa River production moves downstream in the summer and fall and overwinters in the mainstem Wenatchee River before emigrating in the spring (Figure 15). Smolt production from the Chiwawa River has increased since the early 1990s, with peak production occurring in 2001 and 2002.

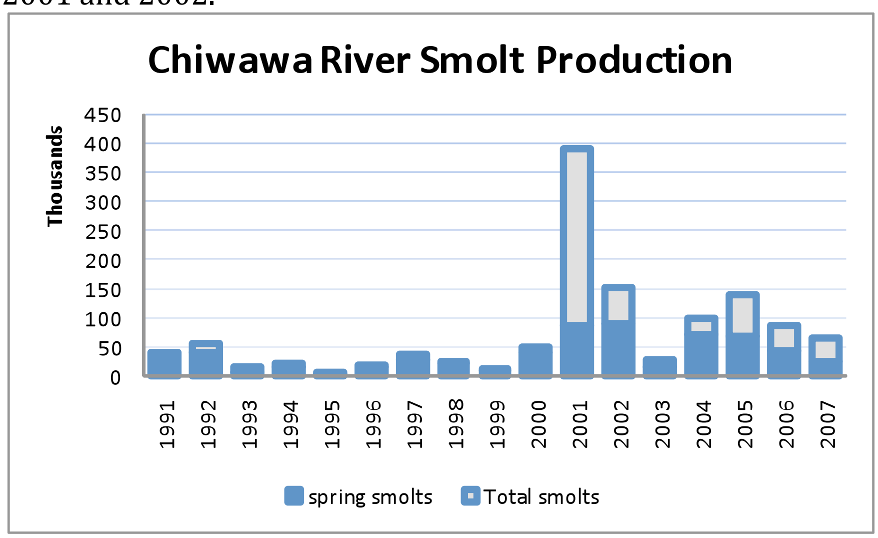


Figure 15 -- Estimated number of natural origin smolts produced from spawning in the Chiwawa River (tributary within the Wenatchee River Spring Chinook population. From Hillman et al. 2010 (Table 5-15).

TRT metrics

Table 10. Viability assessments for Upper Columbia spring Chinook salmon populations in the North Cascades MPG. Spatial structure and diversity risk ratings from ICTRT (2008).

Population	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
	ICTRT Minimum Threshold	*Natural Spawning Abundance*	*ICTRT Productivity*	*Integrated A/P Risk*	*Natural Processes Risk*	*Diversity Risk*	*Integrated SS/D Risk*	
Wenatchee River 1987-2009	**2000**	***449 (119-1,050)***	**0.61 (0.40-0.95)**	**High**	Low	High	**High**	**HIGH RISK**
1981-2003		*222 (18-1,050)*	*0.93 (0.57-1.53)*	*(High)*				
Entiat River 1999-2009	**500**	**105 (27-291)**	**1.08 (0.75-1.55)**	**High**	Moderate	High	**High**	**HIGH RISK**
1981-2003		*59 (10-291)*	*0.72 (0.59-0.93)*	*(High)*				
Methow River 1999-2009	**2000**	**307 (79-1,979*)***	**0.45 (0.26-0.8)**	**High**	Low	High	**High**	**HIGH RISK**
1981-2003		*180 (20-1,979)*	*0.80 (0.52-1.24)*	*(High)*				
Okanogan River	n/a	n/a		n/a	n/a	n/a	n/a	n/a

Overall abundance and productivity (A/P) remains rated at High Risk for the each of the three extant populations in this MPG/ESU (Table 10). The 10-year geometric mean abundance of adult natural origin spawners has increased for each population relative to the levels for the 1981-2003 series but the estimates remain below the corresponding ICTRT thresholds. Estimated productivity (spawner to spawner return rate at low to moderate escapements) was on average lower over the years 1987-2009 than for the previous period (Table 10). The combinations of current abundance and productivity for each population result in a high risk rating when compared to the ICTRT viability curves.

The composite spatial structure/diversity (SS/D) risks for all three of the extant populations in this MPG are rated at High (Table 27). The spatial processes component of the SS/D risk is low for the Wenatchee River and Methow River populations and moderate for the Entiat River (loss of production in lower section increases effective distance to other populations). All three of the extant populations in this MPG are rated at high risk for diversity, driven primarily by chronically high proportions of hatchery-origin spawners in natural spawning areas and lack of genetic diversity among the natural-origin spawners (ICTRT, 2008).

Based on the combined ratings for abundance/productivity and spatial structure/diversity, all three of the extant populations of Upper Columbia Spring Chinook remain rated at high overall risk (Figure 16).

		Spatial Structure/Diversity Risk			
		Very Low	Low	Moderate	High
Abundance/ Productivity Risk	Very Low (<1%)	HV	HV	V	M
	Low (1-5%)	V	V	V	M
	Moderate (6 – 25%)	M	M	M	HR
	High (>25%)	HR	HR	HR	HR Wenatchee R. Entiat R. Methow R. *Okanogan R. (extinct)*

Figure 16 -- North Cascades spring Chinook salmon MPG population risk ratings integrated across the four viable salmonid population (VSP) metrics. Viability Key: HV – Highly Viable; V – Viable; M – Maintained; HR –High Risk (does not meet viability criteria).

Harvest

Spring Chinook salmon from the upper Columbia basin migrate offshore in marine water and where known impacts in ocean salmon fisheries are too low to be quantified. The only significant harvest occurs in the mainstem Columbia River in tribal and non-tribal fisheries directed at hatchery spring Chinook from the Columbia and Willamette Rivers. Prior to 1980, estimated harvest rates on the aggregate run of spring Chinook salmon to the upper Columbia and Snake River basin averaged approximately 55% (WDFW, 2002). Fisheries management measures were implemented beginning in the 1970s to reduce harvest rates in response to a sharp decline in annual returns. Exploitation rates have remained relatively low, generally below 10%, though they have been increasing in recent years (Figure 17). The increases in recent years have resulted from increased harvests allowed in response to record returns of hatchery spring Chinook to the Columbia River basin.

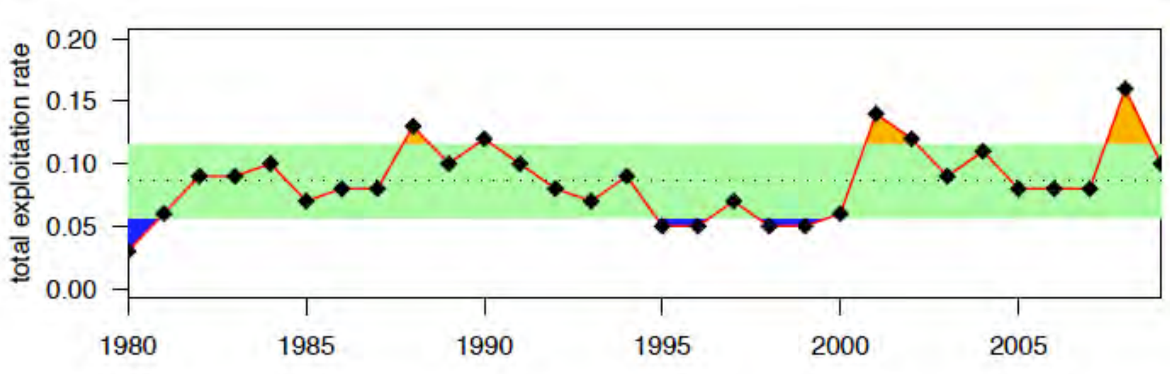


Figure 17 -- Total exploitation rate for upper Columbia River spring Chinook salmon. Data from the Columbia River Technical Advisory Committee (TAC 2010).

Hatchery releases

Trends in hatchery releases within the spawning and rearing areas of the ESU have been fairly flat since the mid-1990s, with the exception of coho salmon releases which have increased (Figure 18). Trends since 2005 have generally been flat.

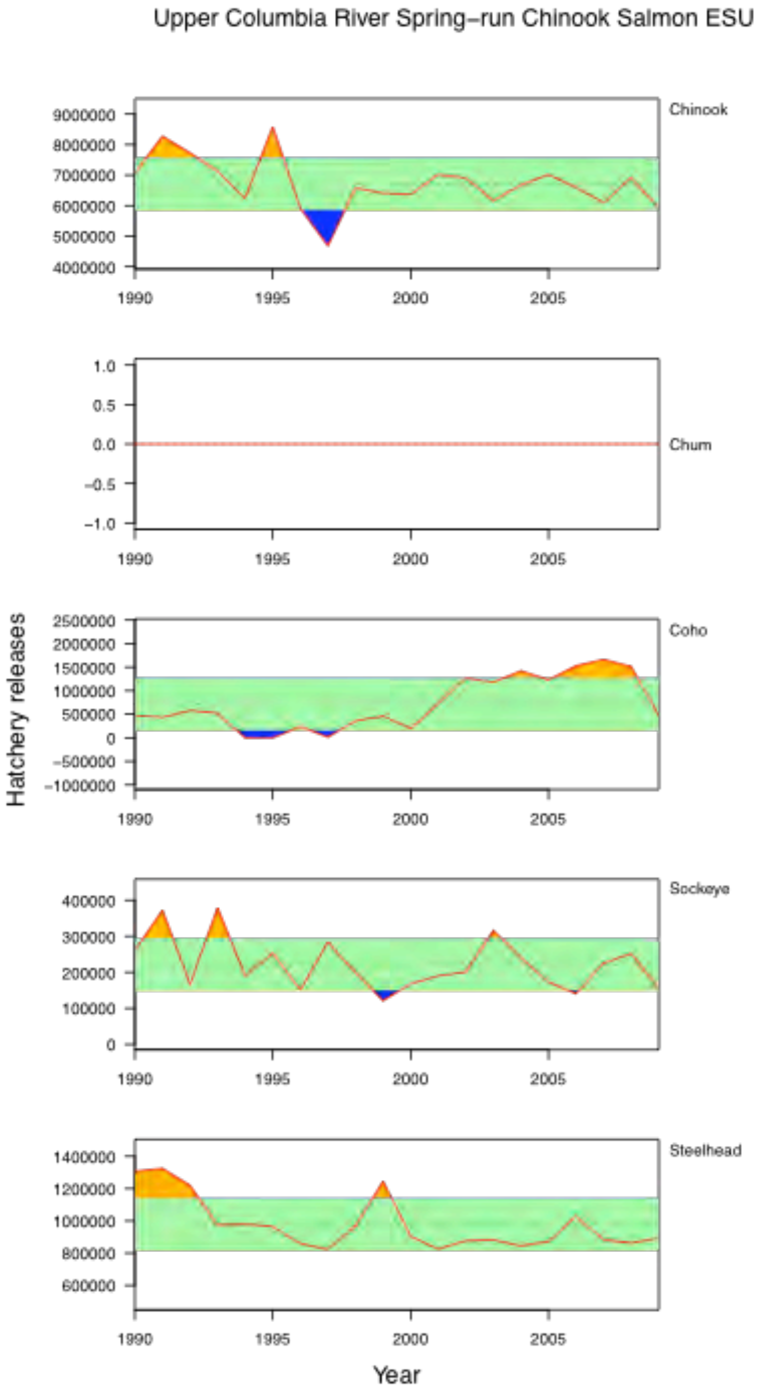


Figure 18 – Trends in hatchery releases within the spawning and rearing area of the Upper Columbia spring Chinook ESU. The dotted line and shared area indidates the long-term mean and standard deviation respectively. Data source: RMIS.

Upper Columbia Spring Chinook: Updated Risk Summary

The Upper Columbia Spring Chinook ESU is not currently meeting the viability criteria (adapted from the ICTRT) in the Upper Columbia Recovery Plan. Increases in natural origin abundance relative to the extremely low spawning levels observed in the mid-1990s are encouraging; however, average productivity levels remain extremely low. Large scale directed supplementation programs are underway in two of the three extant populations in the ESU. These programs are intended to mitigate short-term demographic risks while actions to improve natural productivity and capacity are implemented. While these programs may provide short-term demographic benefits, there are significant uncertainties regarding the long-term risks of relying on high levels of hatchery influence to maintain natural populations. The Upper Columbia Recovery Plan includes a number of strategies for improving survival in tributary habitats and the mainstem migration corridor along with complementary harvest management and hatchery management regimes. The time frames for implementing actions and for those actions to result in improved survivals vary across strategies. Improved passage survivals relative to conditions prevalent at the time of listing are expected to be relatively immediate. Given the anticipated action implementation schedule and assumptions regarding time lags for realizing target habitat improvements incorporated into the UC Recovery Plan, improvements in survival due to changes in habitat conditions are expected accrue over a 10-50 year period. Overall, the viability of the Upper Columbia Spring Chinook salmon ESU has likely improved somewhat since the time of the last BRT status review, but the ESU is still clearly at moderate-to-high risk of extinction.

References

ICTRT, 2003. Independent populations of chinook, steelhead and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Interior Columbia Basin Technical Recovery Team Technical Review Draft. July 2003. 171 p.

ICTRT, 2007. Viability criteria for application to interior Columbia Basin salmonid ESUs. Interior Columbia Basin Technical Recovery Team. Technical Review Draft. March 2007. 91 p + appendices and attachments.

ICTRT (2008) Current status reviews: Interior Columbia Basin salmon ESUs and steelhead DPSs. Vol. 2. Upper Columbia River spring Chinook salmon ESU and upper Columbia River steelhead DPS. 167 p.

Hillman,T., M. Miller, J. Miller, M. Tonseth, T. Miller and A. Murdoch. 2010. Monitoring and evaluation of the Chelan County PUD hatchery programs. Rept. to HCP hatchery committee. 237 p. + attachments

Upper Columbia Salmon Recovery Board (2007). Upper Columbia spring chinook salmon and steelhead recovery plan. 307 p. http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Interior-Columbia/Upper-Columbia/upload/UC_Plan.pdf

Washington Department of Fish and Wildlife. 2000. Status report: Columbia River fish runs and fisheries 1938-2000. Washington Dept. of Fish and Wildlife and Oregon Dept. of Fish and Wildlife joint fisheries staff report. 324 p.

Upper Columbia River steelhead[9]

The Upper Columbia Steelhead DPS ".. includes all naturally spawned anadromous *O. mykiss* (steelhead) populations below natural and manmade impassable barriers in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the US-Canada border, as well as six artificial propagation programs: the Wenatchee River, Wells Hatchery (in the Methow and Okanogan Rivers), Winthrop NFH, Omak Creek and the Ringold steelhead hatchery programs. The Upper Columbia Steelhead DPS was originally listed under the ESA in 1997, it is currently designated as threatened by NOAA Fisheries.

NOAA Fisheries has defined DPSs of steelhead to include only the anadromous members of this species (70 FR 67130). Our approach to assessing the current status of a steelhead DPS is based evaluating information the abundance, productivity, spatial structure and diversity of the anadromous component of this species. (Good et al. 2005; 70 FR 67130). Many steelhead (*O. mykiss*) populations along the West Coast of the U.S. co-occur with conspecific populations of resident rainbow trout. We recognize that there may be situations where reproductive contributions from resident rainbow trout may mitigate short-term extinction risk for some steelhead DPSs (Good et al. 2005; 70 FR 67130). We assume that any benefits to an anadromous population resulting from the presence of a conspecific resident form will be reflected in direct measures of the current status of the anadromous form.

Summary of previous BRT conclusions

The 2005 BRT cited low growth rate/productivity as the most serious risk factor for the Upper Columbia River steelhead DPS. In particular, the BRT concluded that the extremely low replacement rate of natural spawners highlighted in the 1998 review continued through the subsequent brood cycle. The 2005 BRT assessment also identified very low natural spawner abundance vs. interim escapement objectives and high levels of hatchery spawners in natural areas as contributing risk factors. The 2005 BRT report did note that the number of naturally produced steelhead returning to spawn within this DPS had increased over the levels reported in the 1998 status review. As with the Mid-Columbia and Snake River DPS reviews, the 2005 BRT recognized that resident *O. mykiss* were associated with anadromous steelhead production areas for this DPS. The review stated that the presence of resident *O. mykiss* was considered a mitigating factor by many of the BRT members in rating extinction risk.

Brief Review Recovery Planning

The Interior Columbia Technical Recovery Team (ICTRT) identified four extant populations of anadromous *O. mykiss* within this DPS, with each of the populations using a major tributary to the Upper Columbia River for spawning and juvenile rearing (the Wenatchee, Entiat, Methow and Okanogan Rivers). The ICTRT also concluded that Crab Creek could have historically supported an additional population, although it is not clear that the population would have been independent of production in the other four upstream drainages. Grande Coulee and Chief Joseph Dams are upstream of all four extant populations within the DPS. The ICTRT identified several drainages entering the Columbia River above these anadromous blocks that could have historically supported additional populations.

---

[9] Section author: Tom Cooney

TRT and Recovery Plan Criteria

NOAA Fisheries (National Marine Fisheries Service adopted a recovery plan for Upper Columbia Spring Chinook and steelhead in 2007 (FR 72 #194. 57303-57307). The Plan was developed by the Upper Columbia Salmon Recovery Board (UCSRB) and is available at: *http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Interior-Columbia/Upper-Columbia/Upper-Col-Plan.cfm.*

The Upper Columbia Salmon Recovery Plan (UC Recovery Plan) has as an overall goal "...to achieve recovery and delisting of spring Chinook salmon and steelhead by ensuring the long-term persistence of viable populations of naturally produced fish distributed across their native range". The UC Recovery Plan includes quantitative metrics for assessing ESU status based on the status of component populations. The quantitative recovery criteria and objectives in the plan are based on the biological viability criteria recommended by the ICTRT.

The Upper Columbia Salmon Recovery Plan includes three specific quantitative reclassification criteria expressed relative to population viability curves (ICTRT, 2007). Abundance and productivity of naturally produced steelhead within each of the extant Upper Columbia populations, measured as 8 year geometric means (representing approximately two generations), must fall above the viability curve representing the minimum combinations projecting to a 10% risk of extinction over 100 years to be classified as viable. In addition, the plan incorporates explicit criteria for spatial structure and diversity adopted from the ICTRT viability report. The mean score for the three metrics representing natural rates and spatially mediated processes should result in a moderate or lower risk in each of the three populations and all threats defined as high risk must be addressed. In addition, the mean score for the eight ICTRT metrics tracking natural levels of variation should result in a moderate or lower risk score at the population level.

Achieving recovery (delisting) of each ESU via sufficient improvement in the abundance, productivity, spatial structure and diversity is the longer-term goal of the UCSRB Plan. The Plan includes two specific quantitative criteria for assessing the status of the Steelhead DPS against the recovery objective; "The 12-year geometric mean (representing approximately three generations) of abundance and productivity of naturally produced steelhead within the Wenatchee, Entiat and Methow populations must reach a level that would have not less than a 5% extinction-risk (viability) over a 100 year period" and "at a minimum, the Upper Columbia Steelhead DPS will maintain at least 3,000 naturally produced spawners and a spawner:spawner ratio greater than 1:1 distributed among the three populations". The minimum number of naturally produced spawners (expressed as 12 year geometric means) should exceed 1,000 each for the Wenatchee and Methow River populations and 500 each for the Entiat River and Okanogan River populations. Minimum productivity thresholds were also established in the Plan. These natural spawner abundance criteria replace the interim targets referenced in the 2005 BRT report. The 12 year geometric mean productivity should exceed 1.1 spawners per parent spawner for the two larger populations (Wenatchee River and Methow), and 1.2 for the smaller Entiat River and Okanogan populations. The ICTRT had recommended that at least two of the four extant populations be targeted for highly viable status (less than 1% risk of extinction over 100 years) because of the relatively low number of extant populations remaining in the ESU. The UC Plan adopted an alternative approach for addressing the limited number of populations in the ESU – 5% or less risk of extinction for at least three of the four extant populations.

The Upper Columbia Salmon Recovery Plan also calls for "…restoring the distribution of naturally produced spring Chinook salmon and steelhead to previously occupied areas where practical; and conserving their genetic and phenotypic diversity." Specific criteria included in the UCSRB Plan reflect a combination of the specific criteria recommended by the ICTRT (ICTRT, 2007) and an earlier pre-TRT analytical project (Ford et al. 2001). The Plan incorporates spatial structure criteria specific to each Steelhead population in Section 4.4.2. For the Wenatchee River population, the criteria require observed natural spawning in four of the five major spawning areas as well as in at least one of the minor spawning areas downstream of Tumwater Dam. In the Methow River, natural spawning should be observed in three major spawning areas. In each case, the major spawning areas should include a minimum of 5% of the total return to the system or 20 redds, whichever is greater. The Entiat River Spring Chinook population includes a single historical major spawning area.

The Plan calls for meeting or exceeding the same basic spatial structure and diversity criteria adopted from the ICTRT viability report for recovery as for reclassification (see above).

New Data and Updated Analyses

The 2005 BRT report included status assessments of the Upper Columbia Steelhead DPS based on data through the 2003 brood year (2002 run year). Estimates of spawning escapements in Upper Columbia steelhead population tributaries are now available through the 2008/2009 cycle years, along with preliminary estimates of the aggregate counts (broken out by hatchery and wild) over Priest Rapids Dam for the 2009/2010 cycle year.

<u>Standard abundance and trends</u>

The most recent estimates (five year geometric mean) of total and natural origin spawner abundance are higher for all four populations and the Priest Rapids Dam aggregate run relative to the 2005 BRT review time period (Table 11, Figure 19). Annual returns during the most recent five-year series were all above the population specific ranges in returns for the five year period reported in the 2005 BRT review. In spite of the recent increases, natural origin returns remain well below target levels.

Hatchery origin returns continue to constitute a high fraction of total spawners in natural spawning areas for this DPS. Estimates of natural origin spawner abundance are higher for the most recent cycle. The pattern in the proportion of natural-origin spawner among populations for the most current five-year cycle was similar to that reported in the 2005 BRT review. Natural origin proportions were the highest in the Wenatchee River. Estimated proportions of natural origin in the Methow and Okanogan River remained at extremely low levels.

Table 11. Recent abundance and proportion natural origin compared to estimates at the time of listing and in the previous BRT review. Abundance estimates (five year geometric mean with range in parentheses) corresponding to the time of listing and the 2005 BRT

Population North Cascades MPG	Natural Spawning Areas								
	Total Spawners (5 year geometric mean, *range*)			Natural Origin (5 year geometric mean)			% Natural Origin (5 year average)		
	Listing (1991-1995)	*Prior (1997-2001)*	Current (2005-2009)	*Listing (1991-1995)*	*Prior (1997-2001)*	Current (2005-2009)	*Listing (1991-1995)*	*Prior (1997-2001)*	Current (2005-2009)
Wenatchee River	*1,880*	*696 (343-1,655)*	**1,891 *(931-3608)***	*458*	*326 (241-696)*	**819 *(701-962)***	24%	48%	**47%**
Entiat River	*121*	*265 (132-427)*	**530 *(300-892)***	*59*	*46 (31-97)*	**116 *(99-137)***	48%	19%	**23%**
Methow River	*1,184*	*1,935 (1417-3,325)*	**3,504 *(2,982-4,394)***	*251*	*162 (68-332)*	**505 *(361-703)***	21%	9%	**15%**
Okanogan River	*723*	*1,124 (770-1,956)*	**1,832 *(1,483-2,260)***	*84*	*53 (22-109)*	**152 *(104-197)***	12%	5%	**9%**
Aggregate Count at Priest Rapids Dam	*8,420*	*14,592*	**16,989**	*1,147*	*3,007*	**3,604**	*14%*	*19%*	**19%**

Table 12. Trend in natural origin spawners. Upper Columbia Spring Chinook. Comparison of current trends to prior reviews.

Population		Short-term trend		
		1998 BRT (1987-97)	Previous (1990-2001)	**Current (1995-2008)**
Wenatchee River	**Estimate (CI) *Prob>1.0***	0.86 (0.81 - 0.92) 0.0002	1.05 (1.02 - 1.07) 0.99	**1.11 (1.04 - 1.17) 0.99**
Entiat River	**Estimate (CI) *Prob>1.0***	0.86 (0.80 - 0.91) 0.0001	1.04 (1.02 - 1.07) 0.99	**1.11 (1.05 - 1.17) 0.99**
Methow River	**Estimate (CI) *Prob>1.0***	0.91 (0.80 - 1.03) 0.05	1.08 (1.05 - 1.12) 1.00	**1.17 (1.11 - 1.24) 1.00**
Okanogan River	**Estimate (CI) *Prob>1.0***	0.90 (0.79 - 1.02) 0.04	1.03 (1.01 - 1.05) 0.99	**1.16 (1.10 - 1.22) 1.00**

The short term trend metrics for each of the Upper Columbia steelhead populations are also above the levels associated with the prior review. Natural origin spawners increased at an average rate of 11%-17% per year over the period 1995-2009 (Table 12). The estimated population growth rate, assuming a hatchery effectiveness of 0, increased at a similar annual rate across all four populations over the period 1995-2009 (Table 13).

Table 13. Short Term (since 1995) population growth rate (lambda) estimates. Current estimates vs. 2005 BRT short term time series.

Population		Short-term Lambda			
		Hatchery effectiveness= 0		Hatchery effectiveness= 1.0	
		2005 BRT (1990-2001)	**Current (1995-2008)**	2005 BRT (1990-2001)	**Current (1995-2008)**
Wenatchee River	**Estimate**	0.94	**1.10**	0.72	**0.88**
	(CI)	(0.36 - 2.44)	**(0.25 - 4.92)**	(0.21 - 2.50)	**(0.16 - 4.87)**
	Prob>1.0	0.27	**0.71**	0.09	**0.25**
Entiat River	**Estimate**	0.95	**1.11**	0.74	**0.77**
	(CI)	(0.33 - 2.78)	**(0.26 - 4.66)**	(0.62 - 0.89)	**(0.18 - 3.24)**
	Prob>1.0	0.33	**0.73**	0.01	**0.13**
Methow River	**Estimate**	0.93	**1.17**	0.61	**0.70**
	(CI)	(0.14 - 6.16)	**(0.31 - 4.38)**	(0.18 - 2.11)	**(0.23 - 2.12)**
	Prob>1.0	0.35	**0.81**	0.06	**0.07**
Okanogan River	**Estimate**	0.93	**1.15**	0.54	**0.61**
	(CI)	(0.13 - 6.95)	**(0.33 - 4.06)**	(0.14 - 2.08)	**(0.22 - 1.70)**
	Prob>1.0	0.36	**0.80**	0.05	**0.05**

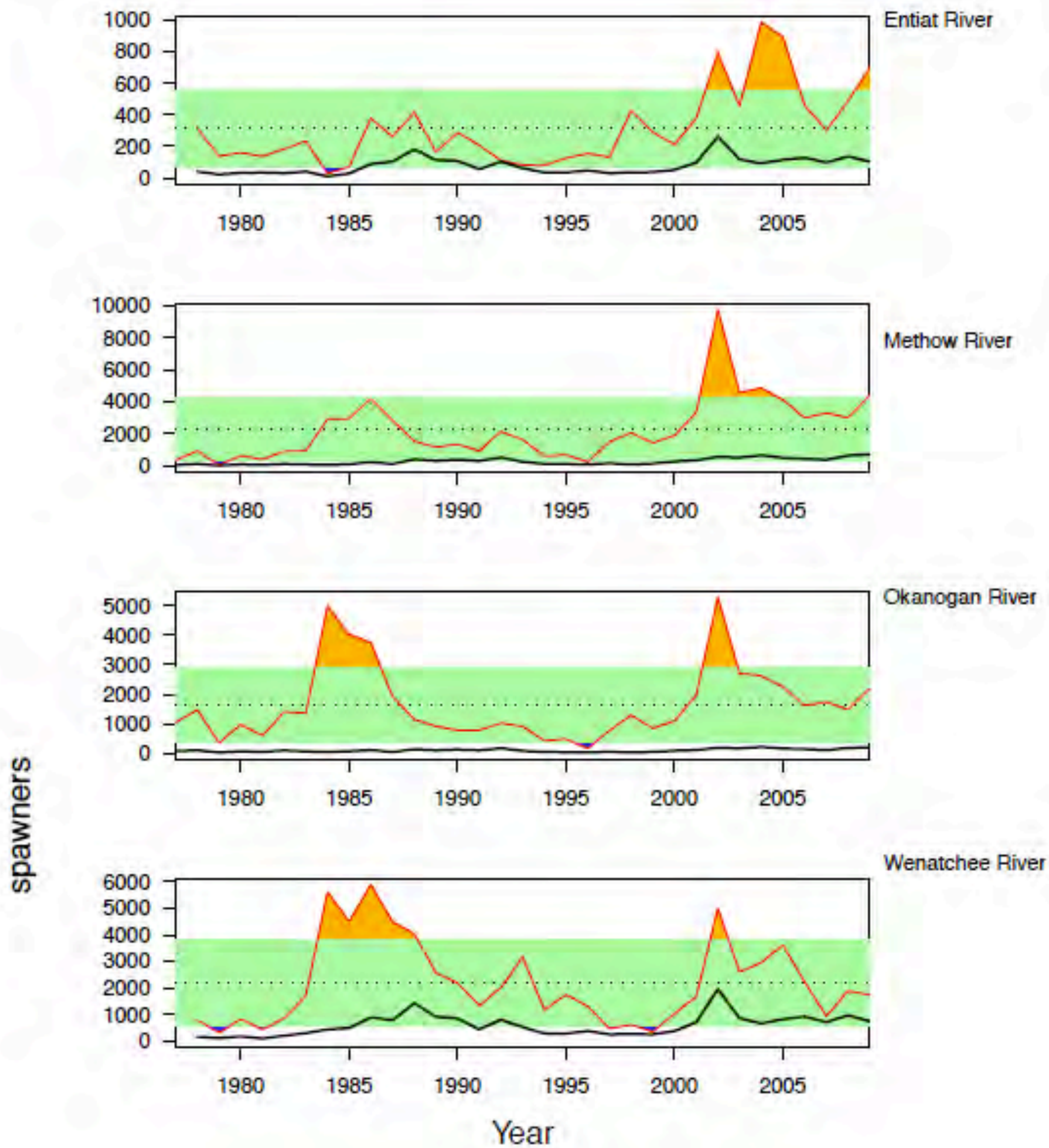
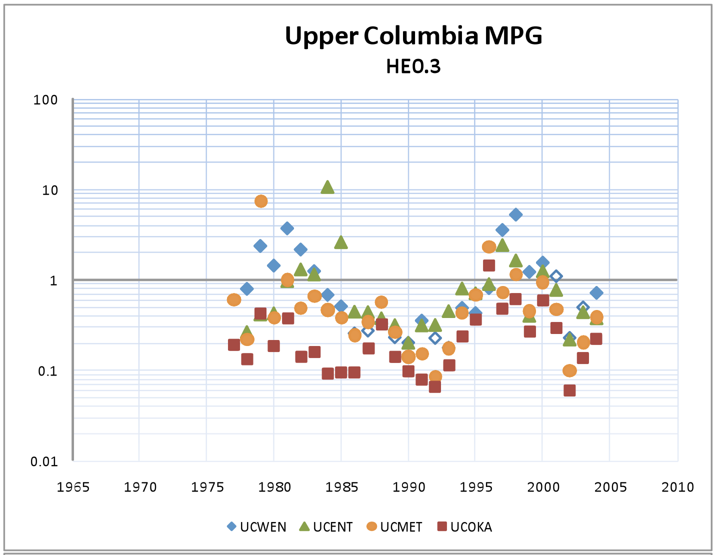


Figure 19 – Annual spawning abundance for Upper Columbia Steelhead populations. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.



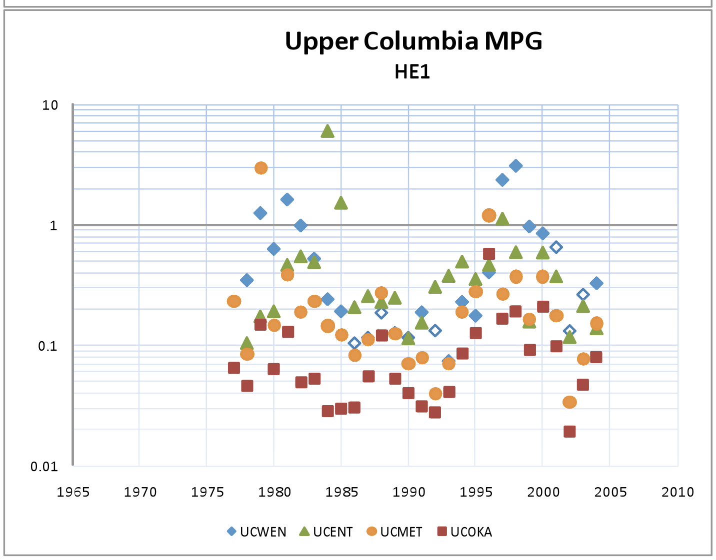


Figure 20 -- Return per spawner estimates for Upper Columbia River steelhead populations. Upper) hatchery effectiveness = 1.0. Lower) hatchery effectiveness =0.30. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.

Annual spawning escapement estimates for Upper Columbia Steelhead populations are available going back to the late 1970's (Figure 19). The long-term trends in natural origin spawners are positive, ranging from an annualized average of 3% per year for the Okanogan River r to 8% per year for the Methow River population (Table 14). The long term population growth rate (lambda) estimates are substantially affected by assumptions regarding the fitness of hatchery fish. If it is assumed that hatchery origin fish are contributing to brood year natural production at the same rate as natural origin parent spawners, the theoretical long term growth rate is strongly negative across all populations. Long term population growth rate estimates calculated under the assumption that hatchery fish are not contributing to observed natural production represent an index of trends in brood year natural production. Population level estimates under this assumption are positive for all populations and are similar to trends in total spawners.

Table 14. Long term trends in natural origin spawning abundance for Upper Columbia Steelhead populations.

Population	Years	Trend in natural origin Spawners Estimate (CI)	Lambda (HF=0) Estimate (CI)	Prob>1	Lambda(HF=1) Estimate (CI)	Prob>1
Wenatchee	1978 - 2009	1.05 (1.02 - 1.07)	1.07 (0.87 - 1.32)	0.78	0.80 (0.67 - 0.98)	0.02
Entiat	1978 - 2009	1.04 (1.02 - 1.07)	1.05 (0.86 - 1.27)	0.71	0.79 (0.67 - 0.93)	0.007
Methow	1977 - 2009	1.08 (1.05 - 1.12)	1.08 (0.89 - 1.32)	0.82	0.67 (0.59 - 0.77)	0.0003
Okanogan	1977 - 2009	1.03 (1.01 - 1.05)	1.03 (0.86 - 1.23)	0.66	0.56 (0.49 - 0.65)	0.0001

Current Status: Recovery Plan and ICTRT Viability Criteria

All four populations of Upper Columbia steelhead remain rated at high risk after incorporating six additional years of status information into the assessment against ICTRT viability criteria (Table 15, Table 16). The most recent estimates of natural origin abundance (10 year geometric mean) and natural origin productivity at low to moderate parent abundance remain well below minimums defined by the ICTRT viability curves for the DPS. Spawning escapements into natural areas, especially for the Methow and Okanogan populations, continue to show a high proportion of hatchery origin. Productivities, assuming that the hatchery origin and natural origin spawners are contributing to natural production at the same effectiveness, are below replacement even at low to moderate spawning levels for all four populations. Recent geometric mean natural origin abundance and productivity estimates are the highest for the Wenatchee River, the population with the lowest relative proportion of hatchery spawners.

Table 15. Viability assessments for Upper Columbia River steelhead populations. Updated to reflect return years through 2009.

Population	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
	ICTRT Minimum Threshold	*Natural Spawning Abundance*	*ICTRT Productivity*	*Integrated A/P Risk*	*Natural Processes Risk*	*Diversity Risk*	*Integrated SS/D Risk*	
Wenatchee River 2000-2009	**1000**	***795*** (365-1947)	**0.87** (0.44-1.74)	**High**	Low	High	**High**	**HIGH RISK**
1994-2003		*559* (241-1947)	0.84 (0.68-1.39)	*(High)*				
Entiat River 2000-2009	**500**	**112** (52-263)	**0.55** (0.35-0.88)	**High**	Moderate	High	**High**	**HIGH RISK**
1994-2003		79 (31-263)	0.48 (0.3-0.66)	*(High)*				
Methow River 2000-2009	**1000**	**468** (256-703)	**0.32** (0.14-0.72)	**High**	Low	High	**High**	**HIGH RISK**
1994-2003		289 (68-554)	0.28 (0.12-0.81)	*(High)*				
Okanogan River 2000-2009	**750**	**147** (84-212)	**0.15** (0.06-0.35)	**High**	High	High	**High**	**HIGH RISK**
1994-2003		95 (22-181)	0.12 (0.07-0.21)	*(High)*				

With the exception of the Okanogan population, the Upper Columbia populations rated as low risk for spatial structure. The high risk ratings for SS/D are largely driven by chronic high levels of hatchery spawners within natural spawning areas and lack of genetic diversity among the populations. The basic major life history patterns (summer A-run type, tributary and mainstem spawning/rearing patterns, and the presence of resident populations and subpopulations) appear to be present. All of the populations were rated at high risk for current genetic characteristics. Genetics samples taken in the 1980s indicate little differentiation within populations in the Upper Columbia River DPS.

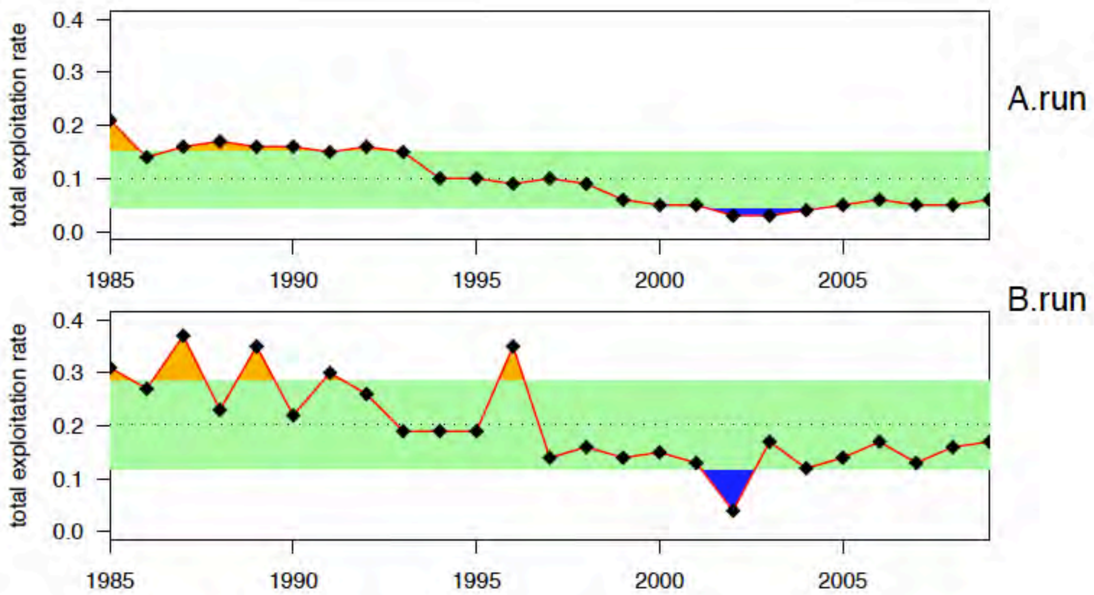
Table 16 - North Cascades MPG steelhead population risk ratings integrated across the four viable salmonid population (VSP) metrics. Viability Key: HV – Highly Viable; V – Viable; M – Maintained; HR –High Risk (does not meet viability criteria).

		Spatial Structure/Diversity Risk			
		Very Low	**Low**	**Moderate**	**High**
Abundance/ Productivity Risk	**Very Low** (<1%)	**HV**	**HV**	**V**	**M**
	Low (1-5%)	**V**	**V**	**V**	**M**
	Moderate (6 – 25%)	**M**	**M**	**M**	**HR**
	High (>25%)	**HR**	**HR**	**HR**	**HR** Wenatchee Entiat Methow Okanogan

Harvest

Summer-run steelhead from the Interior Columbia River Basin are divided into 2 runs by managers: The A-run, and the B-run. These runs are believed have differences in timing, but managers separate them on the basis of size alone in estimating the abundance of each run. The A-run is believed to occur throughout the Middle Columbia, Upper Columbia, and Snake River Basins, while the B-run is believed to occur naturally only in the Snake River ESU, in the Clearwater River, Middle Fork Salmon River, and South Fork Salmon River.

Steelhead were historically taken in tribal and non-tribal gillnet fisheries, and in recreational fisheries in the mainstem Columbia River and in tributaries. In the 1970s, retention of steelhead in non-tribal commercial fisheries was prohibited, and in the mid 1980s, tributary recreational fisheries in Washington adopted mark-selective regulations. Steelhead are still harvested in tribal fisheries, in mainstem recreational fisheries, and there is incidental mortality associated with mark-selective recreation recreational fisheries. The majority of impacts on the summer run occur in tribal gillnet and dip net fisheries targeting Chinook salmon. Because of their larger size, the B-rum fish are more vulnerable to the gillnet gear. Consequently, this component of the summer run experiences higher fishing mortality than the A-run component (Figure 21). In recent years, total exploitation rates on the A-run have been stable at around 5%, while exploitation rates on the B-run have generally been in the range of 15% to 20%.



]
NMFS biological opinion (Peter Dygert, NMFS, personal communication), and for 1999-2008 from TAC run reconstruction (Cindy LeFleur, WDFW personal communication).

Hatchery releases

Hatchery releases of Upper Columbia River steelhead have generally fluctuated between 800,000 and 900,000 yearling smolts since the mid-1990's. (Figure 22). Releases in the Wenatchee River basin have decreased while releases into the Methow and Okanogan drainages have increased over the same period.

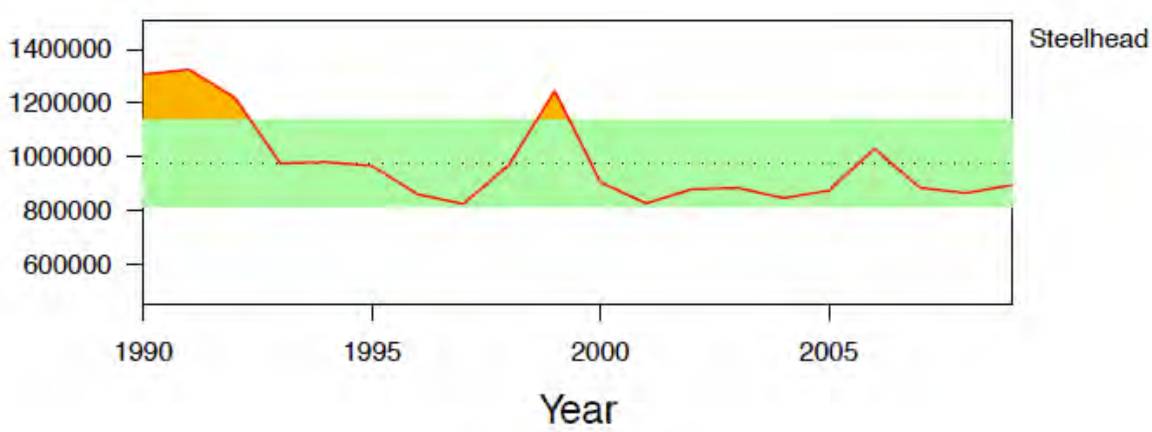


Figure 22 – Trend in hatchery releases of Upper Columbia River steelhead. Source: RMIS.

Upper Columbia Steelhead DPS: Updated Risk Summary
Upper Columbia steelhead populations have increased in natural origin abundance in recent years, but productivity levels remain low. The proportions of hatchery origin returns in natural spawning areas remain extremely high across the DPS, especially in the Methow and Okanogan River populations. The modest improvements in natural returns in recent years are probably primarily the result of several years of relatively good natural survival in the ocean and tributary habitats. Tributary habitat actions called for in the Upper Columbia Recovery Plan are anticipated to be implemented over the next 25 years and the benefits of some of those actions will require some time to be realized. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

ICTRT, 2003. Independent populations of chinook, steelhead and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Interior Columbia Basin Technical Recovery Team Technical Review Draft. July 2003. 171 p.

ICTRT, 2007. Viability criteria for application to interior Columbia Basin salmonid ESUs. Interior Columbia Basin Technical Recovery Team. Technical Review Draft. March 2007. 91 p + appendices and attachments.

ICTRT (2008) Current status reviews: Interior Columbia Basin salmon ESUs and steelhead DPSs. Vol. 2. Upper Columbia River spring Chinook salmon ESU and upper Columbia River steelhead DPS. 167 p.

Hillman,T., M. Miller, J. Miller, M. Tonseth, T. Miller and A. Murdoch. 2010. Monitoring and evaluation of the Chelan County PUD hatchery programs. Rept. to HCP hatchery committee. 237 p. + attachments

Upper Columbia Salmon Recovery Board (2007). Upper Columbia spring chinook salmon and steelhead recovery plan. 307 p. http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Interior-Columbia/Upper-Columbia/upload/UC_Plan.pdf

Snake River spring/summer-run Chinook salmon[10]

The Snake River Spring-Summer Chinook salmon ESU includes all naturally spawned populations of spring/summer-run Chinook salmon in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins, as well as fifteen artificial propagation programs. The ESU was first listed under the ESA in 1992, and the listing was reaffirmed in 2005.

Summary of previous BRT conclusions

The 2005 BRT report evaluated the status of Snake River Spring/Summer Chinook using data on returns through 2001, with the majority of BRT risk rating points being assigned to the most likely to be endangered category. The BRT noted that although there were a number of extant spawning aggregations within this ESU, a substantial number of historical spawning populations have been lost. The most serious risk factor for the DPS was low natural productivity (spawner to spawner return rates) and the associated decline in abundance to extremely low levels relative to historical returns. Large increases in escapement estimates for many (but not all) areas for the 2001 return year were considered encouraging by the BRT. However the BRT also acknowledged that return levels are highly variable and that abundance should be measured over at least an 8 year period and that by this measure recent abundance levels across the ESU fall short of interim objectives. The BRT was concerned about the high level of production/mitigation and supplementation hatchery programs across the ESU, noting that these programs represent ongoing risks to natural populations and can make it difficult to assess trends in natural productivity and growth rates. The phasing out of the non-native Rapid River-origin hatchery program in the Grande Ronde Basin was viewed as a positive action.

Brief Review Recovery Planning

The ICTRT identified 27 extant and 4 extirpated populations of Snake River Spring/Summer Chinook that historically used the accessible tributary and upper mainstem habitats within the Snake River drainages (ICTRT, 2003). The populations are aggregated into five extant Major Population Groupings (MPGs) based on genetic, environmental and life history characteristics. The Lower Snake River MPG includes the Tucannon River and Asotin Creek (extirpated) populations. The Grande Ronde/Imnaha River MPG includes six populations within the Grande Ronde River drainage and two in the Imnaha River. Three populations within the South Fork Salmon River drainage and a fourth in the Little Salmon River form an additional MPG. Chamberlain Creek along with six populations in the Middle Fork drainage constitute the next upstream MPG. The Upper Salmon River MPG includes several major tributary populations along with two mainstem sections also classified as independent populations.

NOAA Fisheries has initiated recovery planning for the Snake River drainage, organized around a subset of management unit plans corresponding to State boundaries. A tributary recovery plan for one of the major management units, the Lower Snake River tributaries within Washington state boundaries, was developed under the auspices of the Lower Snake River Recovery Board and was accepted by NOAA Fisheries in 2005. The LSRB Plan provides recovery criteria, targets and tributary habitat action plans for the two populations of Spring/Summer Chinook in the Lower Snake MPG in addition to the Touchet

[10] Section author: Tom Cooney

River (Mid-Columbia Steelhead DPS) and the Washington sections of the Grande Ronde River. Planning efforts are underway for the Oregon and Idaho drainages. Viability criteria recommended by the ICTRT are being used in formulating recovery objectives within each of the management unit planning efforts.

TRT and Recovery Plan Criteria

The recovery plans being synthesized and developed by NOAA Fisheries will incorporate viability criteria recommended by the ICTRT (ICTRT, 2007). The ICTRT recovery criteria are hierarchical in nature, with ESU/DPS level criteria being based on the status of natural origin Chinook salmon assessed at the population level. A detailed description of the ICTRT viability criteria and their derivation (ICTRT, 2007) can be found at www.nwfsc.noaa.gov/trt/col/trt_viability.cfm. Under the ICTRT approach, population level assessments are based on a set of metrics designed to evaluate risk across the four viable salmonid population (VSP) elements – abundance, productivity, spatial structure and diversity (McElany et al. 2000). The ICTRT approach calls for comparing estimates of current natural origin abundance (measured as a 10 year geometric mean of natural origin spawners) and productivity (estimate of return per spawner at low to moderate parent spawning abundance) against predefined viability curves. In addition, the ICTRT developed a set of specific criteria (metrics and example risk thresholds) for assessing the spatial structure and diversity risks based on current information representing each specific population. The ICTRT viability criteria are generally expressed relative to particular risk threshold - low risk is defined as less than a 5% risk of extinction over a 100 year period and very low risk as less than a 1% probability over the same time period.

<u>Snake River Spring/Summer Chinook: ICTRT Example Recovery Scenarios</u>

The ICTRT recommends that each extant MPG should include viable populations totaling at least half of the populations historically present, with all major life history groups represented. In addition, the viable populations within an MPG should include proportional representation of large and very large populations historically present. Within any particular MPG, there may be several specific combinations of populations that could satisfy the ICTRT criteria. The ICTRT identified example scenarios that would satisfy the criteria for all extant MPGs (ICTRT, 2007; Attachment 2). In each case the remaining populations in an MPG should be at or above maintained status.

Lower Snake River MPG: This MPG contained two populations historically, Asotin Creek is currently considered extirpated. The ICTRT basic criteria would call for both populations being restored to viable status. The ICTRT recommended that recovery planners should give priority to restoring the Tucannon River to highly viable status, evaluating the potential for reintroducing production in Asotin Creek as recovery planning progresses.

Grande Ronde MPG: Eight historical populations (two currently considered functionally extirpated). The basic ICTRT criteria call for a minimum of 4 populations at viable or highly viable status. The potential scenario identified by the ICTRT would include viable populations in the Imnaha River (run timing), the Lostine/Wallowa River (large size) and at least one from each of the following pairs: Catherine Creek or Upper Grande Ronde (large size populations); and Minam River or Wenaha River.

South Fork MPG: Two of the four historical populations in this MPG should be restored to viable or highly viable status. The ICTRT recommends that the populations in the South Fork drainages should be given priority relative to meeting MPG viability objectives given the relatively small size and the high level of potential hatchery integration for the Little Salmon River population.

Middle Fork MPG: The ICTRT criteria call for at least five of the nine populations in this MPG to be rated as viable, with at least one demonstrating highly viable status. The ICTRT example recovery scenario included Chamberlain Creek (geographic position), Big Creek (large size category), Bear Valley Creek, Marsh Creek, and either Loon Creek or Camas Creek.

Upper Salmon MPG: This MPG included nine historical populations one of which, Panther Creek, is considered functionally extirpated. The ICTRT example recovery scenario for this MPG includes the Pahsimeroi River (summer Chinook life history); the Lemhi River and Upper Salmon Mainstem (very large size category); East Fork Salmon River (large size category) and Valley Creek.

New Data and Updated Analyses

The previous BRT review (Good et al., 2005) analyzed abundance data series compiled for a set of index areas distributed across the ESU. Those data series generally covered the period beginning in the early 1960's and ending with the 2001 return year. The ICTRT coordinated the development of representative time series for most populations in this ESU using expansions from index area redd counts and weir estimates (ICTRT, 2010). The current ICTRT data series extend the time period of record through at least the 2008 return year for populations across all of the MPGs in the Spring/Summer Chinook ESU (Figure 23 - Figure 29).

<u>Standard abundance and trends</u>

Estimates of natural origin abundance for the most recent five-year brood cycle are available for 24 populations in the Snake River Spring/Summer Chinook ESU (Table 17). Relative to the previous BRT assessment, escapements are higher by more than 25% for 13 populations, lower by more than 25% for 6 populations and within 25% for 5 populations. The Middle Fork and the Upper Salmon MPGs have the most populations with relatively large increases although each also has a population that decreased by more than 50%. The majority of populations in the South Fork and the Lower Grande Ronde MPG were within +/- 25% of the geometric mean abundance estimates (1997-2001) reported in the 2005 BRT report.

Short-term population trends in total spawner abundance were generally positive over the period 1995 to 2008, with some differences in magnitude for populations within different MPGs (Figure 23 - Figure 29). Trends for most populations in the Middle Fork and Upper Salmon MPGS are strongly positive. Two populations in the Middle Fork MPG (Marsh Creek and Loon Creek) along with one (Lemhi River) in the Upper Salmon MPG had relatively flat trends in total abundance since 1995. Short-term trends in total abundance for the South Fork MPG were also positive but at lower levels than in the Middle Fork and Upper Salmon MPGs, with the exception of the relatively strong trend in the East Fork South Fork population (Figure 25). In the Grande Ronde MPG, three of the populations exhibited moderately positive trends, the remaining three had relatively flat or slightly negative trajectories in total spawning abundance since 1995. The single extant population in the Lower Snake MPG, the Tucannon River, had a strongly positive trend. Relative to the short-term trends corresponding to the time periods analyzed by the 2005 BRT, updated trends are higher for a majority of the populations. For three populations (Catherine

Creek, Imnaha River and Lemhi River), the most recent short-term trends were slightly positive but are substantially below the prior estimates.

The generally positive short term trend indices are largely driven by a common temporal pattern in the spawning abundance estimates across populations in this ESU. The starting point for the current short term trend index is 1995, which corresponds to an extreme low in returns within almost all of the individual population series. Those low returns were the result of extremely low survivals for production from the 1990-1991 brood years (Figure 30). The series also include relatively high abundance estimates in 2001-2003, reflecting the above average survivals for production from spawning in the late 1990s (Figure 30). Spawning escapements in the most recent years in each series are generally well below the peak returns but above the extreme low levels in the mid-1990s.

Relatively long time series of annual spawning abundance are available for most extant Snake River Spring/Summer Chinook populations (Appendix A). Recent return levels are consistently lower than returns in the early years across all series. When expressed as an average annual rate for each population, the decline in spawning escapements averages from 3% to 13% per year.

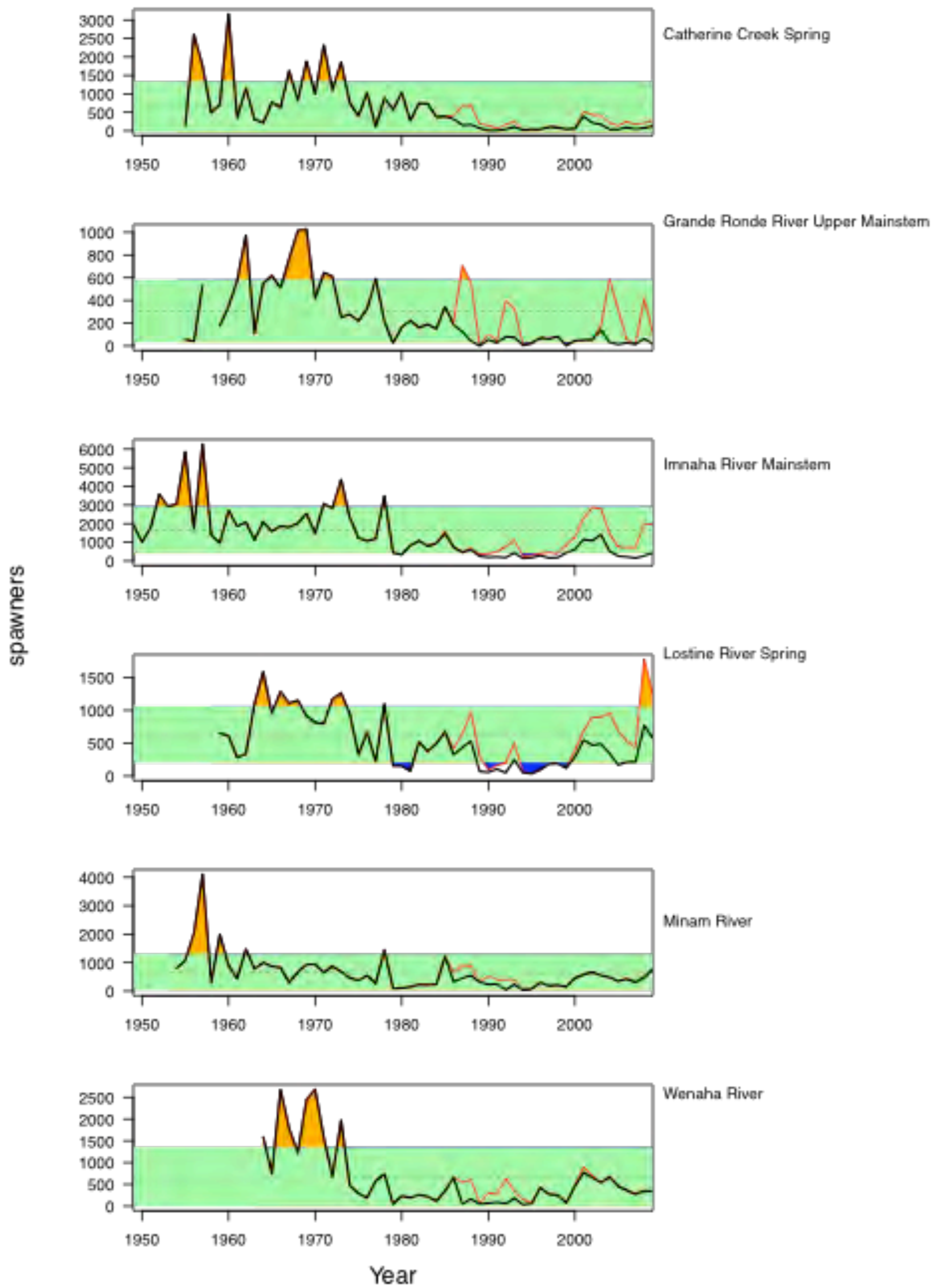


Figure 23 -- Spawning abundance for the Grande Ronde/Imana Major Population Group in the Snake River spring/summer Chinook ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

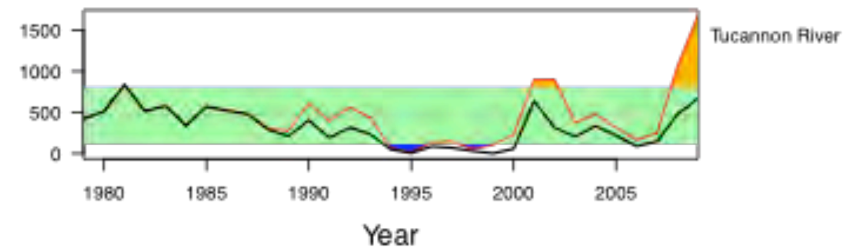


Figure 24 -- Spawning abundance for the Lower Snake Major Population Group in the Snake River spring/summer Chinook ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

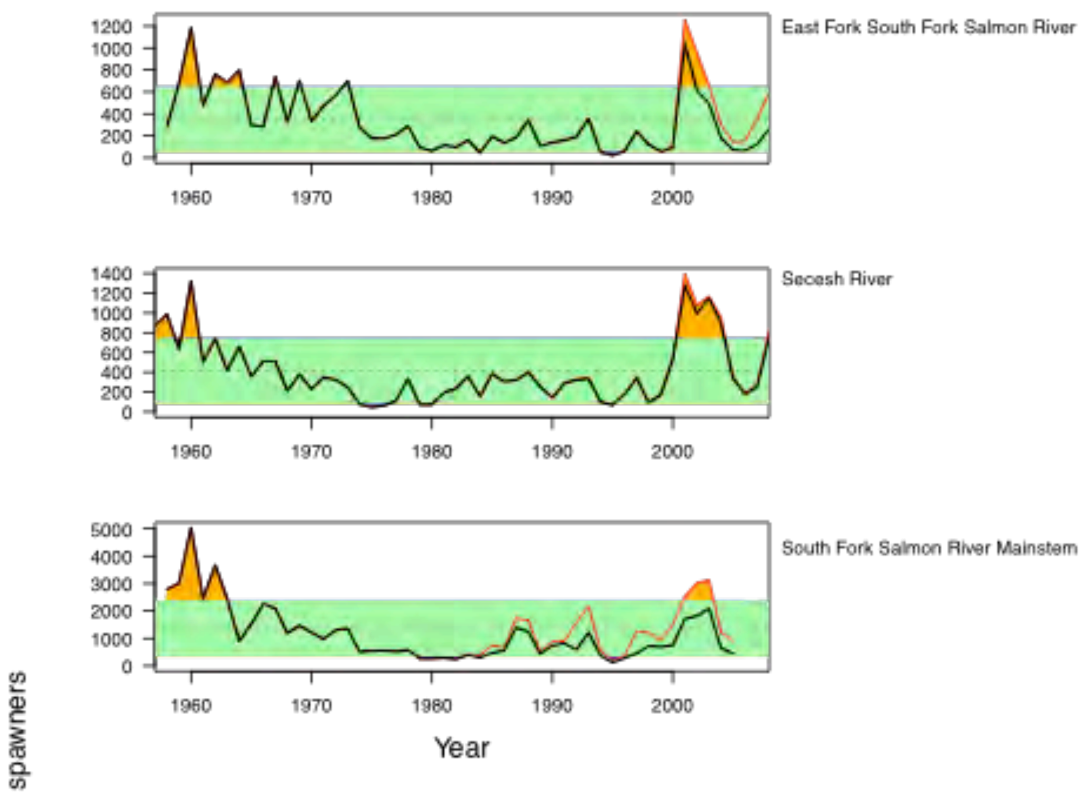


Figure 25 -- Spawning abundance for the South Fork Salmon Major Population Group in the Snake River spring/summer Chinook ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

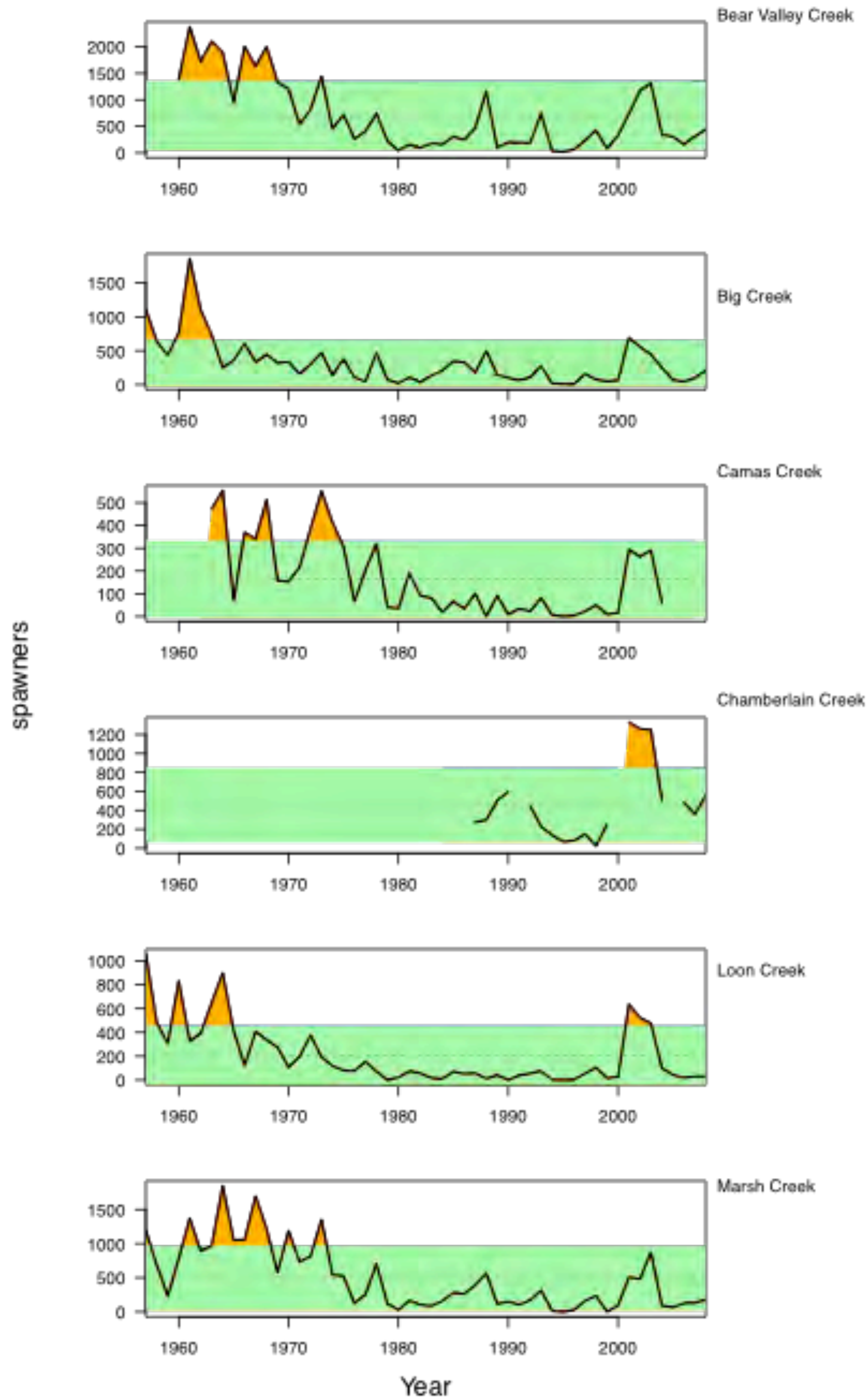


Figure 26 -- Spawning abundance for the Middle Fork Salmon River Population Group in the Snake River spring/summer Chinook ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

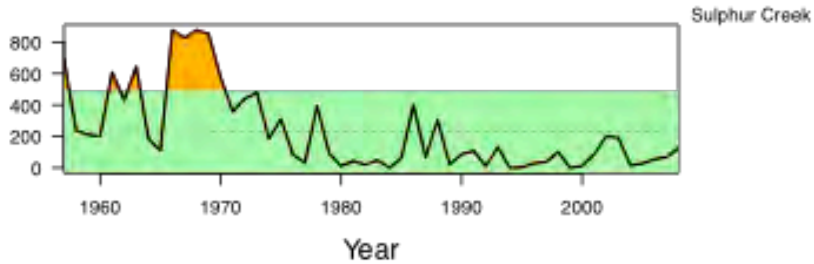


Figure 27 -- Spawning abundance for the Middle Fork Salmon River (cont.) Major Population Group in the Snake River spring/summer Chinook ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

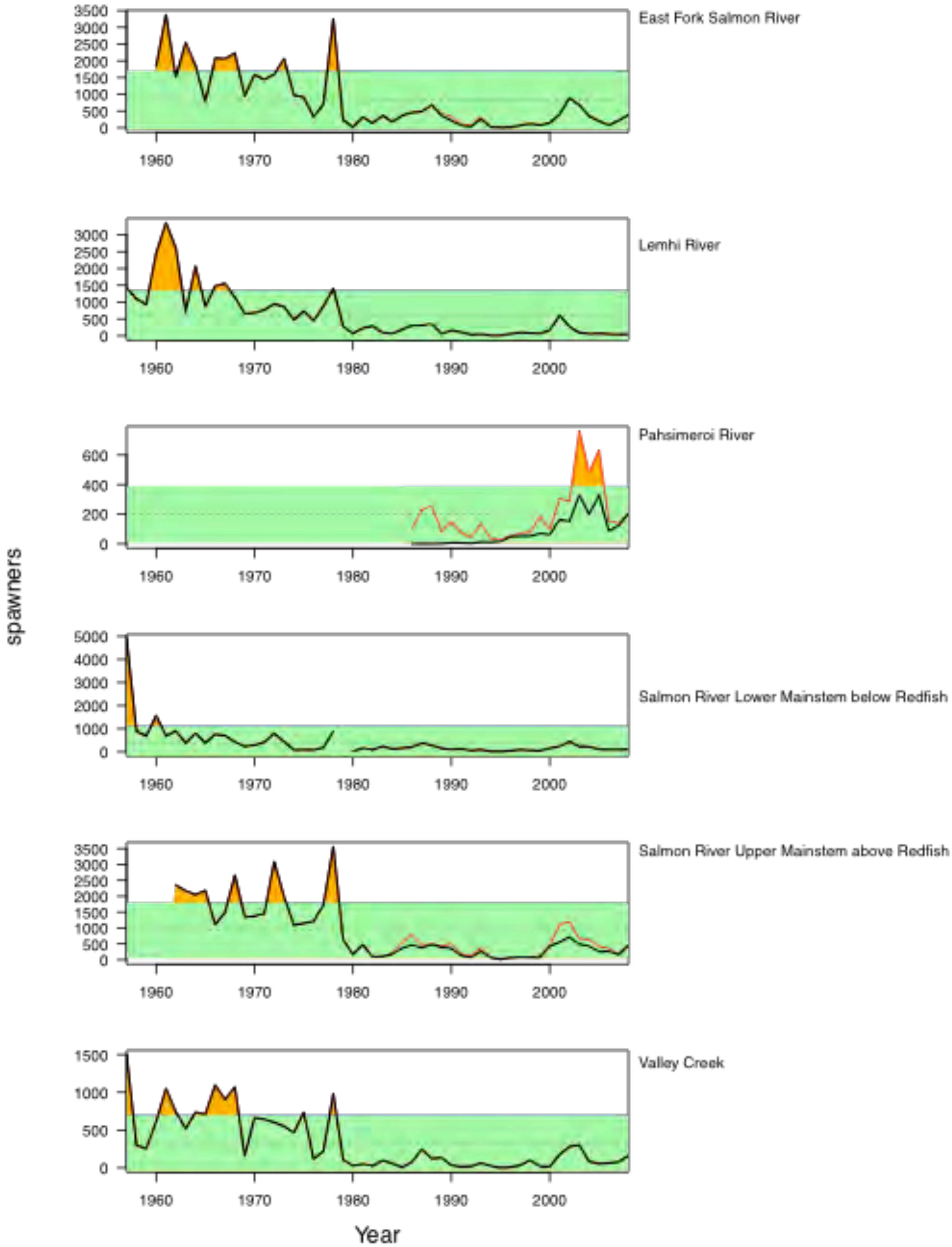


Figure 28 -- Spawning abundance for the Upper Salmon River Major Population Group in the Snake River spring/summer Chinook ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

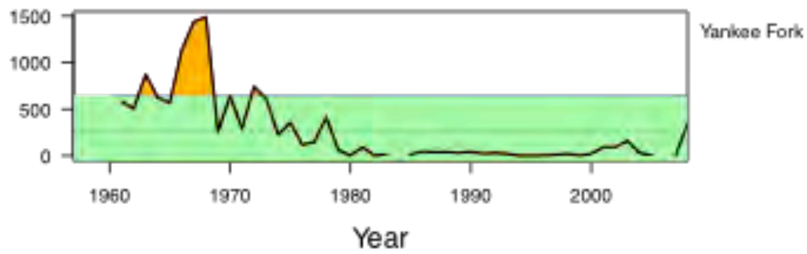


Figure 29 -- Spawning abundance for the Upper Salmon River (cont.) Major Population Group in the Snake River spring/summer Chinook ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

Figure 30 -- Snake River Spring-Summer Chinook. Population recruit per spawner estimates organized by MPG. Recruits expressed as returns to tributary spawning areas. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.

Table 17. Recent (five year geometric mean) estimates of total and natural origin spawning escapement for Snake River spring/summer chinook populations, organized by MPG. Estimates for all periods based on most current population level data sets. These estimates were not available at the time of listing or for the 2005 BRT reviews.

Population (organized by major population group)	Natural Spawning Areas								
	Total Spawners (5 year geometric mean, *range*)			Natural Origin (5 year geometric mean)			% Natural Origin (5 year average)		
	Listing (1992-1996)	*Prior (1997-2001)*	Current (2005-2009)	*Listing (1992-1996)*	*Prior (1997-2001)*	Current (2005-2009)	*Listing (1992-1996)*	*Prior (1997-2001)*	Current (2005-2009)
Lower Snake River									
Tucannon	120	176 (51–894)	469 (161–1676)	66	68 (5-672)	276 (116-682)	56%	40%	53%
Grande Ronde/Imnaha									
Wenaha	260	303 (84-899)	364 (293-478)	93	274 (69-756)	325 (270-430)	49%	92%	95%
Lostine/Wallowa	118	265 (132-689)	812 (443-1778)	73	218 (120-541)	267 (131-668)	70%	88%	41%
Minam	180	277 (149-608)	460 (313-765)	88	262 (142-547)	414 (301-697)	63%	97%	95%
Catherine Creek	69	103 (43-512)	205 (143-275)	38	95 (43-382)	80 (42-122)	63%	95%	34%
Upper Grande Ronde	76	34 (4-83)	109 (17-419)	33	33 (4-83)	19 (13-43)	55%	100%	33%
Imnaha	482	855 (387-2282)	1094 (727-1996)	225	347 (158-1119)	196 (127-281)	50%	46%	25%
South Fork									
Secesh	171	341 (101-1395)	428 (191-956)	166	308 (86-1228)	362 (162-811)	97%	96%	93%
EF/Johnson Cr	87	186 (55-1257)	266 (141-589)	84	146 (45-1018)	113 (63-244)	97%	93%	46%
SF Mainstem	689	1399 (926-2529)	1046 (901-1231)	392	712 (453-1644)	443 (374-585)	58%	58%	47%
Middle Fork									
Bear Valley	86	285 (78-739)	295 (158-440)	86	274 (73-733)	274 (152-408)	100%	100%	100%
Marsh Creek	27	67 (1-507)	115 (67-182)	27	69 (0- 497)	105 (61-165)	100%	100%	100%
Sulphur Creek	9	20 (0-102)	45 (15-126)	9	20 (0-102)	43 (14-118)	100%	100%	100%
Loon Creek	7	67 (15-635)	37 (19–100)	7	65 (14–611)	34 (18–94)	100%	100%	100%
Camas Creek	7	34 (9-294)	89 (41-291)	7	33 (9-282)	83 (39-263)	100%	100%	100%
Big Creek	29	121 (49–690)	109 (44–248)	29	117 (46–662)	101 (42–233)	100%	100%	100%
Chamberlain Cr	150	184 (23-1329)	471 (360–558)	150	179 (23-1308)	437 (321-517)	100%	100%	100%
Upper Salmon									
Lower Salmon Mainstem	32	97 (44-231)	118 (94-221)	32	82 (37-195)	100 (79-186)	100%	100%	100%
Lemhi River	25	141 (69–607)	53 (38–74)	25	139 (69–582)	53 (38–73)	100%	100%	100%
Pahsimeroi River	49	126 (72-306)	266 (139-633)	11	96 (72–233)	156 (80-316)	39%	58%	68%
Upper Salmon Mainstem	82	214 (83-1108)	380 (187-638)	67	203 (98-567)	263 (152-408)	83%	78%	79%
East Fork Salmon	43	137 (79-402)	214 (77-385)	26	114 (60-354)	188 (68-339	61%	95%	100%
Valley Creek	12	43 (14–177)	81 (54–163)	12	42 (13-171)	79 (53–158)	100%	100%	100%
Yankee Fork	6	15 (2-95)	24 (4-341)	6	14 (2-90)	23 (4-324)	100%	100%	100%

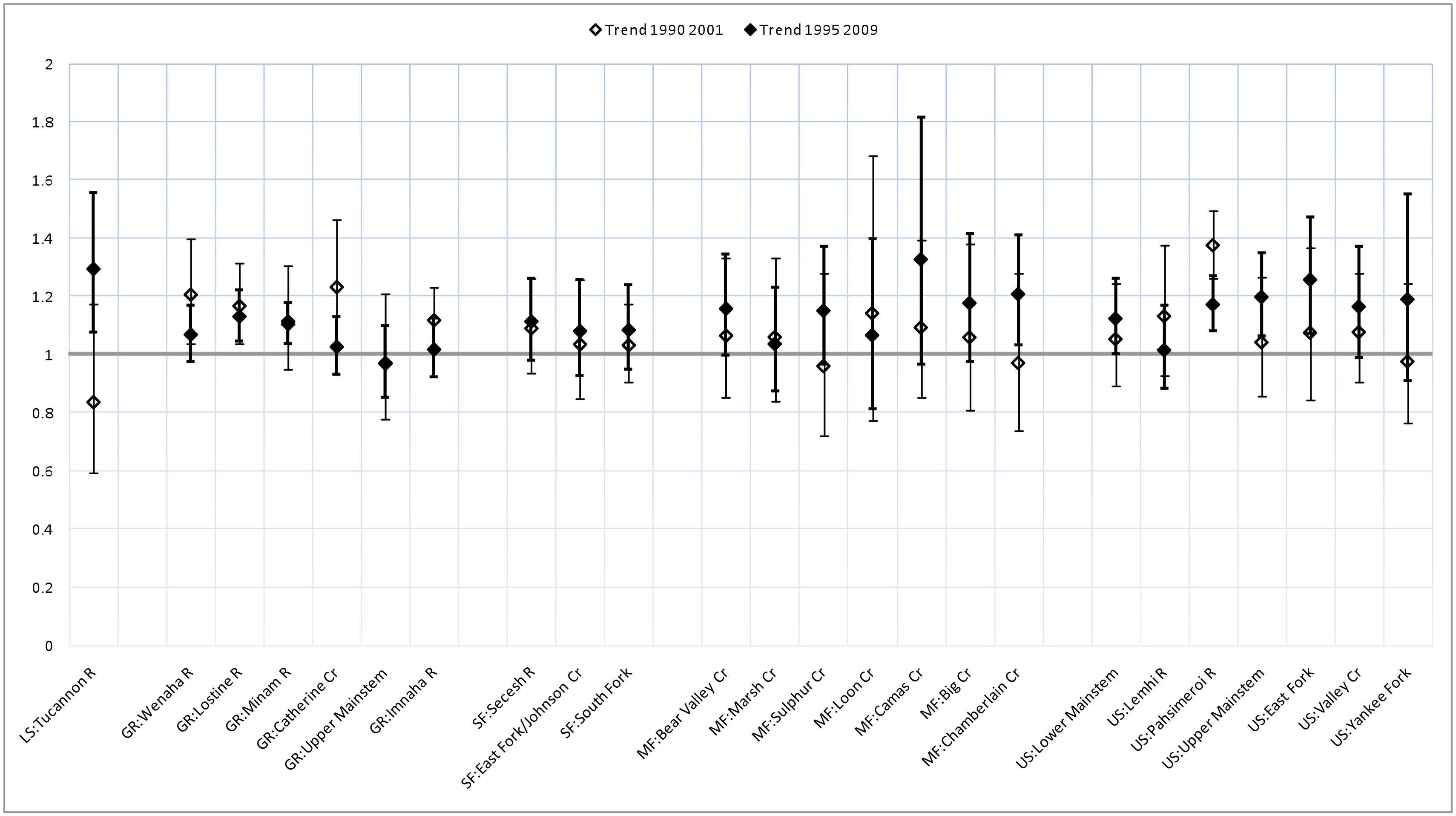


Figure 31 -- Short term trend in natural origin spawning abundance exp (slope of ln(natural origin spawners) vs. year) for Snake River Spring/Summer Chinook salmon populations. Solid diamond/bar: point estimate and 95% cf for 1995-2009. Open diamond/bar: equivalent statistics for prior review.

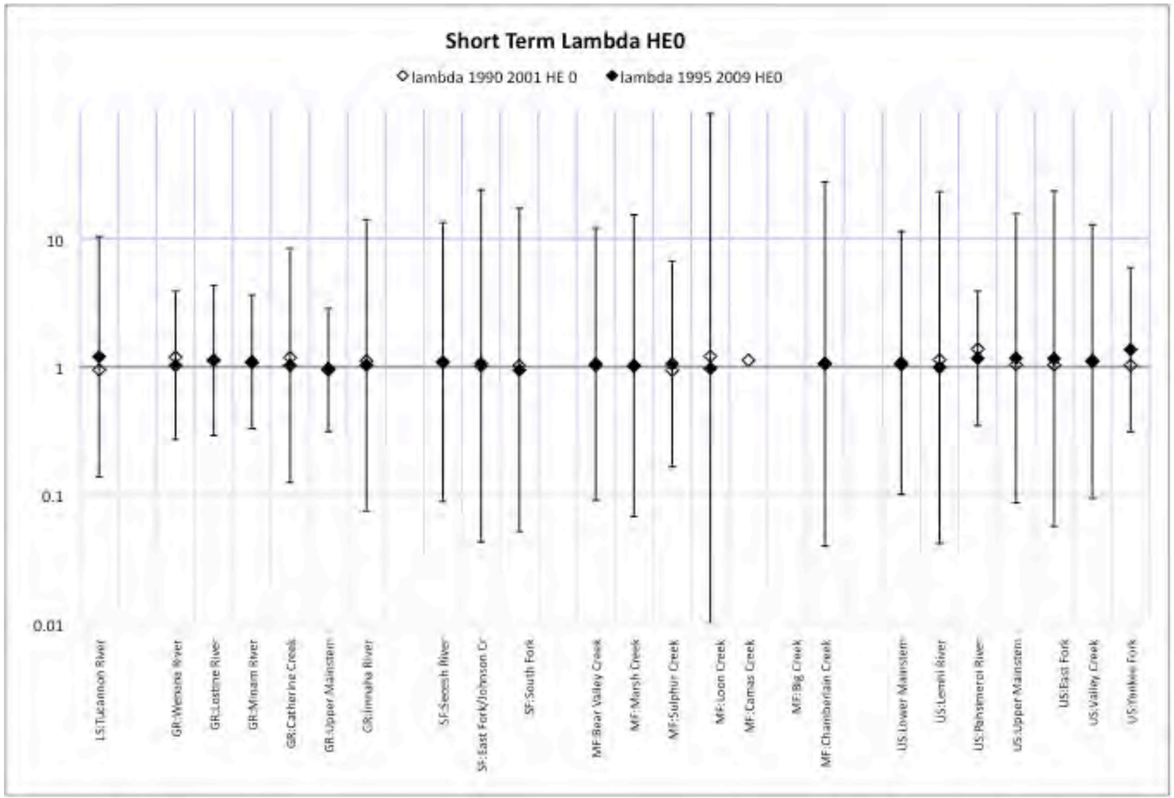


Figure 32 -- Short term population growth rate (lambda) estimates for Snake River Spring/Summer chinook populations. Relative hatchery effectiveness set to 0.0. Solid diamond/bar: point estimate and 95% cf for 1995-2009. Open diamond/bar: equivalent statistics for prior review.

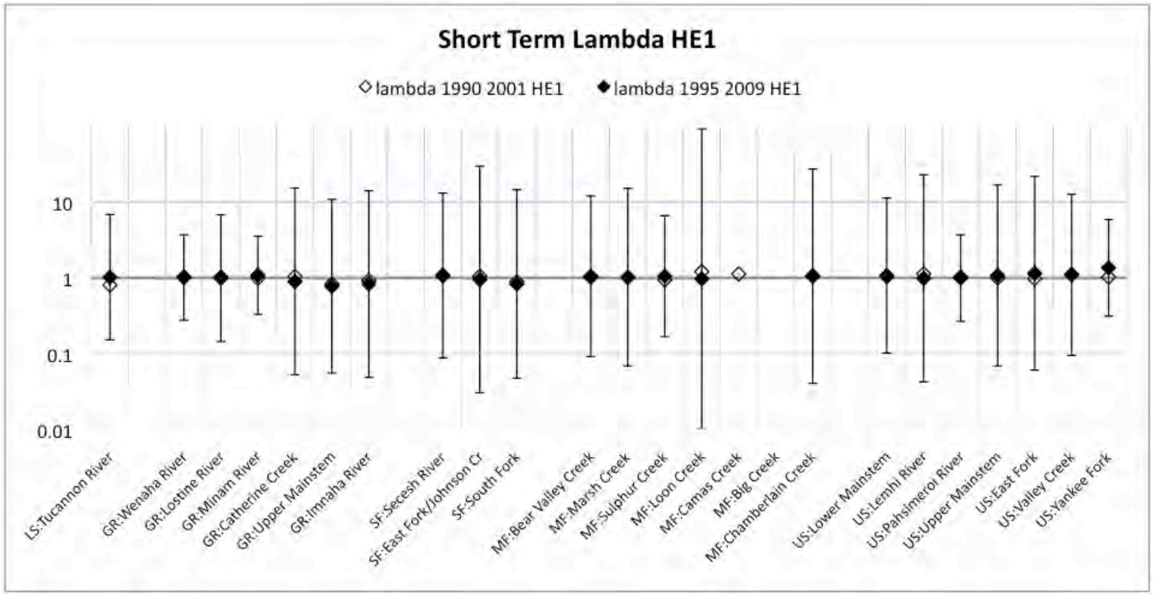


Figure 33 -- Short term population growth rate (lambda) estimates for Snake River Spring/Summer chinook populations. Relative hatchery effectiveness set to 0.0. Solid diamond/bar: point estimate and 95% cf for 1995-2009. Open diamond/bar: equivalent statistics for prior review.

Current Status: ICTRT Viability Criteria

The overall viability ratings for all of the populations in the Snake River Spring/Summer Chinook ESU remain at High Risk after the addition of more recent year abundance and productivity data. Under the approach recommended by the ICTRT, the overall rating for an ESU depends upon population level ratings organized by MPG within that ESU. The following brief summaries describe the current status of populations within each of the extant MPGs in the ESU, contrasting the current ratings with assessments previously done by the ICTRT using data through the 2003 return year.

*Lower Snake River MPG (*Table 18*)*: Abundance and productivity remain the major concern for the Tucannon River population. Natural spawning abundance (10 year geometric mean) has increased but remains well below the minimum abundance threshold for the single extant population in this MPG. Poor natural productivity continues to be a major concern.

*Grande Ronde MPG (*Table 19*)*: The Wenaha River, Lostine/Wallowa River and Minam River populations showed substantial increases in natural abundance relative to the previous ICTRT review, although each remains below their respective minimum abundance thresholds. Geometric mean productivity estimates remain relatively low for all populations in the MPG. The Upper Grande Ronde population is rated at high risk for spatial structure and diversity while the remaining populations are rated at moderate.

*South Fork MPG (*Table 20*)*: Natural spawning abundance (10 year geometric mean) estimates increased for the three populations with available data series. Productivity estimates for these populations are generally higher than estimates for populations in other MPGs within the ESU. Viability ratings based on the combined estimates of abundance and productivity remain at high risk, although the survival/capacity gaps relative to moderate and low risk viability curves are smaller than for other ESU populations. Spatial structure/diversity risks are currently rated moderate for the South Fork mainstem population (relatively high proportion of hatchery spawners) and low for the Secesh River and East Fork South Fork populations.

*Middle Fork Salmon MPG (*Table 21*)*: Natural origin abundance and productivity remains extremely low for populations within this MPG. As in the previous ICTRT assessment, abundance and productivity estimates for Bear Valley Creek and Chamberlain Creek (limited data series) are the closest to meeting viability minimums among populations in the MPG. Spatial structure/diversity risk ratings for Middle Fork populations are generally moderate, largely driven by moderate ratings for genetic structure assigned by the ICTRT because of uncertainty arising from the lack of direct samples from within the component populations.

*Upper Salmon River MPG (*Table 22*)*: Abundance and productivity estimates for most populations within this MPG remain at very low levels relative to viability objectives. The Upper Salmon mainstem has the highest relative abundance and productivity combination of populations within the MPG. Spatial structure/diversity risk (SS/D) ratings vary considerably across the MPG. Four of the eight populations are rated at low or moderate risk for overall spatial structure and diversity and could achieve viable status with improvements in average abundance/productivity. The high SS/D risk rating for the Lemhi population is driven by a substantial loss of access to tributary spawning/rearing habitats and the associated reduction in life history diversity. High SS/D ratings for Pahsimeroi River, East Fork Upper Salmon and Yankee Fork are driven by a combination of habitat loss and diversity concerns related to low natural abundance combined with chronically high proportions of hatchery spawners in natural areas.

Table 18. Lower Snake River MPG. Summary of current population status vs. ICTRT viability criteria

Lower Snake River MPG	**Abundance/Productivity Metrics**				**Spatial Structure and Diversity Metrics**			**Overall Viability Rating**
Population	***ICTRT Minimum Threshold***	***Natural Spawning Abundance***	***ICTRT Productivity***	***Integrated A/P Risk***	***Natural Processes Risk***	***Diversity Risk***	***Integrated SS/D Risk***	
Tucannon 2000-2009	**750**	**269** (58-682)	**0.74** (0.52-1.06)	**High**	Low	Moderate	**Moderate**	**HIGH RISK**
1995-2004		*182* (11-897)	0.69 (0.48-0.98)	**High**				

Table 19. Grande Ronde/Imnaha MPG. Summary of current population status vs. ICTRT viability criteria

Grande Ronde/Imnaha MPG	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
Population	*ICTRT Minimum Threshold*	*Natural Spawning Abundance*	*ICTRT Productivity*	*Integrated A/P Risk*	*Natural Processes Risk*	*Diversity Risk*	*Integrated SS/D Risk*	
Wenaha 2000-2009 1995-2004	**750**	**441** (270-756) *306* (51-756)	**0.72** (0.5-1.06) *0.68* (0.5-0.94)	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**
Lostine/Wallowa 2000-2009 1995-2004	**1000**	**320** (120-668) *198* (33-541)	**0.77** (0.52-1.14) *0.85* (0.58-1.26)	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**
Minam 2000-2009 1995-2004	**750**	**467** (301-697) *287* (62-651)	**0.86** (0.62-1.2) *1.07* (0.74-1.55)	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**
Catherine Creek 2000-2009 1995-2004	**750**	**107** (42-382) *87* (34-382)	**0.71** (0.49-1.03) *0.73* (0.47-1.14)	**High** **High**	Moderate	Moderate	**Moderate**	**HIGH RISK**
Upper Grande Ronde 2000-2009 1995-2004	**1000**	**32** (13-140) *40* (4-140)	**0.42** (0.26-0.68) *0.42* (0.27-0.68)	**High** **High**	High	Moderate	**High**	**HIGH RISK**
Imnaha River 2000-2009 1995-2004	**750**	**388** (127-1342) *378* (74-1342)	**0.90** (0.74-1.13) *0.0.95* (0.77-1.16)	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**

Table 20. South Fork Salmon MPG. Summary of current population status vs. ICTRT viability criteria

South Fork MPG	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
Population	*ICTRT Minimum Threshold*	*Natural Spawning Abundance*	*ICTRT Productivity*	*Integrated A/P Risk*	*Natural Processes Risk*	*Diversity Risk*	*Integrated SS/D Risk*	
Secesh River 2000-2009	**750**	**472** (162-1228)	**1.25** (0.96-1.64)	**High**	Low	Low	**Low**	**HIGH RISK**
1995-2004		*342* (59-1228)	*1.23* (0.97-1.55)	**High**				
EF/Johnson Cr 2000-2009	**1000**	**162** (52-1018)	**1.15** (0.87-1.52)	**High**	Low	Low	**Low**	**HIGH RISK**
1995-2004		*142* (20-1018)	*1.15* (0.91-1.46)	**High**				
South Fork Main 2000-2009	**1000**	**791** (374-1873)	**1.21** (0.67-2.2)	**High**	Low	Moderate	**Moderate**	**HIGH RISK**
1995-2004		*630* (112-1873)	*1.25* (0.85-1.83)	**High**				
Little Salmon River		**Insufficient data**	**Insufficient data**	**Insufficient data**	Low	Low	**Low**	**HIGH RISK**

Table 21. Middle Fork Salmon MPG. Summary of current population status vs. ICTRT viability criteria

Middle Fork Salmon MPG	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
Population	*ICTRT Minimum Threshold*	*Natural Spawning Abundance*	*ICTRT Productivity*	*Integrated A/P Risk*	*Natural Processes Risk*	*Diversity Risk*	*Integrated SS/D Risk*	
Chamberlain Cr 2000-2009 1995-2004	**500**	**605** (239-1308) *249* (23-1308)	**1.79** (0.38-8.44) *1.77* (0.64-4.94)	**High** **High**	Low	Low	**Low**	**HIGH RISK**
Big Creek 2000-2009 1995-2004	**1000**	**146** (42-662) *93* (5-662)	**0.80** (0.57-1.12) *1.17* (0.83-1.66)	**High** **High**	Very Low	Moderate	**Moderate**	**HIGH RISK**
Lower Middle Fork Salmon 2000-2009 1995-2004	**500**	Insufficient data	Insufficient data	**High** **High**	Moderate	Moderate	**Moderate**	**HIGH RISK**
Camas Creek 2000-2009 1995-2004	**500**	**30** (9-282) *30* (0-282)	**0.74** (0.38-1.29) *0.74* (0.44-1.25)	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**
Loon Creek 2000-2009 1995-2004	**500**	**67** (14-611) *49* (0-611)	**1.19** (0.63-2.25) *1.01* (0.61-1.68)	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**
Upper Middle Fork Salmon 2000-2009 1995-2004	**750**	Insufficient data	Insufficient data	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**
Sulphur Creek 2000-2009 1995-2004	**500**	**37** (0-201) *26* (0-201)	**0.76** (0.48-1.24) *1.10* (0.62-1.97)	**High** **High**	Low	Moderate	**Moderate**	**HIGH RISK**
Bear Valley Creek 2000-2009 1995-2004	**750**	**363** (73-1282) *242* (16-1282)	**1.23** (0.9-1.68) *1.45* (1.08-1.94)	**High** **High**	Very Low	Low	**Low**	**HIGH RISK**
Marsh Creek 2000-2009 1995-2004	**500**	**109** (0-861) *51* (0-861)	**0.79** (0.53-1.19) *1.06* (0.7-1.62)	**High** **High**	Low	Low	**Low**	**HIGH RISK**

Table 22. Upper Salmon MPG. Summary of current population status vs. ICTRT viability criteria

Upper Salmon River MPG	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
Population	*ICTRT Minimum Threshold*	*Natural Spawning Abundance*	*ICTRT Productivity*	*Integrated A/P Risk*	*Natural Processes Risk*	*Diversity Risk*	*Integrated SS/D Risk*	
North Fork 2000-2009	**500**	Insufficient data	Insufficient data	**High**	Low	Low	**Low**	**HIGH RISK**
1995-2004				**High**				
Lemhi River 2000-2009	**2000**	**96** (38-582)	**0.94** (0.59-1.52)	**High**	High	High	**High**	**HIGH RISK**
1995-2004		92 (10-582)	1.13 (0.74-1.73)	**High**				
Pahsimeroi River 2000-2009	**1000**	**154** (80-316)	**0.58** (0.33-1.04)	**High**	Moderate	High	**High**	**HIGH RISK**
1995-2004		91 (11-298)	0.48 (0.25-0.96)	**High**				
Upper Salmon Lower Mainstem 2000-2009	**2000**	**120** (37-378)	**1.16** (0.83-1.61)	**High**	Low	Low	**Low**	**HIGH RISK**
1995-2004		83 (9-378)	1.28 (0.93-1.76)	**High**				
East Fork Salmon River 2000-2009	**1000**	**178** (68-784)	**1.04** (0.66-1.65)	**High**	Low	High	**high**	**HIGH RISK**
1995-2004		104 (6-784)	1.16 (0.66-1.65)	**High**				
Yankee Fork 2000-2009	**500**	**21** (2-324)	**0.80** (0.38-1.68)	**High**	Moderate	High	**High**	**HIGH RISK**
1995-2004		16 (0-153)	1.01 (0.51-2.01)	**High**				
Valley Creek 2000-2009	**500**	**78** (13-292)	**1.21** (0.78-1.91)	**High**	Low	Moderate	**Moderate**	**HIGH RISK**
1995-2004		38 (0-292)	1.21 (0.78-1.89)	**High**				
Upper Salmon Mainstem 2000-2009	**1000**	**313** (98-743)	**1.21** (0.87-1.71)	**High**	Very Low	Moderate	**Moderate**	**HIGH RISK**
1995-2004		181 (9-743)	1.42 (0.95-2.13)	**High**				

Harvest

Harvest impacts on the spring component of this ESU are essentially the same as those on the Upper Columbia River (Figure 17). All harvest occurs in the lower portion of the mainstem Columbia River. Snake River summer Chinook share the ocean distribution patterns of the upper basin spring runs and are only subject to significant harvest in the mainstem Columbia River. Harvest of summer Chinook has been more constrained than that of spring Chinook with consequently lower exploitation rates on the summer component of this ESU. Harvest rates on the aggregate runs of up-river spring and summer Chinook Salmon were generally reduced in the 1970s in response to abrupt declines in returns of naturally produced fish. Annual harvest rates varied around 50% in the 1950s and 1960s (WDFW, 2000).

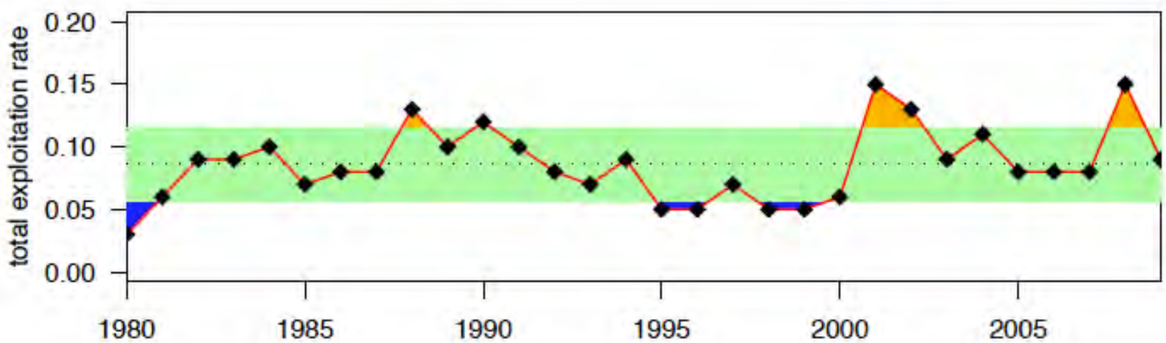


Figure 34 -- Total exploitation rates for Snake River spring/summer Chinook salmon. Data from the Columbia Rive Technical Advisory Team (TAC 2010).

Hatchery releases

Total hatchery releases of spring/summer Chinook in the ESU in recent years have fluctuated around the same level as in the early 1990s. Release levels in the late 1990s were generally lower, largely driven by the transition from Rapid River origin stock in the Grande Ronde River system and shortfalls in broodstock collection in the Upper Salmon River due to low adult return rates (Figure 35). Releases of hatchery steelhead have declined by approximately a third from pre 1995 levels.

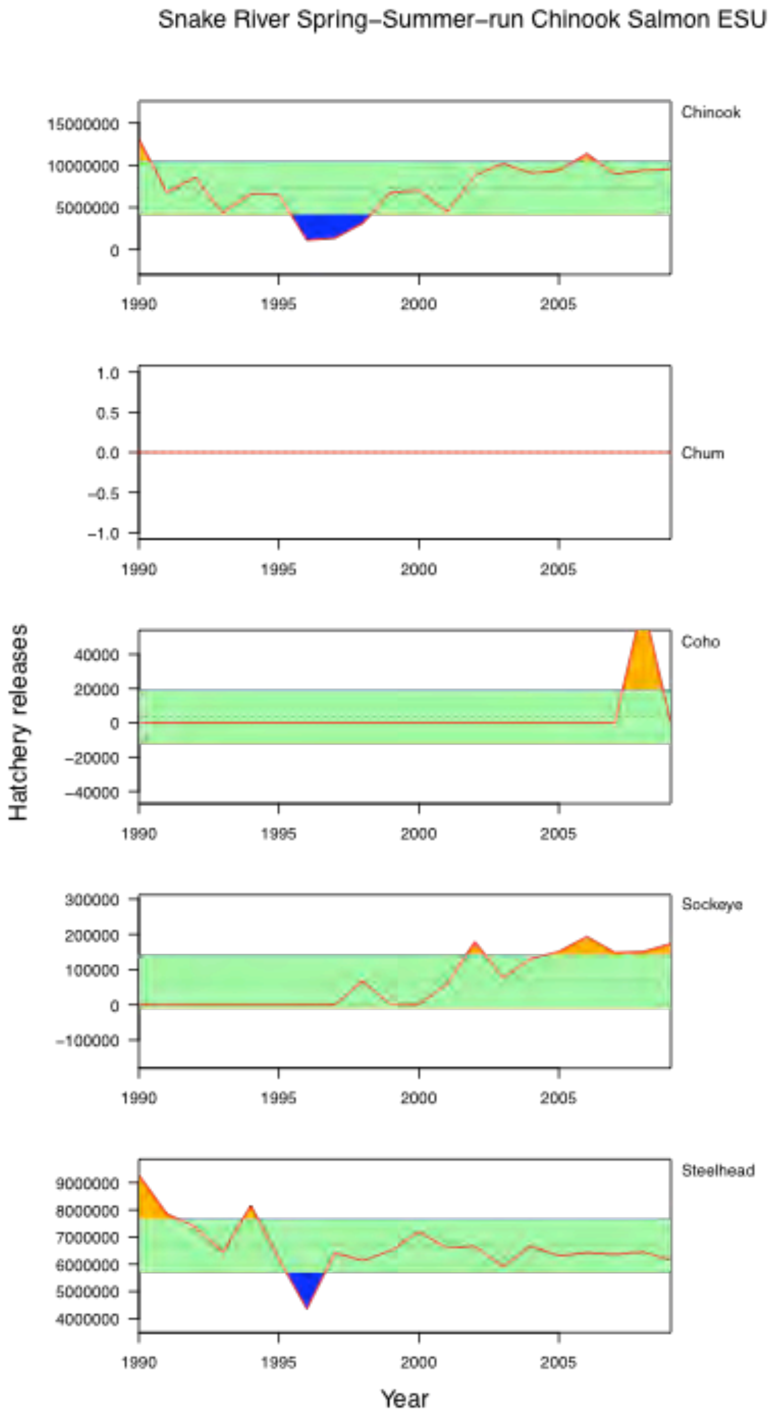


Figure 35 – Trends in hatchery releases within the spawning and rearing areas of the Snake River spring/summer Chinook ESU. Dotted line indicates the mean, and the shaded area the standard deviation. Data source: RMIS.

Snake River Spring/Summer Chinook ESU: Updated Risk Summary

Population level status ratings remain at high risk across all MPGs within the ESU, although recent natural spawning abundance estimates have increased, all populations remain below minimum natural origin abundance thresholds. Relatively low natural production rates and spawning levels below minimum abundance thresholds remain a major concern across the ESU. The ability of populations to be self-sustaining through normal periods of relatively low ocean survival remains uncertain. Factors cited by the 2005 BRT (Good et al. 2005) remain as concerns or key uncertainties for several populations. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good, T.P., R.S. Waples and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

ICTRT, 2003. Independent populations of chinook, steelhead and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Interior Columbia Basin Technical Recovery Team Technical Review Draft. July 2003. 171 p.

ICTRT, 2007. Viability criteria for application to interior Columbia Basin salmonid ESUs. Interior Columbia Basin Technical Recovery Team. Technical Review Draft. March 2007. 91 p + appendices and attachments.

ICTRT (2010) Current status reviews: Interior Columbia Basin salmon ESUs and steelhead DPSs. Vol. 1. Snake River ESUs/DPS. 786 p. + attachments

Washington Department of Fish and Wildlife. 2000. Status report: Columbia River fish runs and fisheries 1938-2000. Washington Dept. of Fish and Wildlife and Oregon Dept. of Fish and Wildlife joint fisheries staff report. 324 p.

Snake River Fall-run Chinook salmon[11]

The Snake River fall Chinook salmon ESU includes fish spawning in the lower mainstem of the Snake River and the lower reaches of several of the associated major tributaries including the Tucannon, the Grande Ronde, Clearwater, Salmon and Imnaha Rivers. This ESU was originally listed under the ESA in 1992 (reaffirmed in 2005: FR 70FR37160). Historically, this ESU included two large additional populations spawning in the mainstem of the Snake River upstream of the Hells Canyon Dam complex. The spawning and rearing habitat associated with the current extant population represents approximately 20% of the total historical habitat available to the ESU (Double, 2000).

Summary of previous BRT conclusions

The most recent BRT review (Good et al., 2005) included an assessment of Snake River Fall Chinook salmon based on data for runs through the 2001 return year. A majority of the rating points assigned by individual BRT members fell into the "likely to become endangered" category (60%). The BRT review noted that "..this outcome represented a somewhat more optimistic assessment of the status of this ESU than was the case at the time of the original status review...". Reasons cited for a more optimistic rating included; the number of natural origin spawners in 2001 was well over 1,000 for first time since 1975, management actions had reduced the number of outside origin stray hatchery fish passing to the spawning grounds, the increasing contribution of native Lyons Ferry fish from supplementation programs and the fact that recent natural origin returns had been fluctuating between 500 and 1,000 spawners – somewhat higher than previous levels. The 2005 BRT status ratings for the Snake River fall Chinook salmon ESU were also influenced by concerns that the geometric mean abundance at the time was below 1,000 ("...a very low number for an entire ESU"), and because of the large fraction of hatchery fish on the spawning grounds. Additional concerns cited by the BRT included the fact that a large portion of historical mainstem habitat is now inaccessible. Some BRT members were concerned about the possibility that a natural historical buffer between Snake River fall chinook and other Columbia River ESUs may have existed and that it has been compromised by hatchery straying.

Brief Review Recovery Planning

NOAA Fisheries is currently drafting a recovery plan for the listed anadromous species in the Snake River basin. The recovery plan will build on management level plans developed for each of the three primary regions in the Snake River basin corresponding to the section of the drainage in the states of Washington, Oregon and Idaho. The management plan covering the Washington section of the Snake basin will be based on an updated version of the Lower Snake River Salmon Recovery Plan provided to NOAA Fisheries in 2005 by the state of Washington.

TRT and Recovery Plan Criteria

The ICTRT developed viability criteria for application to Snake River fall Chinook salmon at the population and ESU levels (ICTRT, 2007). The criteria were based on the same principles as the applications for Interior Basin spring, spring/summer ESUs and steelhead DPSs. At the population level, the ICTRT abundance and productivity criteria are expressed as viability curves. The Lower mainstem population would be considered at low

[11] Section author: Tom Cooney

risk if the combination of abundance (recent 10 year geometric mean natural origin spawners) and productivity (geometric mean spawner to spawner ratios for parent escapements less than 2000 spawners – 75% of the minimum abundance threshold of 3000) exceeds a curve generated by simulation modeling that incorporates observed year-to-year variability in return rates. In any case, the ICTRT criteria for low viability risk stipulate that the 10 year geometric mean natural origin escapement should exceed 3,000, with a minimum of 2,500 natural origin spawners in the mainstem Snake River major spawning areas. Achieving a very low risk rating for abundance and productivity requires exceeding the same natural origin abundance threshold combined with a productivity estimate of 1.5 or higher.

The ICTRT applied the same generic framework in developing population spatial structure and diversity criteria for application to Snake River fall Chinook salmon (ICTRT, 2007). Several of those criteria require a definition of within population structure. The ICTRT described five major spawning areas within the Lower Mainstem population – three mainstem reaches (Salmon River confluence to Hells Canyon Dam site, Lower Granite Dam to the Salmon River confluence and the mainstem off of and including the lower Tucannon River) and two tributary mainstems (lower Grande Ronde River and the Clearwater River). In addition, smaller spawning reaches in the Imnaha River and Salmon River were defined as minor spawning areas.

New Data and Updated Analyses

Annual estimates of spawning escapements for the extant population of Snake River fall Chinook are based on counts and adult sampling at passage over Lower Granite Dam (ref to LFH report). Statistical methods for parsing out components (e.g., natural and hatchery origin fish) have generally improved since the 2005 BRT review. Escapement estimates are now available through the 2008 return year (Figure 36).

<u>Standard abundance and trends</u>

The total spawning escapement into natural areas above Lower Granite Dam has remained relatively high since the rapid increase in the late 1990's. The current five year geometric mean total escapement is above 10,000, substantially greater than the 1997-2001 geometric mean reported in the previous BRT review (Table 23). A relatively high proportion of the estimated spawners are of hatchery origin (78% for the most recent five year cycle). However natural origin returns have also increased substantially over both the geometric mean estimates for the 2005 BRT review and the cycle just prior to the 1997 listing decision.

Table 23 Snake River Fall Chinook. Recent abundance and proportion natural origin compared to estimates at the time of listing and the previous BRT review.

Population	Natural Spawning Areas					
	Total Spawners (5 year geometric mean, *range*)		Natural Origin (5 year geometric mean)		% Natural Origin (5 year average)	
	Prior *(1997-2001)*	Current (2003-2008)	*Prior* *(1997-2001)*	Current (2003-2008)	*Prior* *(1997-2001)*	Current (2003-2008)
Snake River Fall Chinook	*2164* (962-9875)	**11321** (7784-17266)	*1055* (306-5163)	**2291** (1762-2983)	51%	22%

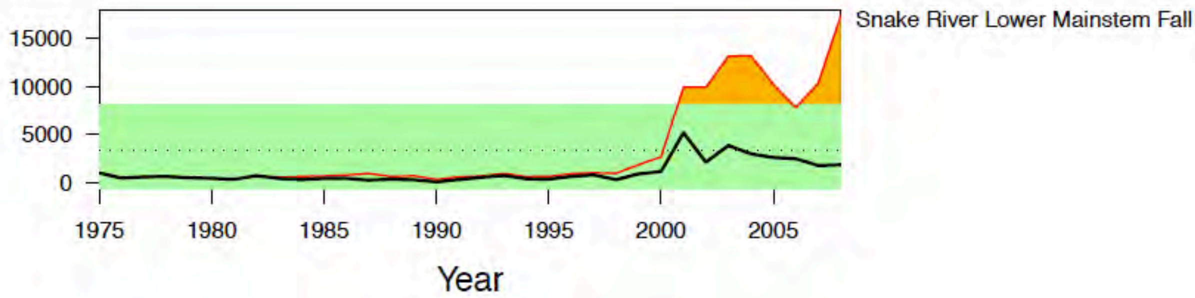


Figure 36 -- Snake River Fall Chinook. Estimated escapement above Lower Granite Dam. Adult run size to Lower Granite Dam minus fish trapped and transferred to hatchery programs. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

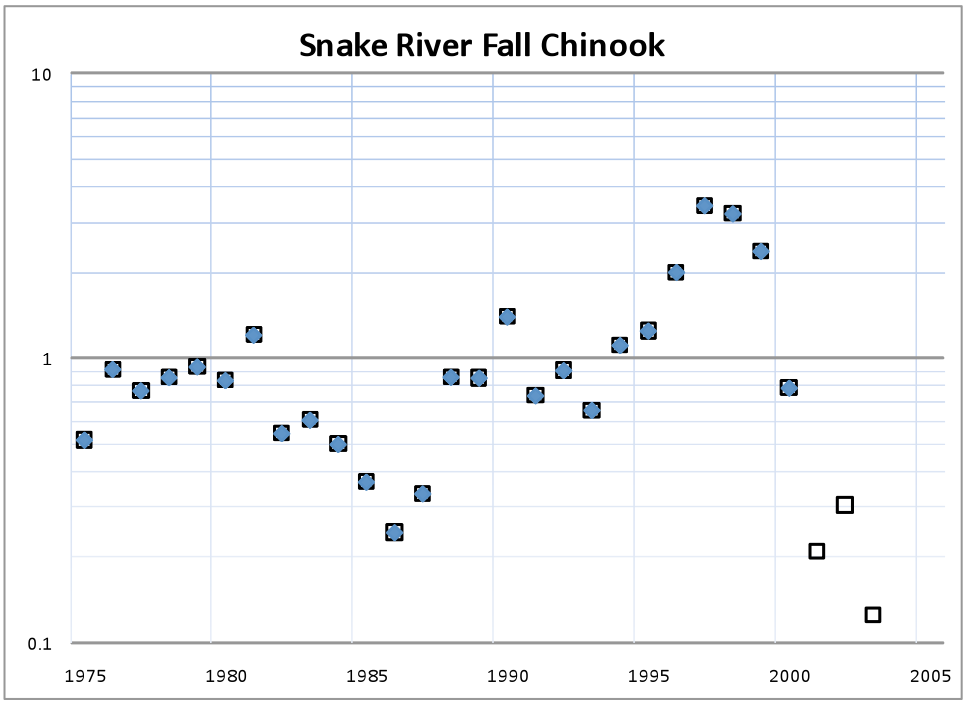


Figure 37 -- Snake River Fall Chinook. Brood year spawner to spawner estimates. Filled diamonds: parent spawner estimate below 75% of minimum abundance threshold. Open squares: parent escapement greater than 75% of minimum abundance threshold.

The most recent short-term trend in natural origin spawners was strongly positive, increasing at an average rate of 16% per year (Table 24). The rate of increase is down from the 23% per year estimated for 1990-2001. Hatchery origin escapements into natural spawning areas continued to increase through the most recent return year (Figure 36). Although natural origin returns have remained well above the levels estimated at the time of listing in the early 1990's, the most recent escapements have dropped from the peak in 2001-2003 and have fluctuated below the ICTRT minimum abundance threshold level. The apparent leveling off of natural returns in spite of the increases in total brood year spawners may indicate that density dependent habitat effects are influencing production or that high hatchery proportions may be influencing natural production rates.

Table 24. Short term (since 1995) trends in natural origin spawning abundance (slope of natural ln adult spawners) for the Lower Snake River Fall Chinook population. Comparisons with time periods corresponding to prior BRT reviews included.

Population		**Short-term trend**		
		1998 BRT (1987-97)	Previous (1990-2001)	**Current (1995-2008)**
Snake River Fall Chinook	**Estimate** **(CI)** ***Prob>1.0***	1.12 (0.996 - 1.26) 0.97	1.23 (1.09 - 1.40) 0.998	**1.16** **(1.06 - 1.27)** **0.998**

Table 25. Short term (since 1995) trends in spawning abundance (population growth rate) for the Lower Snake River Fall Chinook population. Comparisons with time periods corresponding to prior BRT reviews included

Population		**Short-term Lambda**			
		Hatchery effectiveness= 0		**Hatchery effectiveness= 1.0**	
		2005 BRT (1990-2001)	**Current (1995-2008)**	2005 BRT (1990-2001)	**Current (1995-2008)**
Snake River Fall Chinook	**Estimate** **(CI)** ***Prob>1.0***	1.21 (0.46 - 3.17) 0.88	**1.15** **(0.18 - 7.37)** **0.75**	1.08 (0.49 - 2.35) 0.78	**0.90** **(0.08 - 10.23)** **0.34**

The Snake Fall Chinook salmon abundance series begins with the 1975 return year. The average long-term trend in natural origin returns to the spawning grounds is positive (average rate of increase of 6% per year), again largely driven by recent increases. The estimated average population growth rate assuming that hatchery origin parent spawners have been contributing at the same rate as natural origin parents has been less than 1.0, indicating that natural production has not proportionally increased in response to the upward trend in total spawners. The population growth rate estimate under the assumption that hatchery origin spawners have not contributed to production is an indicator of trends in total brood year production across return years. That metric is positive, indicating that on average natural production has increased over the brood years 1975-2003.

Table 26. Long term trend estimates for Lower Snake River Fall Chinook population.

Population	Years	Trend in total Spawners Estimate (CI)	Lambda (HF=0) Estimate (CI)	Prob>1	Lambda(HF=1) Estimate (CI)	Prob>1
Lower Snake Fall	1975 - 2008	1.06 (1.03-1.08)	1.04 (0.89-1.22)	0.73	0.90 (0.76-1.07)	0.09

TRT Viability Criteria Ratings

The ICTRT rated the current status of the Snake River fall Chinook population and the ESU based on data through return year 2007. Total abundance and hatchery contribution estimates and spawner distributions based on redd counts are now available for two additional years.

Table 27. Viability assessment for Lower Snake River Fall Chinook population using ICTRT criteria. Updated to reflect returns through 2008.

Population Snake River Fall Chinook	**Abundance/Productivity Metrics**				**Spatial Structure and Diversity Metrics**			**Overall Viability Rating**
Brood years	***ICTRT Minimum Threshold***	***Natural Spawning Abundance***	***ICTRT Productivity***	***Integrated A/P Risk***	***Natural Processes Risk***	***Diversity Risk***	***Integrated SS/D Risk***	
1990-2004	**3000**	***2208*** (905-5163)	**1.28** (0.82-1.63)	**Moderate**	Low	Moderate	**Moderate**	**Maintained**
1985-2004			**1.07 (0.93-1.75)**	**(Moderate)**				

<u>Abundance and Productivity</u>

The current estimate (1999-2008 10-year geometric mean) of natural origin spawning abundance (10 year geometric mean) of Snake River Fall Chinook is just over 2,200. The ICTRT generally recommends calculating population productivity (expected spawner to spawner return rate at low to moderate parent escapements) using the most recent 20 brood years. Previous ICTRT status reviews for Snake River Fall Chinook included estimates based on a more recent time series to account for potential major, but un-quantified changes in downstream passage conditions (enhanced flows and transport regimes) initiated in 1990. The updated productivity based on the 1990 to present series was 1.28, the estimate for the longer series 1983-2003 brood years, was 1.07 (Table 27). Combining the current natural spawning escapement estimate of 2,200 with either of the productivity estimates results in an abundance and productivity rating of moderate risk using the ICTRT viability curves for this population.

<u>Spatial Structure and Diversity</u>

The addition of two years of spawner distribution and hatchery composition data does not alter the conclusions reached in the ICTRT status report regarding spatial structure and diversity ratings. *"The Lower Snake River fall Chinook population was rated at **low risk** for Goal A (allowing natural rates and levels of spatially mediated processes) and **moderate risk** for Goal B (maintaining natural levels of variation) resulting in an overall spatial structure and diversity rating of **Moderate Risk**. The moderate risk rating was driven by changes in major life history patterns, shifts in phenotypic traits and high levels of genetic homogeneity in samples from natural-origin returns. In addition, the chronic high levels of hatchery spawners in natural spawning areas and substantial selective pressure imposed by* *current hydropower operations and cumulative harvest impacts would also lead to a moderate rating. "*

Scale samples from natural origin fall Chinook taken at Lower Granite Dam continue to indicate that approximately half of the returns overwintered in freshwater (Milks et al., 2009 appendix H).

Given the combination of current ratings for abundance/productivity and spatial structure/diversity summarized above, the Lower Snake River fall Chinook salmon population would be rated as **MAINTAINED** (Figure 38). There is a high level of uncertainty associated with the overall rating for this population, primarily driven by uncertainties regarding current average natural-origin abundance and productivity levels. It is difficult to separate variations in ocean survival from potential changes in hydropower impacts without comparative measures of juvenile passage survivals under current operations or a representative measure of ocean survival rates.

		Spatial Structure/Diversity Risk			
		Very Low	**Low**	**Moderate**	**High**
Abundance/ Productivity Risk	**Very Low** (<1%)	**HV**	**HV**	**V**	**M**
	Low (1-5%)	**V**	**V**	**V**	**M**
	Moderate (6 – 25%)	**M**	**M**	**M** Lower Main. Snake	**HR**
	High (>25%)	**HR**	**HR**	**HR**	**HR**

Figure 38 ---- Snake River Lower Mainstem fall Chinook salmon population risk ratings integrated across the four viable salmonid population (VSP) metrics. ***Viability Key: HV – Highly Viable; V – Viable; M – Maintained; HR – High Risk; Shaded cells – does not meet viability criteria (darkest cells are at highest risk).***

<u>Harvest</u>

Snake River fall Chinook have a very broad ocean distribution and have been taken in ocean salmon fisheries from central California through southeast Alaska. They are also harvested in-river in tribal and non-tribal fisheries. Historically they were subject to total exploitation rates on the order of 80%. Since they were originally listed in 1992, fishery impacts have been reduced in both ocean and river fisheries (Figure 39). Total exploitation rate has been relatively stable in the range of 40% to 50% since the mid-1990s

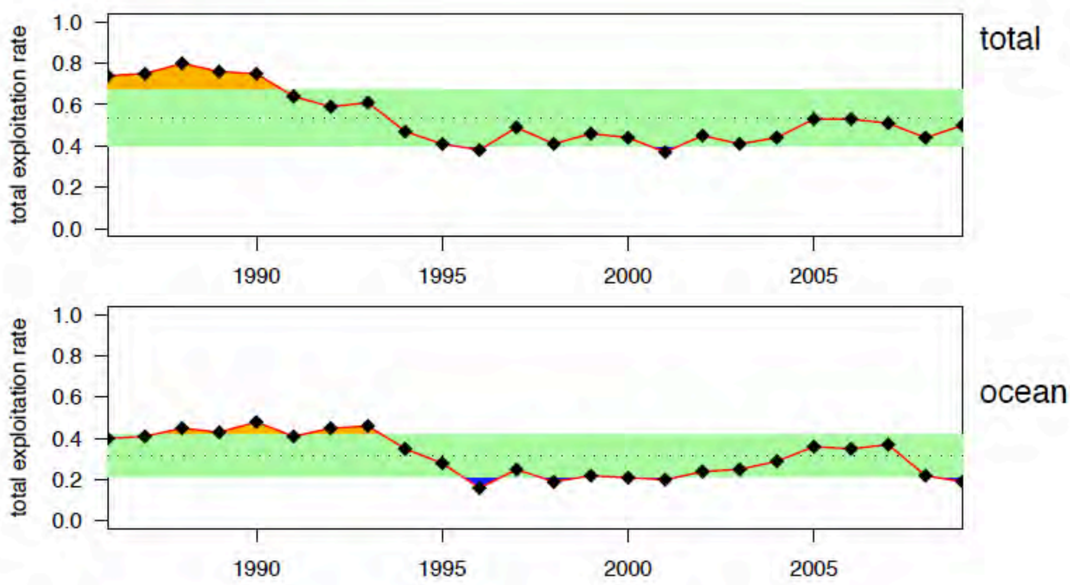


Figure 39 -- Total exploitation rate for Snake River fall Chinook salmon. Data for marine exploitation rates from the Chinook Technical Committee model (CTC in prep) and for in-river harvest rates from the Columbia River Technical Advisory Committee (TAC 2009, and Cindy LeFleur, WDFW, personal communication).

<u>Hatchery releases</u>

Hatchery releases of Snake River fall Chinook salmon have generally been trending upward since the mid-1990s, as have releases of coho and sockeye (Figure 40).

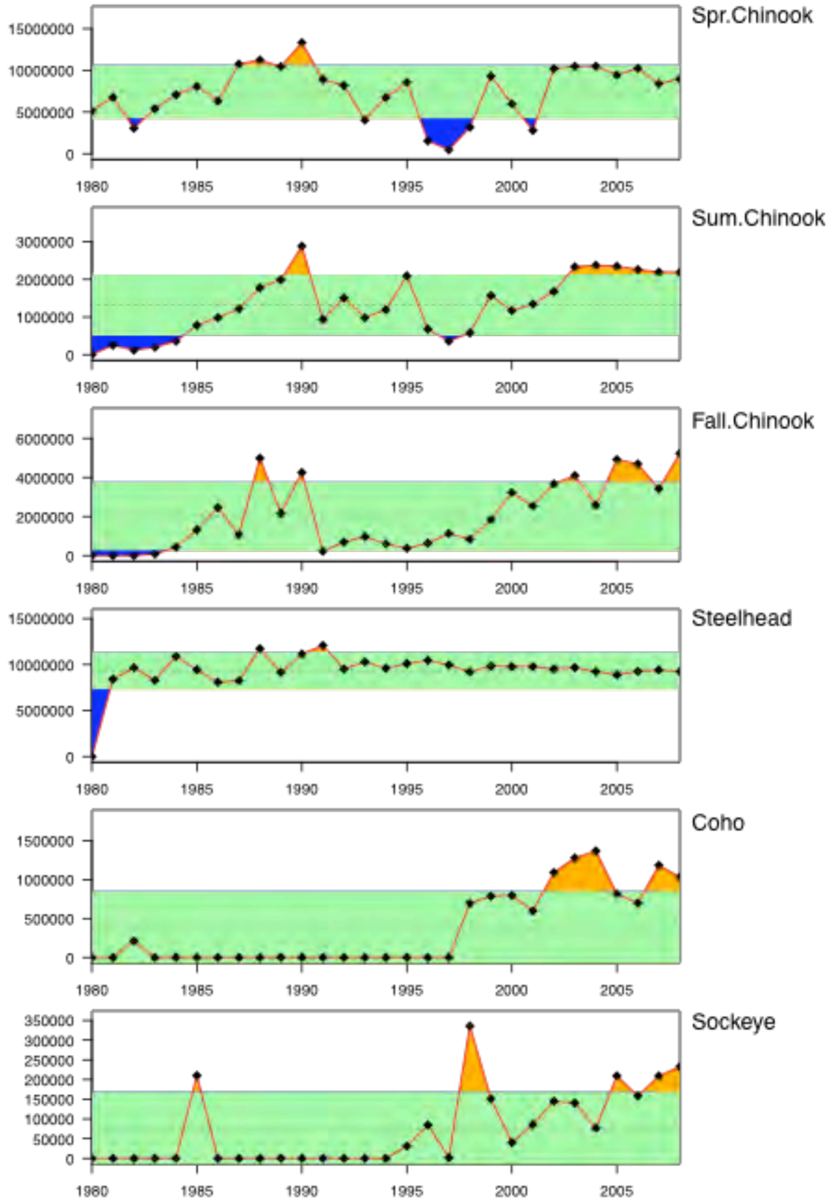


Figure 40 – Snake River hatchery releases since 1980. Data source: Fish Passage Center (http://www.fpc.org/hatchery/misc_docs/SnakeHatcheryReleases.html).

Snake River fall Chinook salmon: Updated Risk Summary

Abundance and productivity estimates for the single remaining population of Snake River Fall Chinook salmon have improved substantially relative to the time of listing. However the current combined estimates of abundance and productivity population still result in a moderate risk of extinction of between 5% and 25% in 100 years. The extant population of Snake River Fall Chinook is the only remaining from an historical ESU that also included large mainstem populations upstream of the current location of the Hells Canyon Dam complex. The recent increases in natural origin abundance are encouraging. However, hatchery origin spawner proportions have increased dramatically in recent years – on average, 78% of the estimated adult spawners have been hatchery origin over the most recent brood cycle. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good, T.P., R.S. Waples and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

ICTRT, 2003. Independent populations of chinook, steelhead and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Interior Columbia Basin Technical Recovery Team Technical Review Draft. July 2003. 171 p.

ICTRT, 2007. Viability criteria for application to interior Columbia Basin salmonid ESUs. Interior Columbia Basin Technical Recovery Team. Technical Review Draft. March 2007. 91 p + appendices and attachments.

ICTRT (2010) Current status reviews: Interior Columbia Basin salmon ESUs and steelhead DPSs. Vol. 1. Snake River ESUs/DPS. 786 p. + attachments

Milks, D., M. Varney and M. Schuck. 2009. Lyons Ferry Hatchery Evalution: Fall Chinook salmon annual report 2006. Washington Department of Fish and Wildlife report to; US Fish and Wildlife Service Lower Snake River Compensation Plan Office. WDFW 09-04. 117p. http://www.fws.gov/lsnakecomplan/Reports/WDFW/Eval/LFH%20Eval%20Fall%20Chinook%20Annual%202006.pdf

Snake River sockeye salmon[12]

The ESU includes all anadromous and residual sockeye salmon from the Snake River Basin, Idaho, as well as artificially propagated sockeye salmon from the Redfish Lake captive propagation program. This ESU was first listed under the ESA in 1991, the listing was reaffirmed in 2005 (70 FR 37160 & 37204).

Summary of previous BRT conclusions

The 2005 BRT assigned the Snake River Sockeye ESU to the "danger of extinction" category. This high risk rating was reflected in the scoring by all members of the BRT. The BRT rated the ESU at extremely high risk across all four basic risk measures (abundance, productivity, spatial structure and diversity), noting that only 16 naturally produced adults have been counted since 1991. The BRT assessment acknowledged that the emergency captive brood program initiated in 1991 has, "..at least temporarily...rescued this ESU from the brink of extinction.." and that ongoing research has substantially increased biological and environmental information about the ESU.

Brief Review Recovery Planning

NOAA Fisheries has initiated recovery planning for the Snake River drainage, including a component addressing the Snake River Sockeye ESU. A draft recovery plan is expected to be available for review in 2011. The Snake River sockeye recovery plan component will build on ongoing efforts including hatchery programs and habitat assessment activities coordinated though the Stanley Basin Sockeye Technical Oversight Committee (SBSTOC). In addition, actions to monitor and improve juvenile downstream and adult upstream passage survivals are being evaluated and implemented through the Federal Columbia River Power System 2008 Biological Opinion.

The initial priorities established in the early 1990s by the SBSTOC were to "... protect the remnant ESA-listed Snake River gene pool existing in Redfish Lake through the use of captive broodstock technology and to develop an understanding of the carrying capacity of Sawtooth Valley lakes." Evaluating the potential success of alternative supplementation strategies was recognized as an important 'second tier' priority (Flagg et al., 2004).

TRT and Recovery Plan Criteria

The ICTRT developed abundance and productivity criteria for application to Snake River sockeye populations (ICTRT, 2007). The criteria reflect the general framework used by the ICTRT in developing ESU/DPS specific criteria for all other listed interior runs. The Stanley Basin Lakes are relatively small compared to other lake systems that historically supported sockeye production in the Columbia Basin. Stanley Lake is assigned to the smallest size category along with Pettit and Yellowbelly Lakes. Redfish Lake and Alturas Lake fall into the next size category – intermediate. The average abundance targets recommended by the Snake River Recovery Team (Bevan, et al. 1994) were incorporated as minimum abundance thresholds into a sockeye viability curve generated using historical age

---

12 Section author: Tom Cooney

structure estimates from Redfish Lake sampling in the 1950s-60s and year to year variations in brood year replacement rates generated from abundance series for Lake Wenatchee sockeye. The minimum spawning abundance threshold is set at 1,000 for the Redfish and Alturas Lake populations (intermediate category), and at 500 for populations in the smallest historical size category (e.g., Alturas and Petit Lakes). The ICTRT recommended that long-term recovery objectives should include restoring at least three of the lake populations in the ESU to viable or highly viable status.

New Data and Updated Analyses

The previous BRT review included a summary of adult returns through the 2002 run year. Estimates of annual returns are now available through 2009 (Table 28). Adult returns in 2008 and 2009 were the highest since the current captive brood based program began with a total of 650 and 809 adults counted back to the Stanley Basin. Approximately two thirds of the adults captured in each year were taken at the Redfish Lake Creek weir, the remaining adults were captured at the Sawtooth Hatchery weir on the mainstem Salmon River upstream of the Redfish Lake Creek confluence. Returns for 2003-2007 were relatively low, similar to the range observed between 1987 and 1999.

Table 28 -- Adult Sockeye returns to Stanley Basin weir sites. In 2008, 50 adult fish were counted in Redfish Lake Creek below the weir site, an additional 2 fish passed the weir site outside of the counting period (check).

Year	Redfish Lake Creek Below Weir	Weir	Subtotal	Sawtooth FH Weir Count	Stanley Basin Total
1987		16	16		16
1988		1	1		1
1989		1	1		1
1990		0	0		0
1991		4	4		4
1992		1	1		1
1993		8	8		8
1994		1	1		1
1995		0	0		0
1996		1	1		1
1997		0	0		0
1998		1	1		1
1999		7	7		7
2000		257	257		257
2001		26	26		26
2002		22	22		22
2003		3	3		3
2004		27	27		27
2005		6	6		6
2006		3	3		3
2007		7	7	3	10
2008	52	380	432	218	650
2009		563	563	246	809

Increased returns in recent years have supported substantial increases in the number of adults released above the Redfish Lake Creek weir in recent years (Table 29). Annual adult releases since 2003 have ranged from 173 to 969 compared to the range for the five year period ending in 2002 (0 to 190 sockeye). The large increases in returning adults in recent years reflects improved downstream and ocean survivals as well as increases in juvenile production since the early 1990s (Table 29). Presmolt outplants into Redfish, Alturas and Petit Lakes were initiated in the mid-1990s, releases have averaged approximately 80,000 per year since 1995. On average, approximately 30,000 per year of the presmolt releases are detected leaving the three lakes the following spring Direct smolt plants in the lower section of Redfish Lake Creek and in the Salmon River (Sawtooth weir) have increased to over 100,000 per year. The number of captive reared or returning anadromous adults allowed to pass over the Redfish Lake weir or outplanted into the lake has also increased substantially in recent years. Unmarked juvenile migrants emigrating from the three lake systems have also dramatically increased in recent years – annual estimates have ranged from 16,000 to 61,000 over the 2005 through 2009 outmigrations. Estimates of the total annual outmigration across all of these components have ranged from 143,500 to 210,300 during the most recent five year period (2005-2008) compared to a range of 19,600-146,300 for (1998-2002), the period corresponding to the 2005 BRT review.

Table 29 -- Estimated annual numbers of smolt outmigrants from the Stanley Basin. Includes hatchery smolt releases, known outmigrants originating from hatchery pre-smolt outplants and estimates of unmarked juveniles migrating from Redfish, Alturas and Stanley Lakes.

All Lakes Combined							
Year	# of pre-smolts planted	Estimated out-migration from pre-smolt plants	# of smolts planted	# of pre-spawn adults planted	# of eyed-eggs planted	Estimated unmarked out-migration	Total estimated out-migration
1993	0	0	0	20	0	569	569
1994	14,119	0	0	65	0	1,820	1,820
1995	91,572	823	3,794	0	0	357	4,974
1996	1,932	14,715	11,545	120	105,000	923	27,183
1997	255,711	401	0	120	105,767	304	705
1998	141,871	61,877	81,615	0	0	2,799	146,291
1999	40,271	38,750	9,718	21	20,311	3,108	51,576
2000	72,114	12,971	148	271	65,200	6,502	19,621
2001	106,166	16,595	13,915	79	0	1,991	32,501
2002	140,410	25,716	38,672	190	30,924	8,156	72,544
2003	76,788	26,116	0	315	199,666	4,952	31,068
2004	130,716	22,244	96	241	49,134	5,660	28,000
2005	72,108	61,474	78,330	173	51,239	22,135	161,939
2006	107,292	33,401	86,052	464	184,596	61,312	180,765
2007	82,105	25,848	101,676	494	51,008	16,023	143,547
2008	84,005	28,269	150,395	969	67,984	22,240	200,904
2009	59,538	24,852	173,055	1,349	72,478	12,429	210,336

Table 30 -- Snake River Sockeye Salmon. Releases of progeny from Redfish Lake captive brood program into Redfish Lake, Redfish Lake Creek and the Salmon River at or above the Sawtooth Hatchery weir.

Release Year	Redfish Lake Adult Releases Captive Lake	Hatch (Anad) Lake	Total Lake	Eggs Lake	Redfish Lake Juvenile Releases Presmolts Lake	Smolts Below weir	Sawtooth Weir Smolts
1993	20		20				
1994	65		65		14,000		
1995			0		82,000	3,800	
1996	120		120	105,000	2,000	11,500	
1997	80		80	85,400	152,000		
1998			0		95,000	25,400	56,200
1999	18	3	21		24,000	4,850	4,850
2000	36	120	156		48,000	148	-
2001	65	14	79		43,000	14,900	-
2002	178	12	190		107,000	38,700	-
2003	312		312		59,800	-	-
2004	241		241		79,900	-	96
2005	173		173		46,400	39,300	39,000
2006	464		464		61,800	-	-
2007	494		494		62,000	54,600	47,100
2008	398	571	969		57,093	73,808	76,600

Table 31 -- Snake River Sockeye Salmon. Releases of progeny from Redfish Lake captive brood program into Alturas and Petit Lakes.

Release Year	Alturas Lake Adult Releases Captive Lake	Hatch (Anad) Lake	Total Lake	Eggs Lake	Alturas Lake Presmolts Lake	Smolts Lake
1993	-	-	-		-	-
1994	-	-	-		-	-
1995	-	-	-		-	-
1996	-	-	-		-	-
1997	20	-	20	20,000	100,000	-
1998	-	-	-		39,000	-
1999	-	-	-		13,000	-
2000	25	52	77		12,000	-
2001	-	-	-		12,000	-
2002	-	-	-		6,000	-
2003	-	-	-	49,700	20,000	-
2004	-	-	-		20,100	-
2005	-	-	-		16,900	-
2006	-	-	-	104,700	27,000	-
2007	-	-	-		10,000	-
2008	-	-	-		16,864	-

Release Year	Petit Lake Adult Releases Captive Lake	Hatch (Anad) Lake	Total Lake	Eggs Lake	Petit Lake Presmolts Lake	Smolts Lake
1993	-	-	-	-	-	-
1994	-	-	-	-	-	-
1995	-	-	-		9,000	-
1996	-	-	-			-
1997	20	-	20	20,000	9,000	-
1998	-	-	-	65,000	7,000	-
1999	-	-	-		3,000	-
2000	28	-	28	30,900	6,000	-
2001	-	-	-	150,000	11,000	-
2002	-	-	-	49,100	28,000	-
2003	-	-	-	51,200	15,000	-
2004	-	-	-	79,900	30,700	-
2005	-	-	-	51,000	15,300	-
2006	-	-	-	67,984	18,500	-
2007	-	-	-		10,000	-
2008	-	-	-	68,000	10,000	-

Ongoing studies of the limnological characteristics of the three Stanley basin lakes and the current densities of *O. nerka* juveniles within each of the lakes are beginning to provide insights into the relative carrying capacities for sockeye production (e.g., Flagg, et. al. 2004).

Juvenile emigration rates

The increased production from the captive brood programhas resulted in sufficient release and outplanting levels for initial evaluations of alternative supplementation strategies (Hebdon et al, 2004). Hatchery reared pre-smolts have been outplanted into each of the three lakes since the mid-1990s (Table 30). Estimates of the proportion of those outplants emigrating downstream from each of the three rearing lakes have been generated since 2000 (Peterson, et al. 2010). Median outmigration proportions for 2000-2008 for Redfish, Alturas and Petit lakes were 0.27, 0.47 and 0.46 respectively, with considerable annual variation in the estimates for each lake (Figure 41).

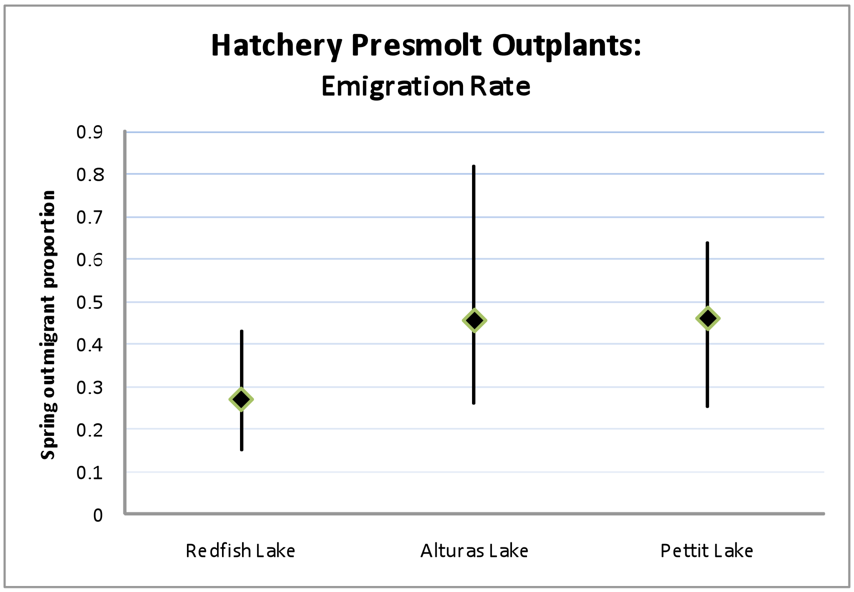


Figure 41 -- Estimated proportion of fall presmolt plants outmigrating in the spring of the following year (2000-2008). Solid diamonds = median estimate, lines = range of annual estimates. Estimates from table 15 in Peterson et al. 2010

<u>Lakes to Lower Granite Dam juvenile migrant surivivals</u>

The increased numbers of juvenile migrants (primarily from hatchery releases), haver also resulted in improved estimates of downstream passage mortality, including the generation of confidence limits using SURPH sampling designs beginning with the 2008 outmigration year (Peterson, et al. 2010). Prior to 2008, survival estimates for the aggregate smolt outmigration of Snake River sockeye juveniles were made based on estimates of the number of O. nerka smolts sampled at Lower Granite Dam relative to the estimated outmigration from the Stanley Basin (Table 29). Annual estimates have varied considerably, ranging from 0.21 to 0.76 (NWFSC, 2008). Average downstream passage survivals across migration groups and areas in 2008 ranged from 0.22 (Petit Lake unmarked smolts) to 0.62 (Alturas Lake unmarked smolts). Downstream passage survival from weirs to Lower Granite Dam for marked and unmarked migrants were generally similar for each of the lakes. Survival from release to Lower Granite Dam for spring releases of hatchery origin smolts into lower Redfish Lake and the Salmon River near Sawtooth Hatchery were similar and fell in the middle of range for all release groups/locations (Figure 42).

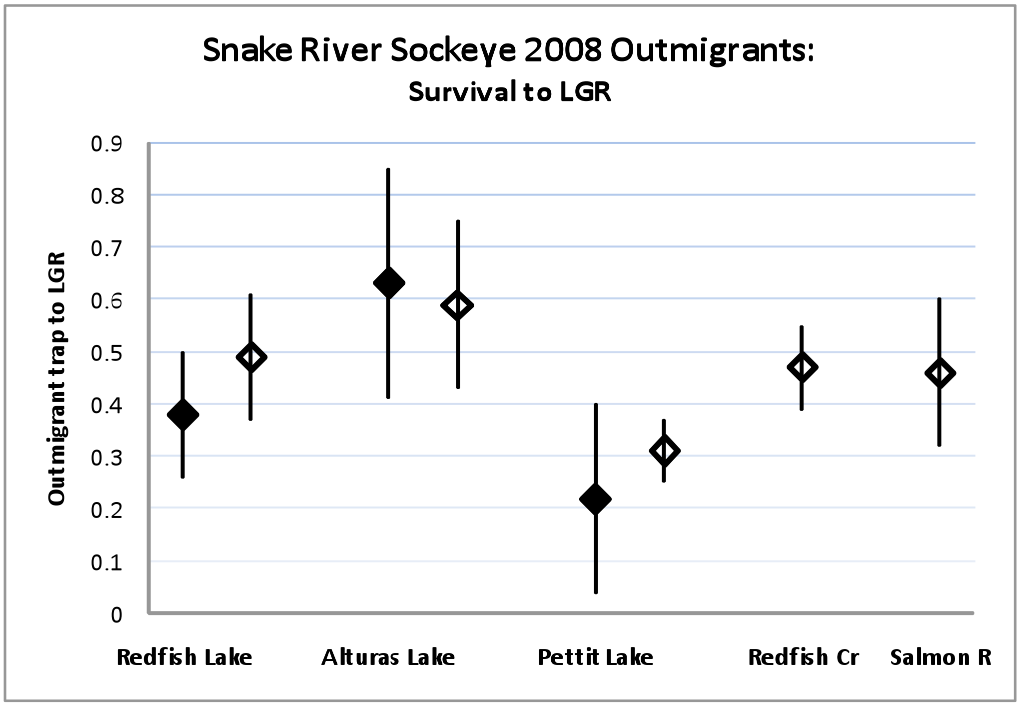


Figure 42 -- Snake River sockeye juvenile downstream survival estimates for 2008 migration year. Estimated survival from trap or release location to Lower Granite Dam. Closed diamonds: natural origin smolts, open diamonds: hatchery origin smolt releases. Bars: 95% confidence limits (SURPH model). Estimates from table 13 in Peterson et al 2010.

Lower Granite Dam SAR estimates

Annual estimates of an index of smolt to adult return rates (SARs) have been generated for Snake River sockeye as the estimated number of smolts at Lower Granite Dam in given year divided into the number of returning adults two years later (NWFSC, 2008). The median SAR index for the 1998-2006 series of annual estimates was 0.2%, with annual indices ranging from a low of 0.07% to a high of 1.04. SAR estimates for five of the nine years in the series were based on less than 50 adults returning to Lower Granite Dam; therefore these results should be interpreted with caution. Currently available SAR estimates do not include the full effect of the relatively large returns in 2009 and 2010 observed for runs returning to the Upper Columbia (Lake Wenatchee and Lake Okanogan) and to the Snake River.

The Lower Granite SARs reflect aggregate return rates across two major downstream migration routes -in-river passage and downstream transport to below Bonneville Dam. Estimates of the proportion transported over the 1998 to 2006 outmigration years have ranged from approximately 50% to over 90%. The median estimated survival of juvenile in-river migrants downriver from Lower Granite Dam through the lower Snake River to McNary Dam on the mainstem Columbia River was 67% for the period 1996-2010, individual year estimates ranged from 28% to 76% (Feguson, 2010). The median estimate of juvenile passage survivals for the McNary Dam to Bonneville Dam reach (1998-2003, 2006-2010) was 0.54, which should be interpreted with caution due to small sample sizes and associated low detection probabilities for many of the individual year estimates (Ferguson, 2010).

Adult upstream passage survivals through the mainstem Columbia River to the mouth of the Snake River are assumed to be relatively high based on inferences from estimates of upstream passage for Upper Columbia River sockeye (NWFSC, 2008). Comparisons of adult sockeye counts at Ice Harbor Dam and Lower Granite Dam indicate direct losses are also low for passage through the Lower Snake River. Adult passage survival estimates based on PIT tag detections at multiple dams also indicate relatively low direct passage mortality upstream to Lower Granite Dam (NMFS, 2008).

However, comparisons of the estimated number of adult sockeye at Lower Granite Dam vs. returning to the Sawtooth Basin indicate relatively high loss rates through this reach in some years. Keefer et al. (2007) conducted an adult radio tagging study of passage survivals upstream from Lower Granite Dam in 2000 and concluded that high in-river mortalities for Snake River adults could be explained by "… a combination of high migration corridor water temperatures and poor initial fish condition or parasite loads." Keefer et al. (2007) examined current run timing patterns of Snake River sockeye vs. records from the early 1960s, concluding that the apparent shift to an earlier run timing in more recent years may reflect increased mortalities for later migrating adults.

Harvest

Ocean fisheries do not significantly impact Snake River sockeye. Within the mainstem Columbia River, treaty tribal net fisheries and non-tribal fisheries directed at Chinook salmon do incidentally take small numbers of sockeye. Most of the sockeye harvested are from the Upper Columbia River (Canada and Lake Wenatchee), but very small numbers of Snake River sockeye are taken incidental to summer fisheries directed at Chinook salmon. In the 1980 fishery impact rates increased briefly due to directed sockeye fisheries on large runs of Upper Columbia River stocks (Figure 43)

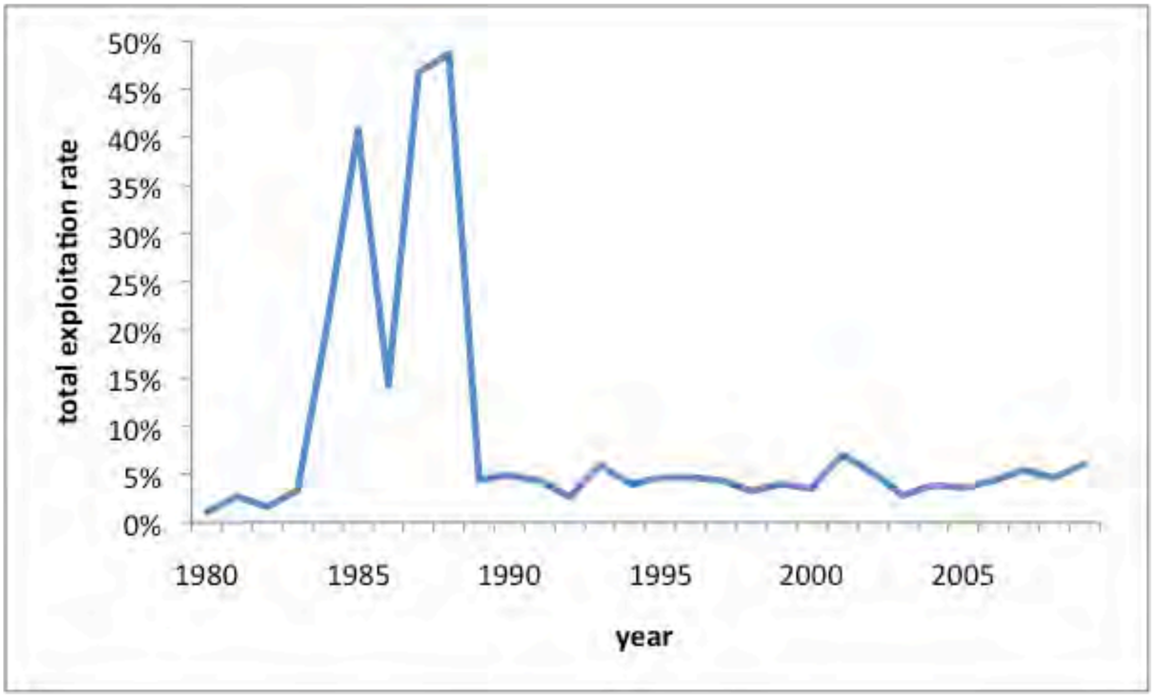


Figure 43 -- Exploitation rates on Snake River sockeye salmon. Data from the Columbia River Joint Staff Report (2010).

Hatchery releases

Releases of Chinook salmon, steelhead and sockeye salmon within the spawning and rearing areas of the Snake River sockeye salmon ESU have remained fairly flat since 2005 (Figure 44).

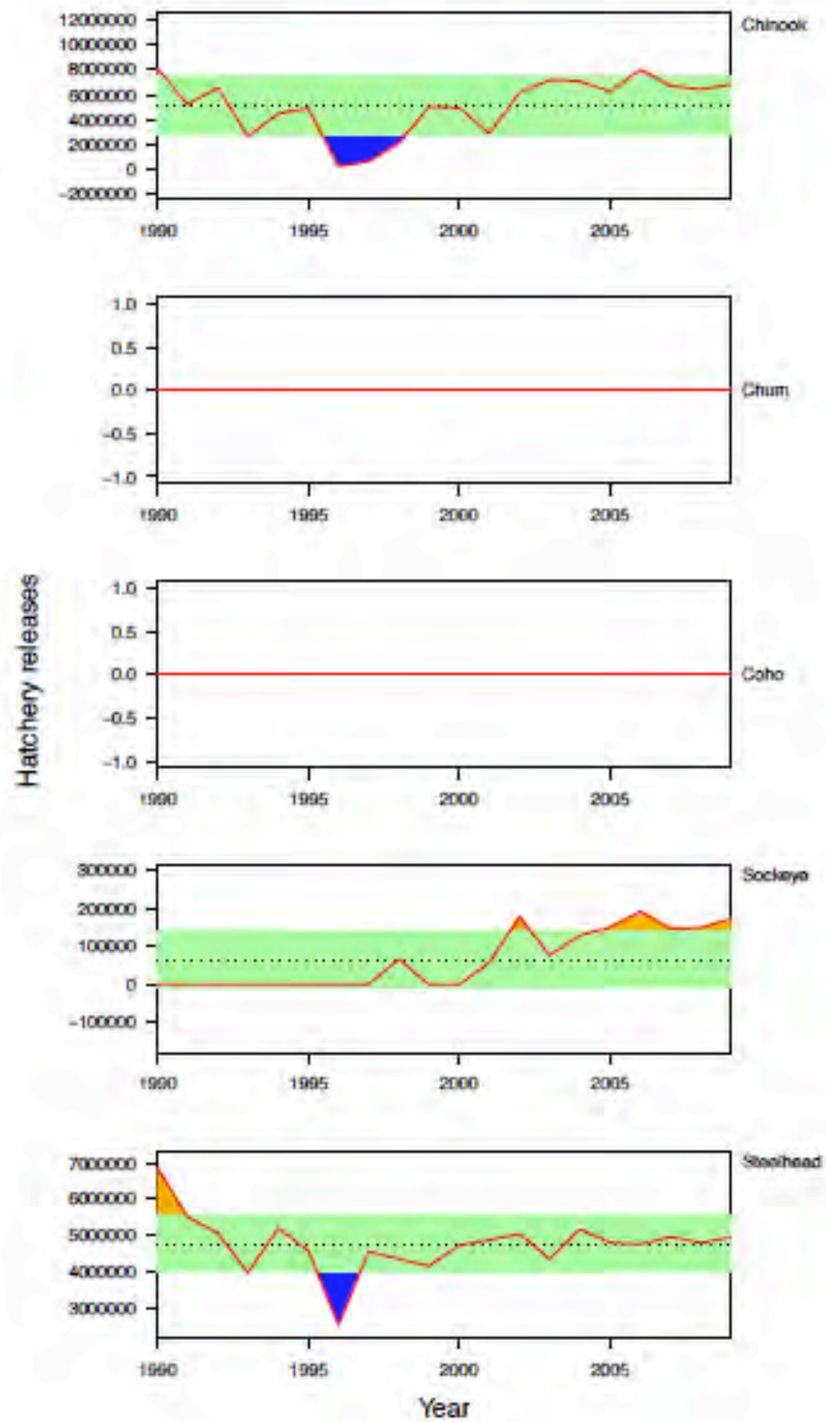


Figure 44 – Annual hatchery releases within the spawning and rearing areas of the Snake River sockeye salmon ESU. Data source: RMIS.

Snake River Sockeye salmon: Updated Risk Summary

Substantial progress has been made with the Snake River sockeye captive brood stock based hatchery program, but natural production levels of anadromous returns remain extremely low for this ESU. In recent years, sufficient numbers of eggs, juveniles and returning hatchery adults have been available from the captive brood based program to allow for initiation of efforts to evaluate alternative supplementation strategies in support of re-establishing natural production of anadromous sockeye. Limnological studies and direct experimental releases are being conducted to elucidate production potential in three of the Stanley Basin lakes that are candidates for sockeye restoration. The availability of increased numbers of adults and juveniles in recent years is supporting direct evaluation of lake habitat rearing potential, juvenile downstream passage survivals and adult upstream survivals. Although the captive brood program has been successful in providing substantial numbers of hatchery produced *O. nerka* for use in supplementation efforts, substantial increases in survival rates across life history stages must occur in order to re-establish sustainable natural production (e.g. Hebdon et al. 2004, Keefer et al. 2008). The increased abundance of hatchery reared Snake River sockeye reduces the risk of immediate loss, but levels of naturally produced sockeye returns remain extremely low. As a result, overall, although the risk status of the Snake River sockeye salmon ESU appears to be on an improving trend, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

ICTRT, 2003. Independent populations of chinook, steelhead and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Interior Columbia Basin Technical Recovery Team Technical Review Draft. July 2003. 171 p.

ICTRT, 2007. Viability criteria for application to Interior Columbia Basin Salmonid ESUs. Interior Columbia Basin Technical Recovery Team Technical Review Draft. March 2007. 91 p + appendices & attachments

Ferguson, J.W. 2010. Preliminary survival estimates for passage during the spring migration of juvenile salmonids through the Snake and Columbia River reservoirs and dams, 2010. NWFSC Memo Sept. 13, 2010. 21 p.

Flagg, T.A., W.C. McAuley, P.A. Kline, M.S. Powell, D. Taki and J.C. Gislason. (2004). Application of captive broodstocks to preservation of ESA-listed stocks of Pacific Salmon: Redfish Lake Sockeye Salmon case example. Am. Fish. Soc. Symp. 44:387-400

Hebdon, J.L., P. Kline, D. Taki and T.A. Flagg. 2004. Evaluating reintroduction strategies for Redfish Lake Sockeye Salmon captive brood progeny. Amer. Fish. Soc. Symp. 44:401-413.

Keefer, M.L., C.A. Peery and M.J. Henrich. 2008. Temperature mediated en route migration mortality and travel rates of endangered Snake River sockeye salmon. Ecol. of Freshwater Fish 17:136-145.

Kohler, A., B. Griswold, D. Taki and S. Letzing 2008. Snake River Sockeye Salmon habitat and limnological research: 2008 annual progress report. Project no. 199107100. Report to Bonneville Power administration.

National Marine Fisheries Service (NMFS). 2008. Supplemental comprehensive analysis of the federal Columbia River power system and mainstem effects of the Upper Snake and other tributary actions - Adult survival estimates appendix. May 5, 2008.
Northwest Fisheries Science Center (2009). Factors affecting sockeye salmon returns to the Columbia River in 2008. NOAA Fisheries Rept. 37 p.
Peterson, M. K. Plaster, L. Redfield and J. Heindel. Snake River Sockeye Salmon captive broodstock program: Research element. Annual Progress Report: January 1 2008-December 31 2008. IDFG Rept. #10-08. Prepared for Bonneville Power Administration.

Snake River Basin steelhead[13]

The Snake River Steelhead DPS "….includes all naturally spawned anadromous *O. mykiss* (steelhead) populations below natural and manmade impassable barriers in streams in the Snake River Basin of southeast Washington, northeast Oregon, and Idaho as well as six artificial production programs: the Tucannon River, Dworshak NFH, Lolo Creek, North Fork Clearwater River, East Fork Salmon River, and the Little Sheep Creek/Imnaha River Hatchery steelhead hatchery programs" (Federal Register notice 71FR834). Snake River steelhead are classified as summer run based on their adult run timing patterns. Much of the freshwater habitat used by Snake River steelhead for spawning and rearing is warmer and drier than that associated with other steelhead DPSs. Snake River steelhead spawn and rear as juveniles across a wide range of freshwater temperature/precipitation regimes. Fisheries managers classify Columbia River summer run steelhead into two aggregate groups, A-run and B-run, based on ocean age at return, adult size at return and migration timing. A-run steelhead are predominately spend one year at sea and are assumed to be associated with low to mid-elevation streams throughout the Interior Columbia basin. B-run steelhead are larger with most individuals returning after 2 years in the ocean.

NOAA Fisheries has defined DPSs of steelhead to include only the anadromous members of this species (70 FR 67130). Our approach to assessing the current status of a steelhead DPS is based evaluating information the abundance, productivity, spatial structure and diversity of the anadromous component of this species. (Good et al. 2005; 70 FR 67130). Many steelhead (*O. mykiss*) populations along the West Coast of the U.S. co-occur with conspecific populations of resident rainbow trout. We recognize that there may be situations where reproductive contributions from resident rainbow trout may mitigate short-term extinction risk for some steelhead DPSs (Good et al. 2005; 70 FR 67130). We assume that any benefits to an anadromous population resulting from the presence of a conspecific resident form will be reflected in direct measures of the current status of the anadromous form.

Summary of previous BRT conclusions

The 2005 BRT report highlighted moderate risks across all four primary factors (productivity, natural origin abundance, spatial structure and diversity) for this DPS. A majority (70%) of the risk assessment points assigned by the BRT were allocated to the "likely to become endangered" category. The continued relatively depressed status of B-run populations was specifically cited as a particular concern. The BRT identified that the general lack of direct data on spawning escapements in the individual population tributaries as a key uncertainty, rendering quantitative assessment of viability for the DPS difficult. The BRT also identified the high proportion hatchery fish in the aggregate run over Lower Granite Dam combined with the lack of tributary specific information on relative spawning levels as a second major uncertainty and concern. The BRT cited the upturn in return levels in 2000 and 2001 as evidence that the DPS "…is still capable of responding to favorable environmental conditions." However the report also acknowledged that abundance levels remain well below interim targets for spawning aggregations across the DPS.

---

[13] Section author: Tom Cooney

Brief Review Recovery Planning

The Interior Columbia Basin Technical Recovery Team (ICTRT) identified 24 extant populations within this DPS, organized into 5 major population groups (ICTRT, 2003). The ICTRT also identified a number of potential historical populations associated with tributary habitat above the Hells Canyon Dam complex on the mainstem Snake River, a barrier to anadromous migration. The five major population groups (MPGs) with extant populations are: the Lower Snake River MPG (2 populations); the Grande Ronde MPG (4 populations); the Imnaha River population/MPG; the Clearwater River MPG (5 extant populations, 1 extirpated); and the Salmon River MPG (12 populations). In addition, the ICTRT concluded that small tributaries entering the mainstem Snake River below Hells Canyon Dam may have historically been part of a larger population with a core area currently cut off from anadromous access. That population would have been part of one of the historical upstream MPGs.

NOAA Fisheries has initiated recovery planning for the Snake River drainage organized around a subset of management unit plans corresponding to State boundaries. A tributary recovery plan for one of the major management units, the Lower Snake River tributaries within Washington state boundaries, was developed under the auspices of the Lower Snake River Recovery Board and was accepted by NOAA Fisheries in 2005. The LSRB Plan provides recovery criteria, targets and tributary habitat action plans for the two populations of Spring/Summer Chinook in the Lower Snake MPG along with the Touchet River (Mid-Columbia Steelhead DPS) and the Washington sections of the Grande Ronde River. Planning efforts are underway for the Oregon and Idaho drainages. Viability criteria recommended by the ICTRT are being used in formulating recovery objectives within each of the management unit planning efforts.

TRT and Recovery Plan Criteria

The NOAA Fisheries has initiated recovery planning for the Snake River drainage, organized around a subset of management unit plans corresponding to State boundaries. A tributary recovery plan developed under the auspices of the Lower Snake River Recovery Board (Washington State) was accepted by NOAA Fisheries in 2005). The LSRB Plan provides recovery criteria, targets and tributary habitat action plans for the two populations of steelhead in the Lower Snake MPG along with the Touchet River (Mid-Columbia Steelhead DPS) and the Washington sections of the Grande Ronde River. Planning efforts are underway for the Oregon and Idaho drainages. Viability criteria recommended by the ICTRT are being used in formulating recovery objectives within each of the management unit planning efforts. The ICTRT recovery criteria are hierarchical in nature, with ESU/DPS level criteria being based on the status of natural origin steelhead assessed at the population level. A detailed description of the ICTRT viability criteria and their derivation (ICTRT, 2007) can be found at www.nwfsc.noaa.gov/trt/col/trt_viability.cfm. Under the ICTRT approach, population level assessments are based on a set of metrics designed to evaluate risk across the four viable salmonid population elements – abundance, productivity, spatial structure and diversity (McElany et al. 2000). The ICTRT approach calls for comparing estimates of current natural origin abundance (measured as a 10 year geometric mean of natural origin spawners) and productivity (estimate of return per spawner at low to moderate parent spawning abundance) against predefined viability curves. In addition, the ICTRT developed a set of specific criteria (metrics and example risk thresholds) for assessing the spatial structure and diversity risks based on current information representing each specific population. The ICTRT viability criteria are generally expressed relative to particular risk threshold - low risk is defined as less than a 5% risk of extinction over a 100 year period and very low risk as less than a 1% probability over the same time period.

Snake River Steelhead DPS: ICTRT Example Recovery Scenarios

The ICTRT recommends that each extant MPG should include viable populations totaling at least half of the populations historically present, with all major life history groups represented. In addition, the viable populations within an MPG should include proportional representation of at large and very large populations historically present. Within any particular MPG, there may be several specific combinations of populations that could satisfy the ICTRT criteria. The ICTRT identified example scenarios that would satisfy the criteria for all extant MPGs (ICTRT, 2007). In each case the remaining populations in an MPG should be at or above maintained status.

Lower Snake River MPG: The ICTRT recommends that both populations (Tucannon River and Asotin Creek) in this MPG should be restored to viable status, with at least one meeting the criteria for highly viable.

Grande Ronde MPG: Two of the four populations should be restored to viable status to meet ICTRT criteria for this MPG. The ICTRT example scenario includes the Upper Grande Ronde River (large size) and either Joseph Creek (current low risk status) or the Lower Grande Ronde River.

Imnaha River MPG: The Imnaha River population should meet highly viable status for this one population MPG to be rated as viable under the basic ICTRT criteria.

Clearwater River MPG: This MPG includes five extant and one extirpated (North Fork Clearwater River) populations. The ICTRT example recovery scenario includes the Lower Clearwater River (large size) and two out of the following three populations (Lochsa River, Selway River and South Fork Clearwater River).

Salmon River MPG: This relatively large MPG includes 11 extant and 1 extirpated (Panther Creek) populations. The ICTRT example scenario for this MPG includes consideration for historical population size, inclusion of both major life history patterns (A and B run timing), and achieving a distribution of viable populations across the region occupied by extant populations. The scenario includes Chamberlain Creek, the Upper Middle Fork and the South Fork populations along with three additional populations at least two of which should be large or intermediate in size.

New Data and Updated Analyses

Adult abundance data series for the Snake River Steelhead DPS are limited to a set of aggregate estimates (total, A-run and B-run counted at Lower Granite Dam), estimates for two Grande Ronde populations (Joseph Creek and Upper Grande Ronde River), and index area or weir counts for subsections of several other populations. A series of juvenile counts based on snorkel transects representative of production within several population aggregates are also available going back to the mid-1980s.

The ICTRT identified the main priorities for addressing key uncertainties regarding the status of this DPS as getting population specific estimates of annual abundance and obtaining information on the relative distribution of hatchery spawners at the population level (ICTRT, 2010). Two projects have been initiated to gain more specific data on the distribution of spawners among populations or geographic aggregations of populations. Preliminary results from a mixed stock analysis genetics sampling approach are promising (Pete Hassemer, IDFG Boise office, personal communication). In addition, adult PIT tag arrays are being installed in the lower sections of several drainages, allowing for mark-recaptured based estimates for some populations or population aggregates.

Standard abundance and trends

Population level abundance data series are available for just 2 populations within this DPS, both are within the Grande Ronde MPG (Table 32). Three other types of abundance indices representative of the remaining populations are available and can be used to infer the overall status of the DPS.

The two population level data sets available for the DPS both show a drop in total abundance since the previous review (Table 32, Figure 45). Natural origin abundance in Joseph Creek is also down relative to the previous review while natural origin abundance for the Upper Grande Ronde is up. Both populations have relatively high proportions of natural origin spawners.

Longer term trend estimates for the populations differ slightly (Table 36). Both series begin with estimates for the early 1970s and extend through 2009. The average trend over the full time period was a negative 1 to 5% per year for the Upper Grande Ronde and a positive 1-4% per year for Joseph Creek across the range of long term trend metrics (Table 36). Estimates of annual spawning escapements into the Upper Grande Ronde River fluctuated around lower levels for a prolonged period except for a peak in the mid-1980s and an increase in the most recent two years. Estimated escapements in Joseph Creek were generally lower in the 1970s, and fluctuated around higher levels after also peaking in the mid-1980s. The aggregate LGR abundance estimates are available for years back to 1986-87 cycle. The general trend in returns has been slightly positive across all groups.

With the exception of the Tucannon River, all of the populations within this DPS are associated with tributaries above Lower Granite Dam. Annual counts of steelhead passing Lower Granite Dam along with estimates of the relative proportions of the hatchery and natural origin are available and can be used as an index of trends in aggregate production. Fisheries managers break the run over Lower Granite into A run and B run types based on fish length data recorded along with the counts. A run returns are believed to primarily represent returns to lower elevation tributaries including the Grande Ronde River, the Imnaha River and some population tributaries in the Clearwater and Salmon Rivers. The larger B run returns are believed to be produced primarily in higher elevation tributaries in the Clearwater and Salmon River basins.

The most recent five-year geometric mean total run (wild plus hatchery origin) to Lower Granite Dam was up substantially from the corresponding estimates for the prior BRT review and the time period leading up to listing (Table 33, Figure 47). Natural origin and hatchery origin returns each showed increases, although hatchery fish increased at a higher rate. Both the aggregate A and B run estimates have increased relative to the levels associated with prior assessments. A large proportion of the hatchery run over Lower Granite Dam returns to hatchery racks or is removed by hatchery selective harvest prior to reaching spawning areas. As a result, the hatchery proportions in the aggregate run over Lower Granite Dam are not indicative of the proportions in spawning escapements into most population tributaries. Monitoring the relative contribution of hatchery returns to spawning in natural areas, particularly those areas near major hatchery release sites, is a high priority for improving future assessments in the DPS.

Table 32. Recent abundance and proportion natural origin compared to estimates at the time of listing and in the previous BRT review. Abundance estimates (five year geometric mean with range in parentheses) corresponding to the time of listing and the 2005 BRT based on best currently available data. Organized by MPG.

Population	Natural Spawning Areas								
	Total Spawners (5 year geometric mean, *range*)			Natural Origin (5 year geometric mean)			% Natural Origin (5 year average)		
	Listing (1991-1996)	Prior (1997-2001)	Current (2003-2008)	*Listing (1991-1996)*	Prior (1997-2001)	Current (2003-2008)	*Listing (1991-1996)*	Prior (1997-2001)	Current (2003-2008)
Joseph Creek	*1337*	2135 (1251-3171)	**1925 (1212-3598)**	*1337*	2134 (1251-3170)	**1925 (1212-3597)**	*100%*	100%	**100%**
Upper Grande Ronde River	*1594*	1772 (1084-2756)	**1442 (949-1943)**	*1249*	1332 (767-2277)	**1425 (941-1943)**	*79%*	76%	**99%**

Table 33. Recent abundance and proportion natural origin for aggregate returns to Lower Granite Dam with comparisons to estimates at the time of listing and in the previous BRT review . Estimates represent run prior to upstream harvest and prespawning mortalities and include fish returning to hatchery racks as well as fish that will spawn in natural areas.

Population	Natural Spawning Areas								
	Total Spawners (5 year geometric mean, *range*)			Natural Origin (5 year geometric mean)			% Natural Origin (5 year average)		
	Listing (1991-1996)	Prior (1997-2001)	Current (2003-2008)	*Listing (1991-1996)*	Prior (1997-2001)	Current (2003-2008)	*Listing (1991-1996)*	Prior (1997-2001)	Current (2003-2008)
LGR Run	*77,761*	*85,343*	***162,323***	*11,462*	*10,693*	**18,847**	*15%*	13%	**10%**
A Run	*61,727*	*70,130*	***144,230***	*8,869*	*8,888*	**15,395**	*14%*	13%	**11%**
B Run	*15,104*	*14,491*	***33,056***	*2,505*	*1,718*	**3,291**	*17%*	11%	**10%**

Index area data series representing portions of three additional populations in the Grande Ronde and Lower Snake MPGs are available (Figure 46). All four series are highly variable and show similar temporal patterns to the population and DPS aggregate level data sets.

The Idaho Department of Fish and Game (IDFG) has routinely collected juvenile *O. mykiss* density estimates across a series of fixed transects distributed across tributary habitats in Idaho since the mid-1980s. The sampling design and intensity was not set up to generate total production estimates at the population or regional level, but the results are considered to be generally indicative of trends in total natural production. IDFG considers the set of transects in B channel type habitat as indicative of steelhead production and aggregates annual results across transects in four subcategories (Figure 48). Average densities in areas assigned as A run habitats trended downwards from 1985 through the mid-1990s, returning to levels similar to the earliest years in the series after 2000. Similar patterns were observed in transects in natural (areas near hatchery production release sites) vs. areas classified as wild. Areas classified as B run wild appear to follow a similar pattern. The average juvenile densities in areas classified by IDFG as natural fluctuated around a relatively constant level from 1985 through the most recent year in the series (2007).). In general, the median densities across individual transect series were the highest for lower elevation populations or tributaries (Figure 48). The highest median densities were observed in the small tributaries below Hells Canyon Dam, the Lower Clearwater and Lochsa Rivers (Clearwater MPG) and the Secesh, Little Salmon River, North ForkSalmon River, Panther Creek and Lemhi River (Salmon MPG).

Table 34. Trend in total (natural areas) spawners. Snake River steelhead. Comparison of current trends to prior reviews.

Population	**Short-term trend**		
	1998 BRT (1987-97)	Previous (1990-2001)	**Current** **(1995-2008)**
Estimate **(CI)** ***Prob>1.0***	0.84 (0.73 - 0.96) 0.01	1.04 (0.93 - 1.16) 0.75	**1.11** **(1.01 - 1.22)** **0.98**
Estimate **(CI)** ***Prob>1.0***	0.98 (0.85 - 1.13) 0.39	0.981 (0.85 - 1.13) 0.79	**0.98** **(0.85 - 1.13)** **0.20**

Table 35. Short Term (since 1995) population growth rate (lambda) estimates. Current estimates vs. 2005 BRT short term time series.

Population	**Short-term Lambda**			
	Hatchery effectiveness= 0		**Hatchery effectiveness= 1.0**	
	2005 BRT (1990-2001)	**Current** **(1995-2008)**	2005 BRT (1990-2001)	**Current** **(1995-2008)**
Joseph Creek	1.02 (0.33 - 3.16) 0.57	**1.08** **(0.64 - 1.83)** **0.84**	1.02 (0.33 - 3.16) 0.57	**1.08** **(0.64 - 1.83)** **0.84**
Upper Grande Ronde River	1.03 (0.91 - 1.167) 0.89	**0.96** **(0.79 - 1.15)** **0.10**	0.97 (0.82 - 1.15) 0.14	**0.92** **(0.65 - 1.29)** **0.09**

Table 36. Long term trends in spawning abundance for Snake River Steelhead populations.

Population	Years	Trend in total Spawners Estimate (CI)	Lambda (HF=0) Estimate (CI)	Prob>1	Lambda(HF=1) Estimate (CI)	Prob>1
Joseph	1970-2010	1.04 (1.01 - 1.07)	1.01 (0.83 - 1.24)	0.56	1.01 (0.83 - 1.24)	0.56
UGR	1967-2010	0.99 (0.97 - 1.01)	0.97 (0.87 - 1.09)	0.296	0.95 (0.85 - 1.07)	0.18

Figure 45. Snake River Steelhead population estimates. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

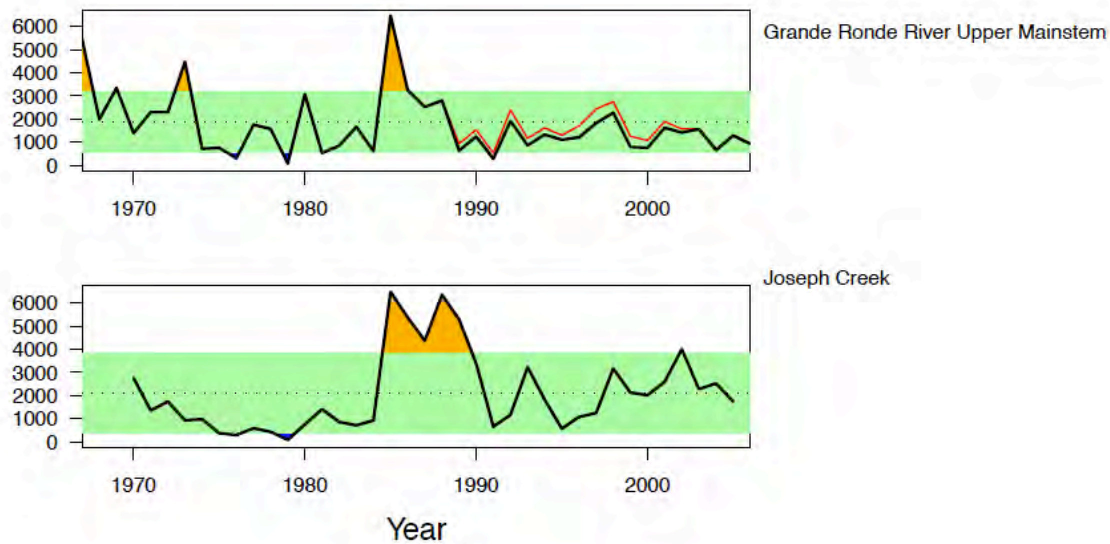
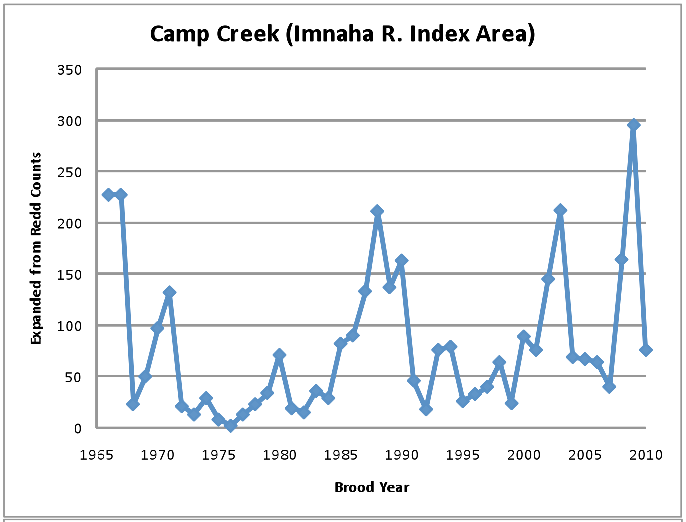
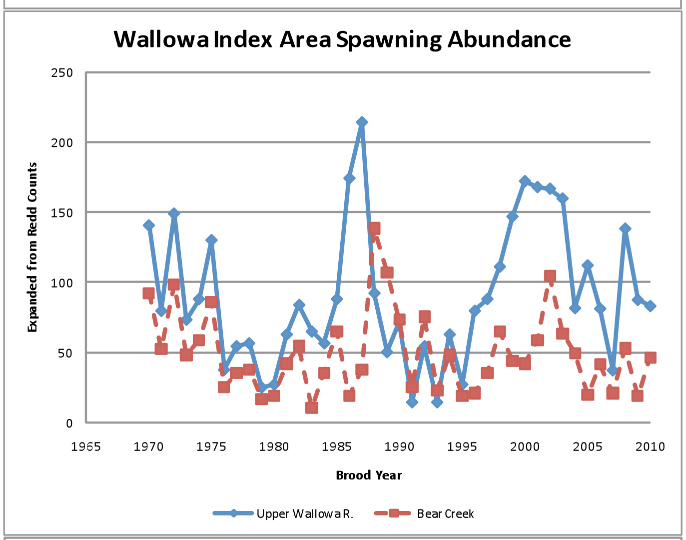


Figure 46. Snake River Steelhead index areas. Annual spawner abundance for index area only (natural origin and total).





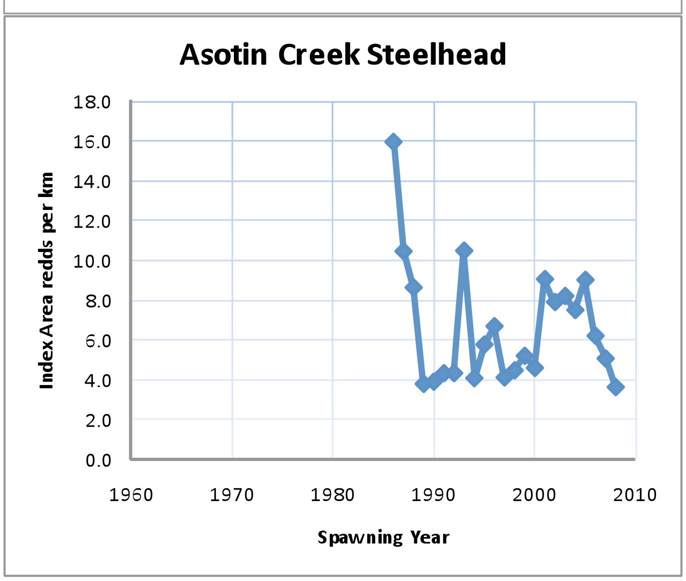
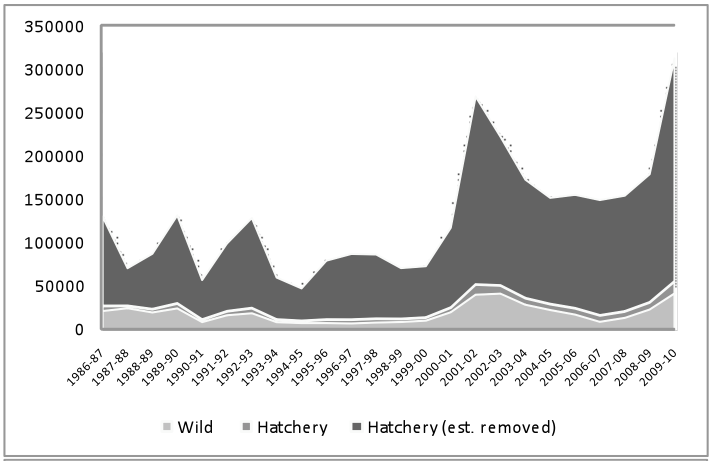
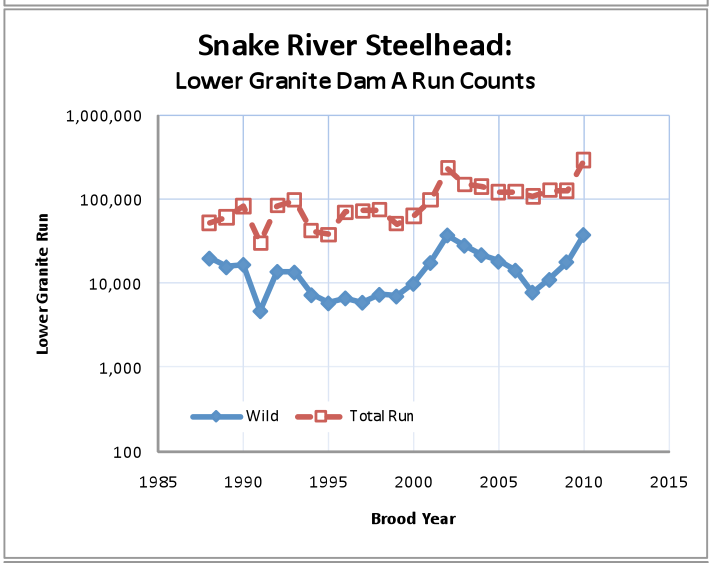


Figure 47. Lower Granite Dam Counts for Snake River Steelhead.





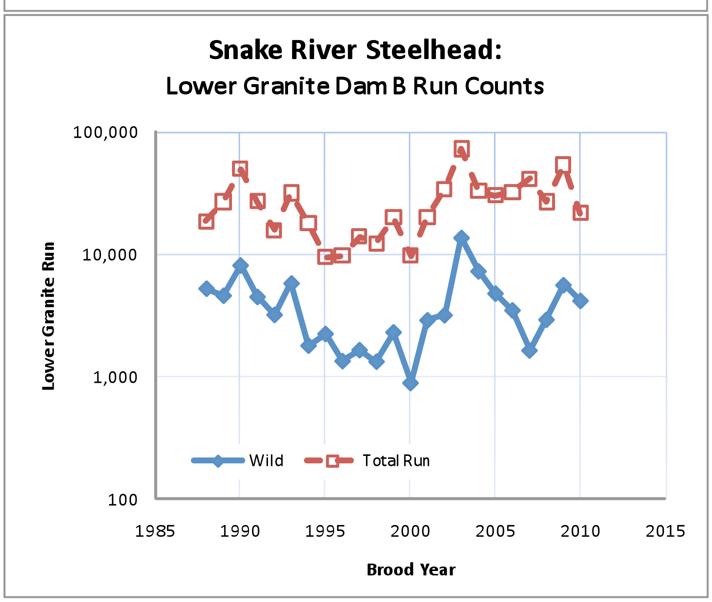
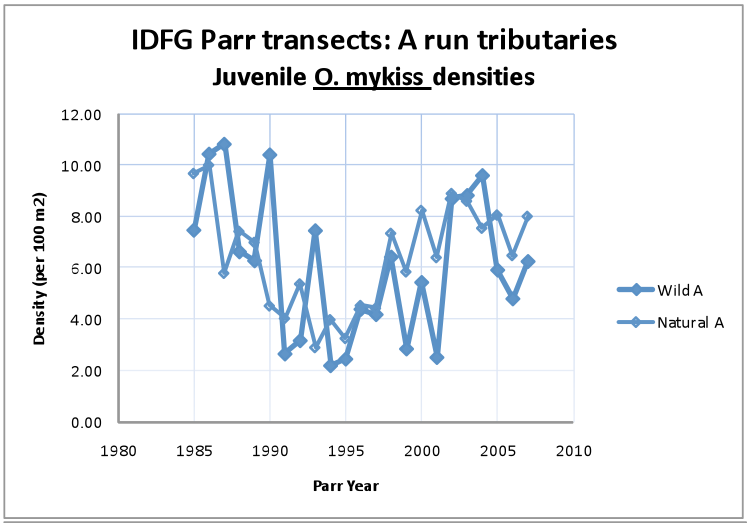
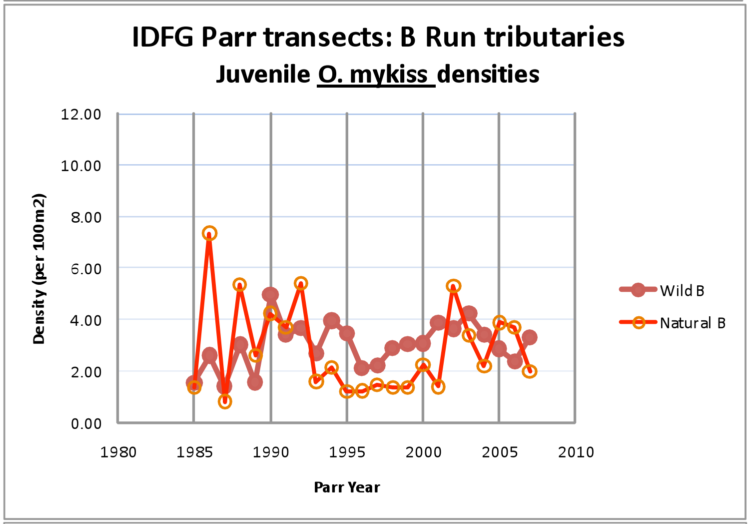
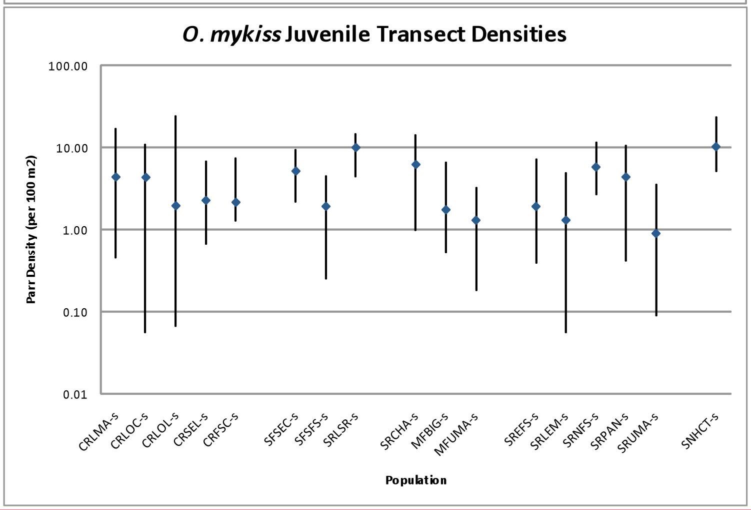


Figure 48. Juvenile Snake River Steelhead parr densities observed in IDFG snorkel transects.







Current Status: ICTRT Viability Criteria

Only two of the twenty-three extant populations of Snake River steelhead have estimates of population specific spawning abundance. The ICTRT used aggregate estimates of abundance at Lower Granite Dam along with juvenile indices of abundance available for some areas to infer abundance and productivity ratings for populations without specific adult abundance time series (ICTRT, 2010). Both populations with specific spawning abundance data series are in the Grande Ronde MPG. The rating for the Joseph Creek population overall viability rating remained as Highly Viable after updating the analysis to include returns through the 2009 spawning year. The increase in natural origin abundance for the other population with a data series, the Upper Grande Ronde River, was not sufficient to change the abundance/productivity criteria rating from moderate risk. Changes in status as a result of updating the aggregate or isolated index abundance series used to assign generic ratings to the remaining populations were relatively small (see discussion under short term abundance and trends above). Therefore the ratings assigned to those populations in the previous ICTRT status review (ICTRT, 2010) were retained in Table 37.

The ICTRT identified obtaining annual estimates of population level spawning abundance and hatchery/wild proportions as among the highest priority opportunities for improved assessments of Interior Basin ESUs/DPSs (ICTRT, 2010). Direct survey methods for assessing annual spawning escapement into Idaho tributaries have been tried in the past and have proved extremely difficult to carry out in a way that produces consistent estimates across areas and years, largely because of visibility and access conditions during the late spring steelhead spawning window. Two different approaches with potential for routinely generating representative annual estimates of spawning escapements into specific or subgroupings of populations have recently been initiated. First year results from both efforts are promising. Initial results from one of the approaches, using a genetic baseline with representation of several populations or population subgroupings to partition the natural origin return estimates at Lower Granite among areas, indicate that some populations assumed to be either A or B run may support a mixture of the two run types (P. Hassemer, IDFG pers. comm.). Results from this ongoing effort and the companion study based on adult PIT tag detections should allow for improved population specific assessments for the next five year status review.

<u>Harvest</u>

Summer-run steelhead from the upper basin are divided into 2 runs by managers: The A-run, and the B-run. These runs are believed have differences in timing, but managers separate them on the basis of size alone in estimating the size of the runs. The A-run is believed to occur throughout the Middle Columbia, Upper Columbia, and Snake River Basins, while the B-run is believed to occur naturally only in the Snake River ESU, in the Clearwater River, Middle Fork Salmon River, and South Fork Salmon River.

Steelhead were historically taken in tribal and non-tribal gillnet fisheries, and in recreational fisheries in the mainstem Columbia River and in tributaries. In the 1970s, retention of steelhead in non-tribal commercial fisheries was prohibited, and in the mid-1980s, tributary recreational fisheries in Washington adopted mark-selective regulations. Steelhead are still harvested in tribal fisheries, in mainstem recreational fisheries, and there is incidental mortality associated with mark-selective recreation recreational fisheries. The majority of impacts on the summer run occur in tribal gillnet and dip net fisheries targeting Chinook salmon. Because of their larger size, the B-rum fish are more vulnerable to the gillnet gear. Consequently, this component of the summer run experiences higher fishing mortality than the A-run component (Figure 49). In recent years, total exploitation rates on the A-run have been stable at around 5%, while exploitation rates on the B-run have generally been in the range of 15% to 20%.

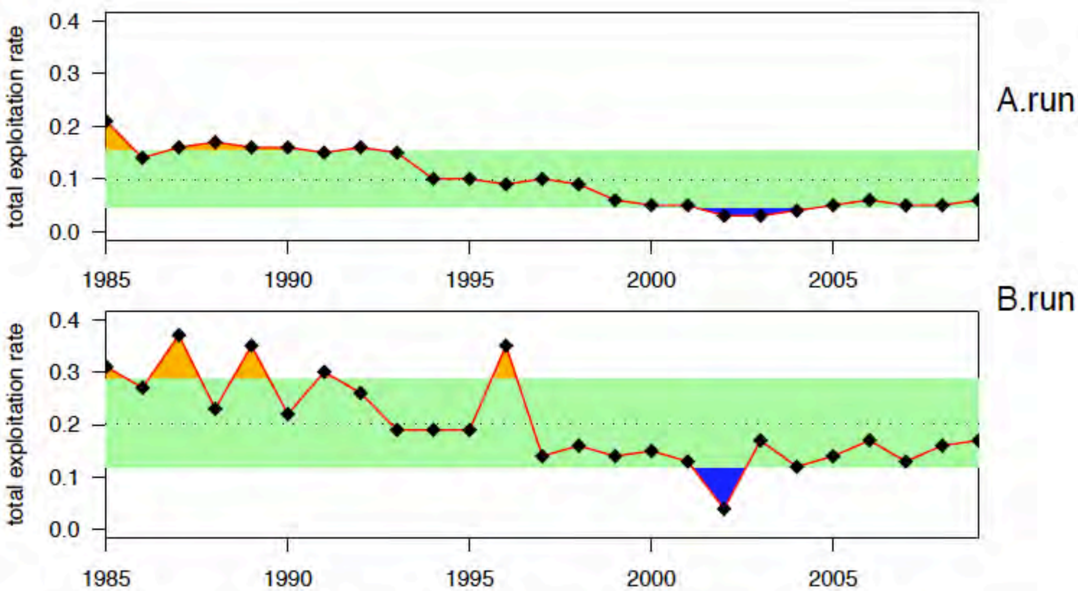


Figure 49 -- Total harvest impacts on natural summer steelhead above Bonneville Dam. Data for 1985-1998 from NMFS biological opinion (Peter Dygert, NMFS, personal communication), and for 1999-2008 from TAC run reconstruction (Cindy LeFleur, WDFW personal communication).

Hatchery releases

Steelhead hatchery releases within the ESU have generally trended downwards since 1990. The most recent five year average release is approximately 20% below the 1997-2001 average (Figure 50).

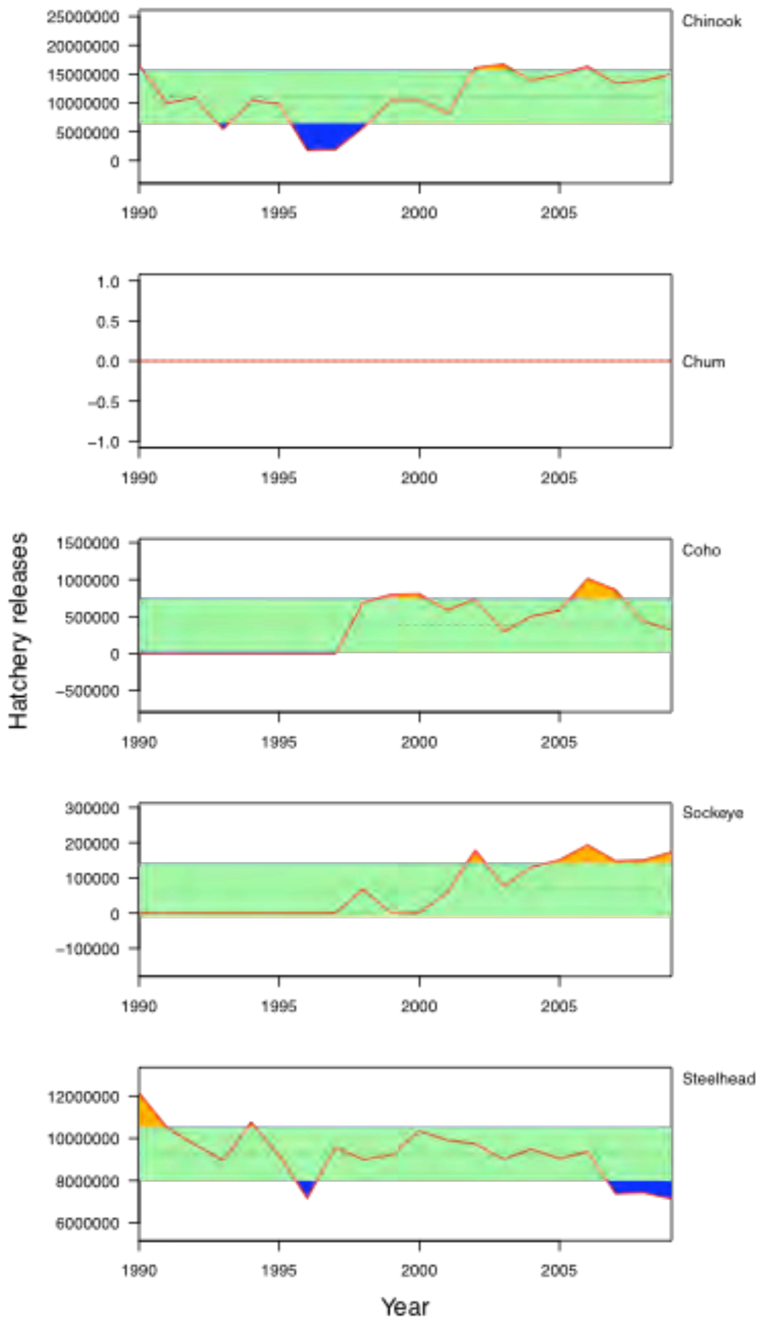


Figure 50 – Hatchery releases within the Snake River steelhead DPS. Dotted line indicates the mean and the shared area indicates the standard deviation. Data source: RMIS.

Table 37. Current status ratings using ICTRT viability criteria for Snake River Steelhead populations grouped by MPG.

Population	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
	ICTRT Minimum Threshold	*Natural Spawning Abundance*	*ICTRT Productivity*	*Integrated A/P Risk*	*Natural Processes Risk*	*Diversity Risk*	*Integrated SS/D Risk*	
Tucannon River	1,000	Insufficient data	Insufficient data	**High??**	Low	Moderate	**Moderate**	**HIGH RISK??**
Asotin Creek	500	Insufficient data	Insufficient data	**Maintained**	Low	Moderate	**Moderate**	**MAINTAINED?** (HIGH RISK??)
Lower Grande Ronde River	1,000	Insufficient data	Insufficient data		Low	Moderate	**Moderate**	**MAINTAINED?**
Joseph Creek 2000-2009 *1995-2004*	500	2186 (1212-4751) 1878 (573-4751)	1.94 (1.52-2.46) 2.91 (2.21-3.82)	**Very Low**	Very Low	Low	**Low**	**HIGHLY VIABLE**
Upper Grande Ronde River 2000-2009 *1995-2004*	**1500**	1340 (673-1943) 1240 (673-2277)	2.13 (1.20-3.77) 2.70 (1.65-4.41)	**Viable** (Moderate)	Very Low	Moderate	**Moderate**	**MAINTAINED**
Wallowa River	1,000	Insufficient data		**High??**	Very Low	Low	**Low**	**HIGH RISK??**
Lower Main. Clearwater R.	1,500	Insufficient data	Insufficient data	**Moderate?**	Very Low	Low	**Low**	**MAINTAINED?**
South Fork Clearwater R.	1,000	Insufficient data	Insufficient data	**High**	Low	Moderate	**Moderate**	**HIGH RISK?**
Lolo Creek	500	Insufficient data	Insufficient data	**High**	Low	Moderate	**Moderate**	**HIGH RISK?**
Selway R.	1,000	Insufficient data	Insufficient data	**High**	Very Low	Low	**Low**	**HIGH RISK?**
Lochsa R.	1,000	Insufficient data	Insufficient data	**High**	Very Low	Low	**Low**	**HIGH RISK?**
Little Salmon R.	500	Insufficient data	Insufficient data	**Moderate**	Low	Moderate	**Moderate**	**MAINTAINED?**
South Fork Salmon R.	1,000	Insufficient data	Insufficient data	**High**	Very Low	Low	**Low**	**HIGH RISK?**
Secesh R.	500	Insufficient data	Insufficient data	**High**	Low	Low	**Low**	**HIGH RISK?**
Chamberlain Creek	500	Insufficient data	Insufficient data	**High**	Low	Low	**Low**	**HIGH RISK?**
Lower Middle Fork Salmon R.	1,000	Insufficient data	Insufficient data	**High**	Very Low	Low	**Low**	**HIGH RISK?**
Upper Middle Fork Salmon R.	1,000	Insufficient data	Insufficient data	**High**	Very Low	Low	**Low**	**HIGH RISK?**
Panther Creek	500	Insufficient data	Insufficient data	**Moderate**	High	Moderate	**High**	**HIGH RISK?**
North Fork Salmon R.	500	Insufficient data	Insufficient data	**Moderate**	Low	Moderate	**Moderate**	**MAINTAINED?**
Lemhi R.	1,000	Insufficient data	Insufficient data	**Moderate**	Low	Moderate	**Moderate**	**MAINTAINED?**
Pahsimeroi R.	1,000	Insufficient data	Insufficient data	**Moderate**	Moderate	Moderate	**Moderate**	**MAINTAINED?**
East Fork Salmon R.	1,000	Insufficient data	Insufficient data	**Moderate**	Very Low	Moderate	**Moderate**	**MAINTAINED?**
Up Main. Salmon R.	1,000	Insufficient data	Insufficient data	**Moderate**	Very Low	Moderate	**Moderate**	**MAINTAINED?**

Snake River Steelhead: Updated Risk Summary

The level of natural production in the two populations with full data series and the Asotin Creek index reaches is encouraging, but the status of most populations in this DPS remains highly uncertain. Population-level natural origin abundance and productivity inferred from aggregate data and juvenile indices indicate that many populations are likely below the minimum combinations defined by the ICTRT viability criteria. A great deal of uncertainty remains regarding the relative proportion of hatchery fish in natural spawning areas near major hatchery release sites. There is little evidence for substantial change in ESU viability relative to the previous BRT and ICTRT reviews. Overall, therefore, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good, T.P., R.S. Waples and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. of Commer, NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

ICTRT, 2003. Independent populations of chinook, steelhead and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Interior Columbia Basin Technical Recovery Team Technical Review Draft. July 2003. 171 p.

ICTRT, 2007. Viability criteria for application to interior Columbia Basin salmonid ESUs. Interior Columbia Basin Technical Recovery Team. Technical Review Draft. March 2007. 91 p + appendices and attachments.

ICTRT (2010) Current status reviews: Interior Columbia Basin salmon ESUs and steelhead DPSs. Vol. 1. Snake River ESUs/DPS. 786 p. + attachments

Puget Sound Chinook salmon[14]

The ESU was identified and assessed as part of the Chinook salmon coastwide status review in 1998 (Myers et al. 1998) and reassessed in 2005 (Good et al. 2005). The ESU was listed as a threatened species on March 24, 1999; threatened status reaffirmed on June 28, 2005. The ESU includes all naturally spawned populations of Chinook salmon from rivers and streams flowing into Puget Sound including the Strait of Juan De Fuca from the Elwha River, eastward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington, as well as twenty-six artificial propagation programs: the Kendal Creek Hatchery, Marblemount Hatchery (fall, spring yearlings, spring subyearlings, and summer run), Harvey Creek Hatchery, Whitehorse Springs Pond, Wallace River Hatchery (yearlings and subyearlings), Tulalip Bay, Issaquah Hatchery, Soos Creek Hatchery, Icy Creek Hatchery, Keta Creek Hatchery, White River Hatchery, White Acclimation Pond, Hupp Springs Hatchery, Voights Creek Hatchery, Diru Creek, Clear Creek, Kalama Creek, George Adams Hatchery, Rick's Pond Hatchery, Hamma Hamma Hatchery, Dungeness/Hurd Creek Hatchery, Elwha Channel Hatchery Chinook hatchery programs.

Previous Status Reviews and Recovery Documents

In the 2005 review (Good et al. 2005), it was determined that overall, the natural spawning escapement for Puget Sound Chinook salmon populations were improved relative to those at the time of the previous status review of Puget Sound Chinook salmon conducted with data through 1997 (Myers et al. 1998). Also, the overall trends in natural spawning escapements for Puget Sound Chinook salmon populations estimated in 2005 remained similar to that presented in the previous status review (data through 1997), with some populations doing marginally better and others worse.

A recovery plan was submitted by Shared Strategy and adopted by NMFS in January 2007. The Puget Sound Technical Recovery Team (TRT) finalized their population identification for this ESU in 2006 (Ruckelshaus et al. 2006) and developed their viability planning ranges in 2002 (PSTRT 2002).

ESU Status at a Glance

Listing status:	Threatened	
Historical peak run size	≈690,000	(1908)
Historical populations	31	
Peak run size since 1990	152,000	(1990)
Maximum spawners since 1990	45,000	(2004)
Extant populations	22	
Geographic recovery regions	5	
Viable spawner abundance at equilibrium		
For populations	See Table 38	
For ESU	307,500	
Number of populations per region with low extinction risk for ESU to be viable	2-4	

[14] Section author: Norma Sands

ESU Structure

The Puget Sound Chinook salmon ESU is composed of 31 historically quasi-independent populations, 22 of which are extant (Ruckelshaus et al. 2006). The populations are distributed in 5 geographic regions identified by the TRT (PSTRT 2002) based on similarities in hydrographic, biogeographic, and geologic characteristics of the Puget Sound basin. Maintaining populations in each region is important to the ESU viability. The TRT presented viable spawning abundances for 16 of the 22 populations in their viability report. For this status review, values for the missing populations are extrapolated based on a recovered productivity equal to that of the average for the 16 populations (recruits per spawner (R/S) = 3.2), and maximum sustainable yield (MSY) spawner estimates based on the linear relationship between maximum observed spawners and MSY spawners for the 16 populations, and a linear relationship between MSY spawners and replacement spawners. These are tentative estimates until population specific estimates are available. In Table 38, the spawning abundances at replacement (growth rate = 1) are the minimum target viability abundance. It is important to note that these are viability abundances assuming low (replacement only) productivity – higher productivity would result in lower viable spawning abundances. For example, spawners at MSY represent the spawning level at MSY under properly functioning habitat conditions. As populations begin to recover, additional viability analysis should be undertaken to determine the variability and viability of each population.

Table 38 -- Extant populations of Chinook salmon in the Puget Sound Chinook ESU, grouped by geographic region, and their minimum viability spawning abundance and abundance at equilibrium or replacement, and spawning abundance and productivity (R/S) at maximum sustainable yield (MSY) for a recovered state as determined by EDT analyses of properly functioning conditions and expressed as a Beverton-Holt function (values in regular font are from PSTRT 2002 and those in italics are derived as explained in text). The TRT minimum viability abundance was the equilibrium abundance or 17,000, which ever was less.

	TRT viability	Under Properly Functioning Conditions (PFC)		
Region & Population	min viability abundance	equilibrium abundance	spawners at MSY	prod at MSY
Strait of Georgia				
NF Nooksack	16,000	16,400	3,680	3.4
SF Nooksack	9,100	9,100	2,000	3.6
Whidbey Basin				
Lower Skagit	16,000	15,800	3,900	3.0
Upper Skagit	17,000	26,000	5,368	3.8
Cascade	1,200	1,200	290	3.0
Lower Sauk	5,600	5,600	1,400	3.0
Upper Sauk	3,000	3,000	750	3.0
Suiattle	600	600	160	2.8
NF Stillaguamish	17,000	18,000	4,000	3.4
SF Stillaguamish	15,000	15,000	3,600	3.3
Skykomish	17,000	39,000	8,700	3.4
Snoqualmie	17,000	25,000	5,500	3.6
Central/South Puget Sound				

Sammamish (1)	*10,500*	*10,500*	*2,400*	*3.2*
Cedar	*11,500*	*11,500*	*2,600*	*3.2*
Green	*17,000*	*22,000*	*4,900*	*3.2*
White	*14,200*	*14,200*	*3,200*	*3.2*
Puyallup	17,000	18,000	5,300	2.3
Nisqually	13,000	13,000	3,400	3.0
Hood Canal				
Skokomish	*12,800*	*12,800*	*2,900*	*3.2*
Mid Hood Canal (2)	*11,000*	*11,000*	*2,500*	*3.2*
Strait of Juan de Fuca				
Dungeness	4,700	4,700	1,000	3.0
Elwha	*15,100*	*15,100*	*3,400*	*3.2*
ESU	261,300	307,500	70,948	3.2

1. The Sammamish population was referred to as North Lake Washington population in the TRT viability report.

2. The Mid Hood Canal population consists of spawning aggregations from Dosewallips, Duckabush, and Hamma Hamma. Only the Dosewallips was listed in the TRT viability report.

New Data and Updated Analyses

This status report reflects updates in population data through 2009 that were received as data files from the comanagers as result of the request for data in the federal register. Availability of updates for age and hatchery contribution data varied from population to population and estimates were obtained from the annual post-season harvest reports provided by comanagers. Age data are not available for all years with escapement data. Missing age distribution data are estimated by weighting the average cohort age distribution by the escapement abundance for years contributing to the cohort return (Sands 2007). It is important to note that data collection methodologies have changed somewhat over the course of the time series analyzed, which creates some uncertainty and potential bias in the calculations of trends.

This status analysis starts with data from 1985 when we have escapement data from all populations in the ESU. In addition to including additional recent years of spawning data compared to the 2005 status review, the report also incorporates updates/corrections made in past escapement, age, and hatchery contribution data for several of the populations.

Harvest rate estimates, age specific for mixed maturity catch and mature (terminal) catch are from the Pacific Salmon Commission Chinook Technical Committee's exploitation rate analysis of coded-wire tagged hatchery indicator stocks. Estimates were available through the 2006 brood year age 2 catch (catch in 2008). To complete estimates for brood years 2004 to 2006, the average age-specific rate for the previous three years of available data was used. Thus for brood year 2006, the rate is mostly from the previous years. Catch is estimated as a product of harvest rate and escapement, so in the most recent 5 years as harvest rates have not varied greatly from year to year; variations in catch are influenced more by variations in escapement estimates.

Productivity estimation is from cohort run reconstruction using the PS TRT Abundance & Productivity Excel Files (Sands 2009).

Abundance of Natural Spawners and Natural-Origin Pre-Harvest Recruits

During the period 1985-2009, for which we have escapement data for all populations in the ESU, ESU natural spawning abundance was at a mid range from 1985-1990, declined during the period from 1991-1999, increased from 2000-2004, and then decreased again from 2004-2009, with 2009 being back down at the 1990's low levels (Figure 51). The highest abundances were in 2002, 2004, and 2006, with 2004 having the highest abundance with 45,000 NOR spawners and 60,000 total (NOR + hatchery) natural spawners. Hatchery fish contributed from 15% to 40% of the natural spawners for the ESU as a whole during these years.

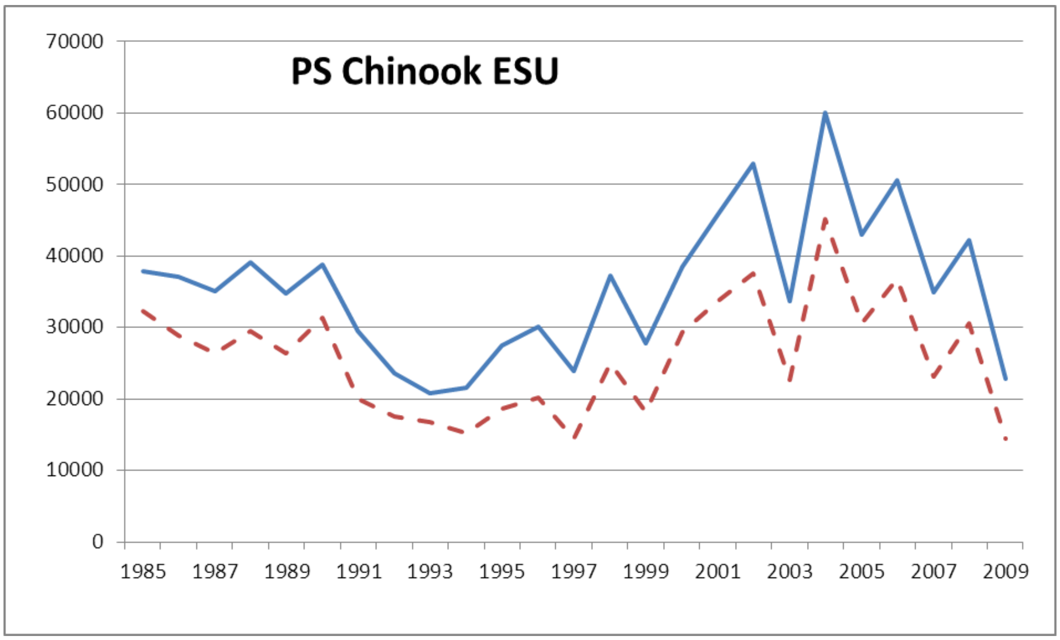


Figure 51 -- Total natural spawners (natural and and hatchery origin combined) for the Puget Sound Chinook ESU (solid line) and the natural-origin spawners (dashed line).

Average escapements (geometric mean) for five-year intervals are given in Table 39 along with estimates of trends[15] over the intervals for natural escapement (hatchery plus natural-origin) and for natural-origin only escapement. Annual escapement data, both total natural spawners and natural origin spawners are given in Table 44.

The most recent 5-year (2005-2009) geometric mean of natural spawners in populations of Puget Sound Chinook salmon ranges from 81 (in the Mid-Hood Canal population) to almost 10,345 fish (in the upper Skagit population) (Table 39, Figure 52 to Figure 57). Most populations contain natural spawners numbering in the high hundreds (median recent natural escapement = 909). No trend is notable for the total ESU escapements; while trends vary from decreasing to increasing among populations.

[15] Trend is calculated over the natural log of escapement, taking the exponential to transform the result back to normal numbers.

Table 39 -- Abundance –Five-year geometric means for adult (age 3+) natural (natural and hatchery origin) and natural origin only spawners for the ESU with ranges and medians given for the populations. The trend is calculated over 5 periods of 5 year averages.

	Natural Escapement			Natural Origin Escapement		
Year Range	ESU	pop range	pop median	ESU	pop range	pop median
85-89	36,750	46-8,276	770	28,601	30-7,965	725
90-94	26,094	101-5,511	395	19,511	20-5,304	381
95-99	28,981	104-6,792	479	19,011	18-5,982	380
00-04	45,214	202-12,109	999	32,794	71-11,678	430
05-09	37,409	81-10,345	909	25,848	44-9,724	482
Trend	1.06	0.77-2.42	1.07	1.03	0.67-2.35	1.00

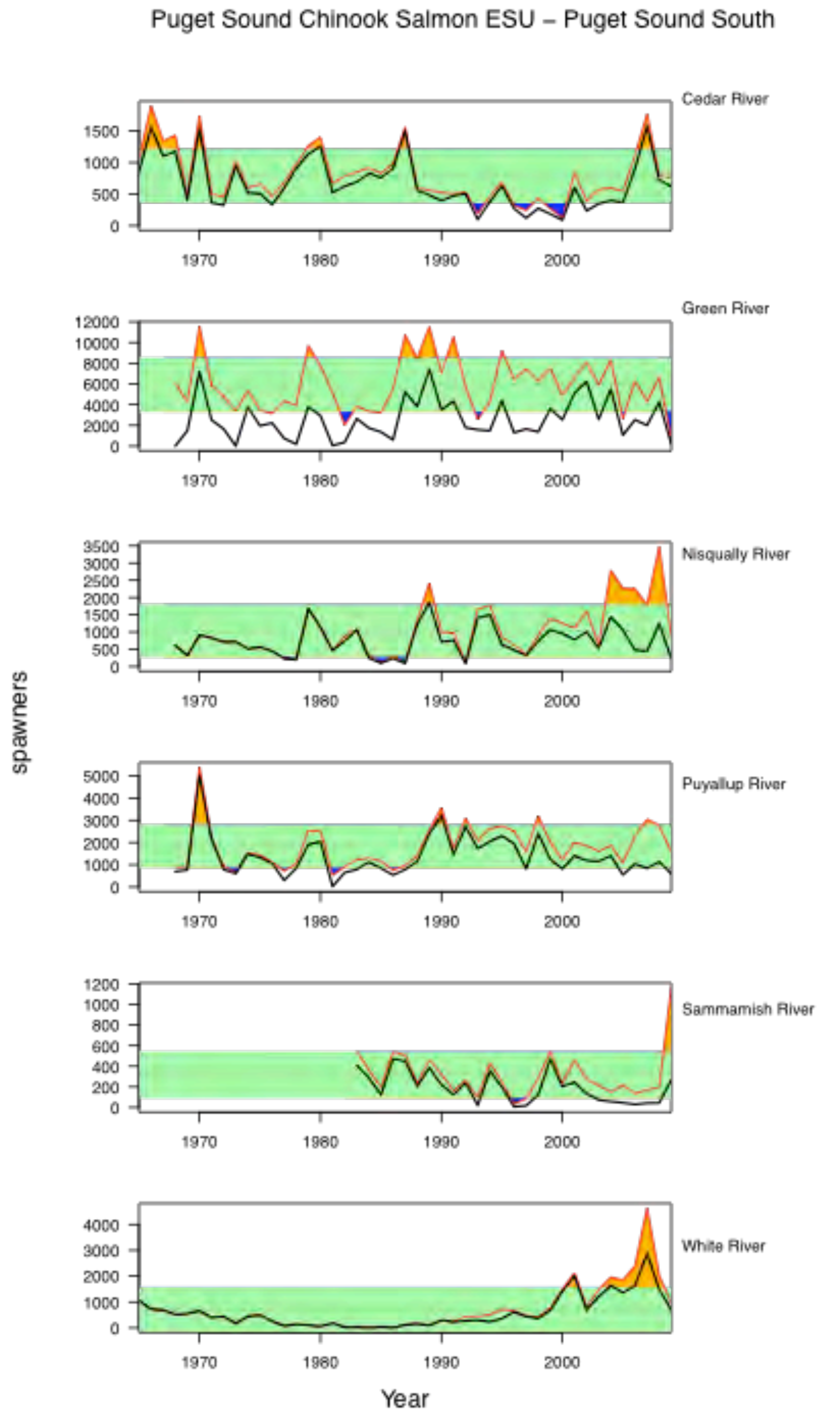


Figure 52 – Spawning abundance for the Central/South Major Population Group in the Puget Sound Chinook salmon ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

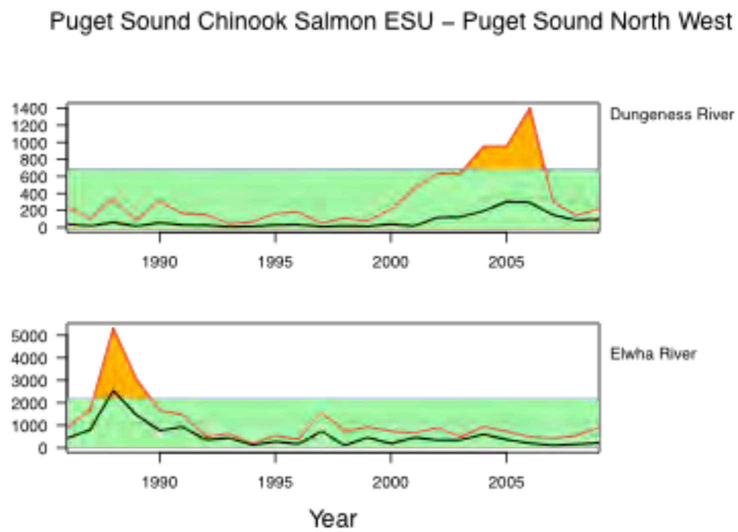


Figure 53 -- Spawning abundance for the North West or Strait of Juan de Fuca Major Population Group in the Puget Sound Chinook salmon ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

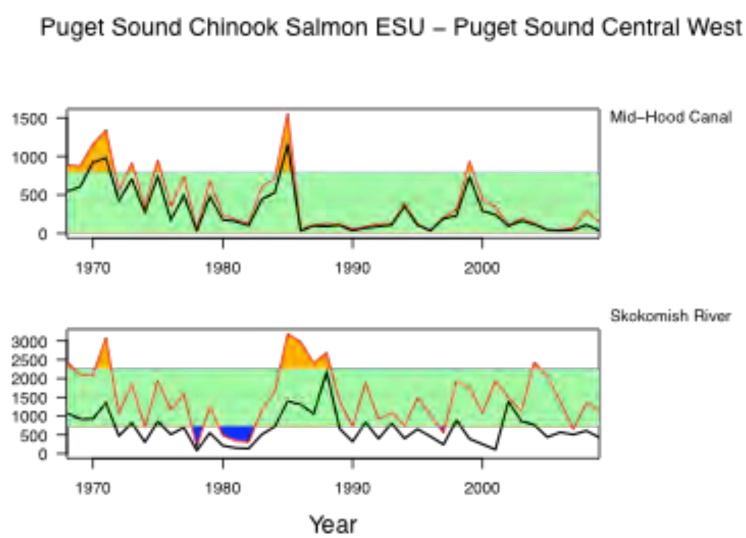


Figure 54 -- Spawning abundance for the Central West or Hood Canal Major Population Group in the Puget Sound Chinook salmon ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time

series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

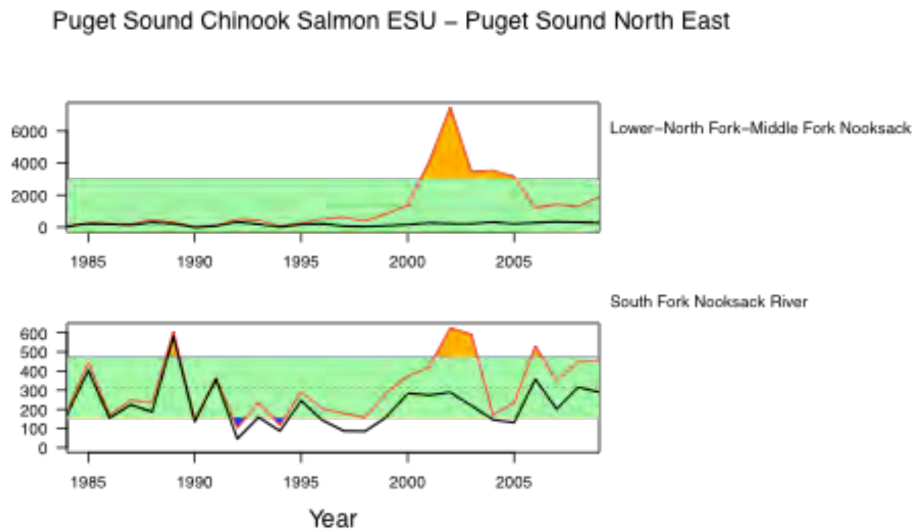


Figure 55 -- Spawning abundance for the North East or Strait of Georgia Major Population Group in the Puget Sound Chinook salmon ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

Puget Sound Chinook Salmon ESU – Puget Sound Central East

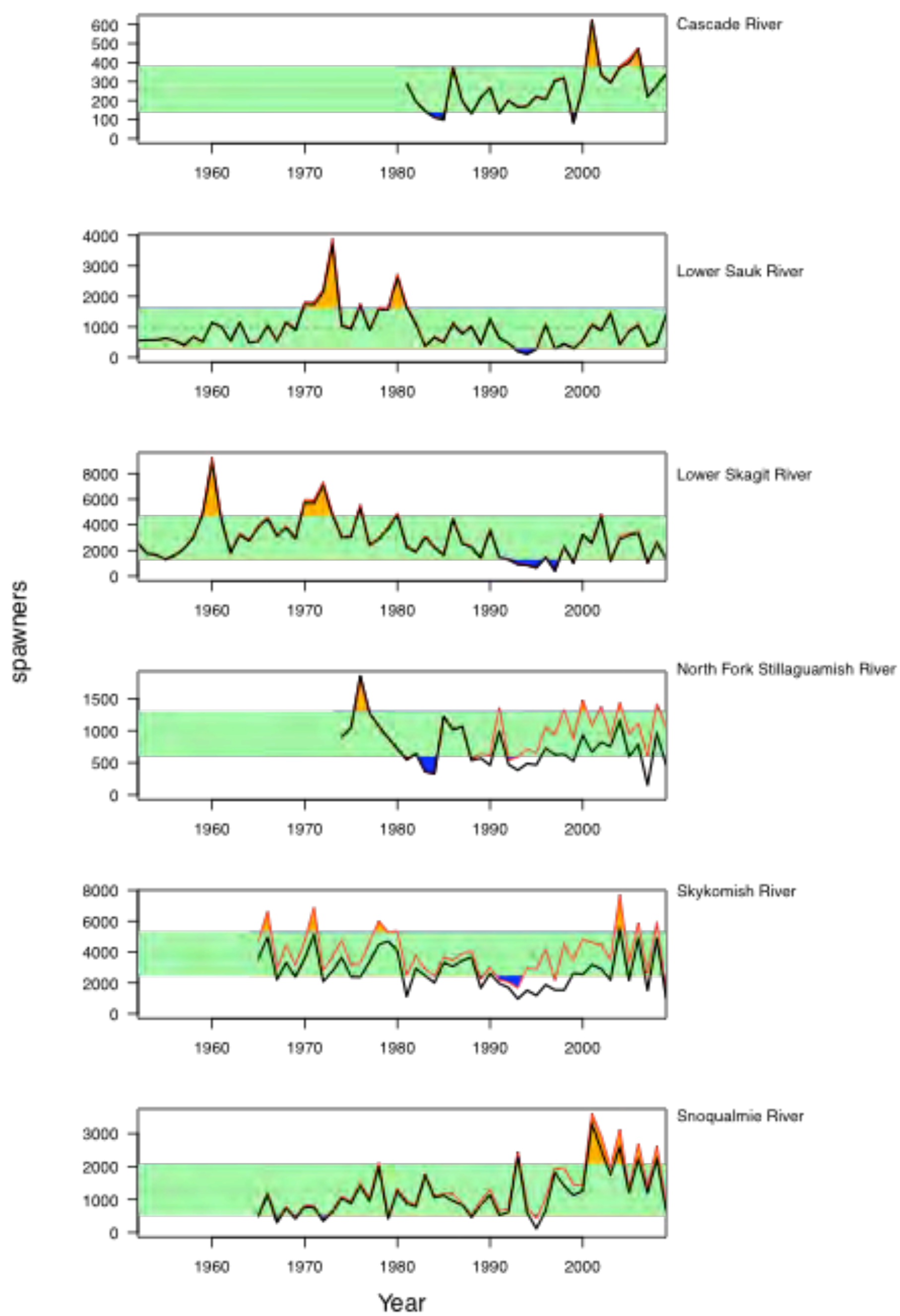


Figure 56 -- Spawning abundance for the Central East or Whidby Basin Major Population Group in the Puget Sound Chinook salmon ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole

time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

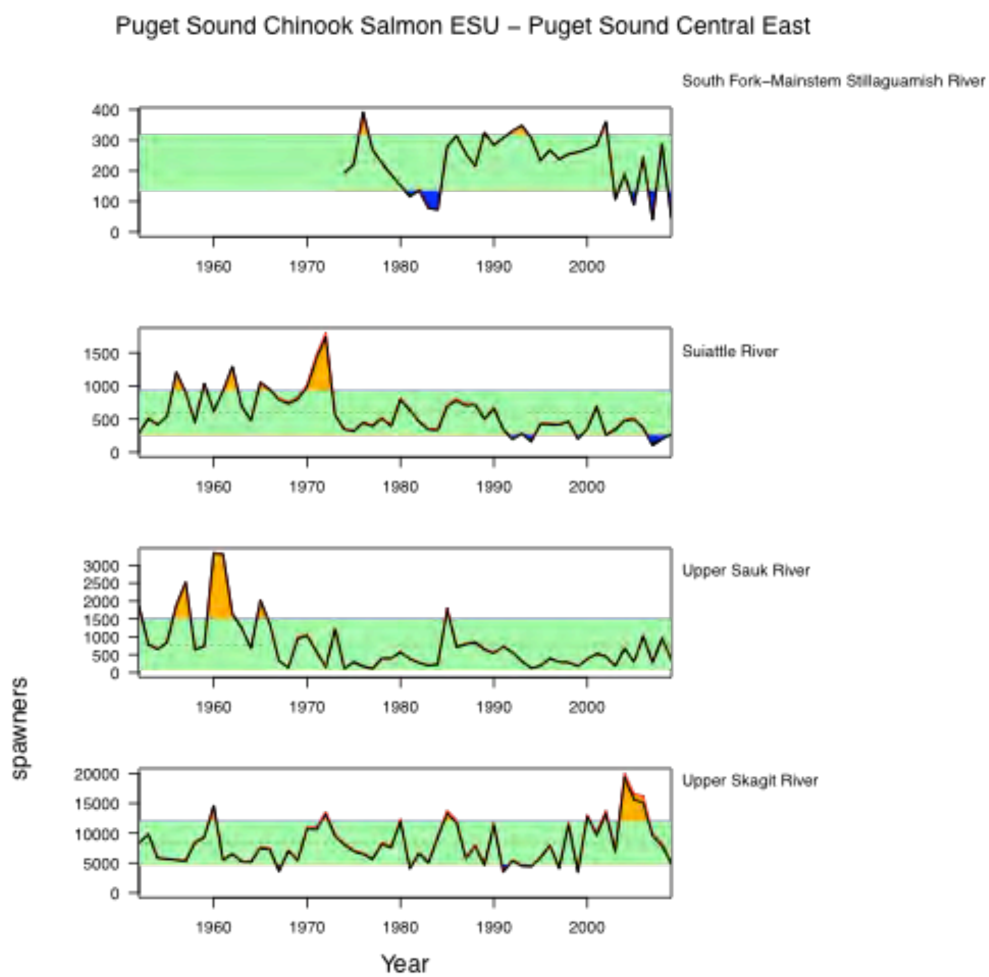


Figure 57 -- Spawning abundance for the Central East or Whidby Basin (continued) Major Population Group in the Puget Sound Chinook salmon ESU. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

During this period (1985-2000), returns (pre-harvest run size) from the natural spawners was highest in 1985 and showed a decline through 1994, remained low through 1999, increased in 2000 and again in 2001 and has shown a decline through 2009, with 2009 having the lowest returns since 1997. Pre-harvest returns reflect productivity of the populations due to environmental conditions, while spawning abundance returns reflects both environmental variation and the pressures from harvest and broodstock take.

Short and long term trends and growth rates (lambda) are provided in Table 40. Estimates of lambda are provided for two alternative assumptions: that hatchery fish have zero success on the spawning grounds and that their spawning success is equivalent to natural origin fish. For the

Puget Sound Chinook populations, it makes a big difference as to the estimate of NOR growth and productivity whether the hatchery fish are supporting natural spawning production. It would be good to be able to get estimates of hatchery fish success on the spawning grounds for most all of the populations, except for populations where hatchery fish are only a small component of the natural spawners, such as the Skagit populations.

Table 40 -- Short and long term population trend and growth rate estimates for the Puget Sound Chinook ESU populations.

			Hatchery Fish Success =0		Hatchery Fish Success =1	
Regions and Populations	Years	Trend Nat Sp w/CI	Lambda w/CI	p>1	Lambda w/CI	p>1
Strait of Georgia Region						
Lower-North Fork-Middle Fork Nooksack early run	1995-2009	1.092 (1.023 - 1.165)	1.082 (0.622 - 1.884)	0.84	0.607 (0.232 - 1.589)	0.05
	1984-2009	1.049 (0.995 - 1.106)	1.032 (0.909 - 1.172)	0.74	0.729 (0.571 - 0.93)	0.01
South Fork Nooksack River early run	1995-2009	1.05 (0.995 - 1.107)	1.068 (0.507 - 2.251)	0.77	0.938 (0.388 - 2.269)	0.26
	1984-2009	1.006 (0.976 - 1.038)	1.009 (0.883 - 1.154)	0.57	0.927 (0.825 - 1.041)	0.07
Widby Basin Region						
Lower Skagit River late run	1995-2009	1.064 (0.976 - 1.158)	1.051 (0.404 - 2.733)	0.69	1.041 (0.394 - 2.748)	0.65
	1952-2009	0.987 (0.978 - 0.996)	1.003 (0.926 - 1.086)	0.53	0.993 (0.916 - 1.076)	0.42
Upper Skagit River late run	1995-2009	1.033 (0.968 - 1.103)	1.022 (0.59 - 1.77)	0.65	1.013 (0.574 - 1.787)	0.59
	1952-2009	1.004 (0.997 - 1.01)	1.004 (0.953 - 1.059)	0.57	0.996 (0.945 - 1.051)	0.44
Lower Sauk River late run	1995-2009	1.054 (0.981 - 1.133)	1.044 (0.443 - 2.458)	0.68	1.033 (0.437 - 2.441)	0.64
	1952-2009	0.994 (0.984 - 1.004)	1.007 (0.929 - 1.09)	0.57	0.999 (0.922 - 1.083)	0.49
Upper Sauk River early run	1995-2009	1.061 (0.995 - 1.131)	1.076 ()	?	1.066 ()	?
	1952-2009	0.977 (0.966 - 0.99)	0.991 (0.909 - 1.081)	0.41	0.984 (0.903 - 1.073)	0.35
Cascade River early run	1995-2009	1.035 (0.977 - 1.095)	1.02 (0.63 - 1.653)	0.66	1.015 (0.622 - 1.658)	0.62
	1981-2009	1.029 (1.01 - 1.049)	1.023 (0.968 - 1.082)	0.84	1.018 (0.962 - 1.077)	0.79
Suiattle River early run	1995-2009	0.955 (0.903 - 1.01)	0.946 (0.584 - 1.533)	0.19	0.939 (0.572 - 1.54)	0.18
	1952-2009	0.981 (0.974 - 0.989)	0.988 (0.926 - 1.055)	0.35	0.982 (0.919 - 1.048)	0.27

North Fork Stillaguamish River late run	1995-2009	0.987 (0.928 - 1.05)	0.996 (0.59 - 1.681)	0.47	0.886 (0.596 - 1.317)	0.08
	1974-2009	0.985 (0.971 - 1.0)	0.976 (0.898 - 1.062)	0.26	0.922 (0.852 - 0.998)	0.02
South Fork Stillaguamish River late run	1995-2009	0.915 (0.85 - 0.986)	0.958 (0.542 - 1.692)	0.26	0.958 (0.542 - 1.692)	0.26
	1974-2009	0.991 (0.972 - 1.009)	0.983 (0.889 - 1.086)	0.34	0.983 (0.889 - 1.086)	0.34
Skykomish River late run	1995-2009	1.036 (0.97 - 1.105)	1.065 (0.688 - 1.65)	0.84	0.952 (0.752 - 1.205)	0.11
	1965-2009	0.99 (0.98 - 1.0)	0.997 (0.934 - 1.064)	0.46	0.921 (0.874 - 0.972)	0.00
Snoqualmie River	1995-2009	1.075 (0.972 - 1.188)	1.043 (0.427 - 2.546)	0.67	1.0 (0.428 - 2.334)	0.50
	1965-2009	1.021 (1.007 - 1.036)	1.021 (0.957 - 1.09)	0.76	0.993 (0.933 - 1.057)	0.40
Central/South Puget Sound Region						
Sammamish River late run	1995-2009	1.005 (0.862 - 1.172)	1.01 (0.153 - 6.667)	0.52	0.808 (0.085 - 7.709)	0.22
	1983-2009	0.938 (0.889 - 0.989)	0.948 (0.779 - 1.155)	0.25	0.823 (0.638 - 1.061)	0.05
Cedar River late run	1995-2009	1.105 (1.016 - 1.202)	1.104 (0.645 - 1.887)	0.87	1.008 (0.538 - 1.89)	0.55
	1965-2009	0.98 (0.966 - 0.995)	0.995 (0.903 - 1.097)	0.46	0.944 (0.865 - 1.031)	0.09
Green River late run	1995-2009	0.952 (0.851 - 1.065)	1.003 (0.274 - 3.67)	0.51	0.835 (0.3 - 2.324)	0.13
	1968-2009	1.01 (0.981 - 1.039)	0.994 (0.892 - 1.108)	0.45	0.799 (0.716 - 0.89)	0.00
White River early run	1995-2009	1.102 (1.034 - 1.175)	1.128 (0.583 - 2.185)	0.87	1.07 (0.499 - 2.295)	0.77
	1965-2009	1.035 (1.003 - 1.068)	1.02 (0.859 - 1.21)	0.60	0.989 (0.841 - 1.161)	0.44
Puyallup River late run	1995-2009	0.94 (0.898 - 0.983)	0.936 (0.795 - 1.103)	0.06	0.83 (0.65 - 1.06)	0.03
	1968-2009	1.005 (0.984 - 1.027)	0.977 (0.895 - 1.068)	0.28	0.91 (0.827 - 1.002)	0.03
Nisqually River late run	1995-2009	0.998 (0.931 - 1.069)	1.01 (0.549 - 1.86)	0.57	0.882 (0.294 - 2.644)	0.19
	1968-2009	1.008 (0.988 - 1.027)	0.997 (0.887 - 1.122)	0.48	0.94 (0.828 - 1.068)	0.15
Hood Canal Region						
Mid-Hood Canal late run	1995-2009	0.911 (0.818 - 1.016)	0.921 (0.224 - 3.787)	0.30	0.859 (0.209 - 3.532)	0.20
	1968-2009	0.952 (0.93 - 0.974)	0.934 (0.781 - 1.118)	0.20	0.871 (0.724 - 1.047)	0.06
Skokomish River late run	1995-2009	1.019	0.995	0.48	0.76	0.07

		(0.936 - 1.108)	(0.408 - 2.424)		(0.345 - 1.674)	
	1968-2009	0.994 (0.976 - 1.013)	0.982 (0.861 - 1.12)	0.37	0.784 (0.692 - 0.888)	0.00
Strait of Juan de Fuca Region						
Dungeness River summer run	1995-2009	1.209 (1.093 - 1.336)	1.191 (0.279 - 5.074)	0.82	0.805 (0.269 - 2.408)	0.12
	1986-2009	1.096 (1.039 - 1.156)	1.079 (0.764 - 1.523)	0.73	0.728 (0.53 - 1.001)	0.03
Elwha River early late run	1995-2009	0.973 (0.9 - 1.052)	0.944 (0.394 - 2.261)	0.28	0.781 (0.36 - 1.693)	0.08
	1986-2009	0.934 (0.896 - 0.974)	0.902 (0.717 - 1.135)	0.12	0.763 (0.624 - 0.931)	0.01

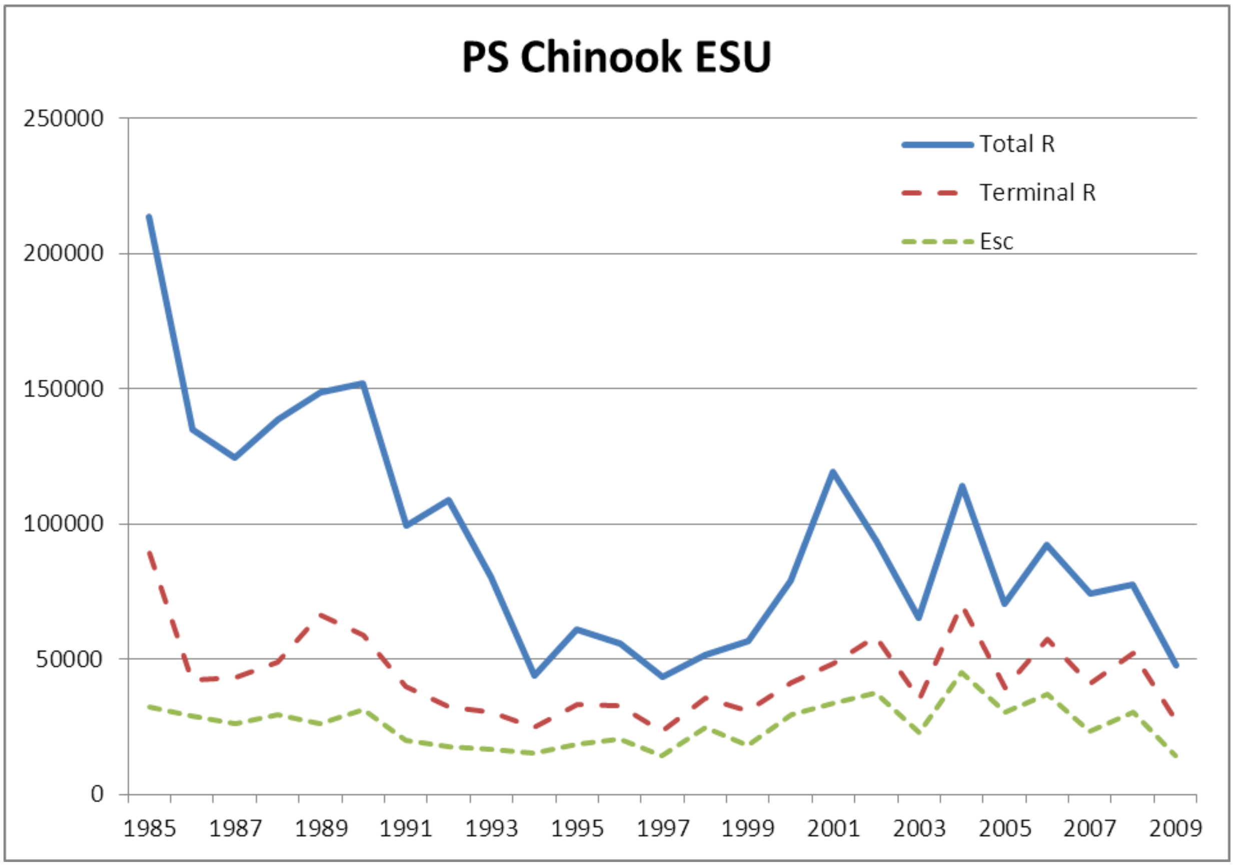


Figure 58 -- Total natural origin returns of chinook to Puget Sound in return years representing total return (pre any harvest and brood stock take), terminal return (pre terminal harvest and broodstock take), and natural origin spawners to the spawning grounds.

Productivity

Productivity is estimated based on cohort run reconstruction using the Puget Sound TRT Abundance & Productivity Excel Files (Sands 2009). Median recruits per spawner and spawners per spawner for each population over the five 5-yr intervals are summarized in Table 41 provided in detail in Table 45. Recruits are estimated for broodyears through 2006 (Figure 58). Since coded-wire-tag data are only available through 2009, estimates of 2005 age 5 returns and 2006 age 4 and 5 returns are made using forecast methods. The estimates for these two years are not as precise as for earlier years and will be updated as data become available.

While NOR escapements have remained fairly constant during this time period (1985-2009), returns and productivity has continued to decline (Figure 58, Table 41). Median recruits per spawner for the last five-year period (from BY 2002-2006) is the lowest over any of the five year intervals.

Table 41 -- Productivity - range and median for the populations for the 5-year ranges.

	Recruits per Spawner		Spawners per Spawner	
BY	pop range	pop median	pop range	pop median
1982-1986	0.6-42.8	5.51	0.2-17.2	1.23
1987-1991	0.3-44.1	2.61	0.1-3.8	0.77
1992-1996	0.3-15	2.20	0.2-3.4	1.04
1997-2001	0.5-5.2	2.65	0.3-3	0.93
2002-2006	0.3-3.6	1.52	0.1-1.6	0.65
Trend	-12.3 - +0.3	-1.08	-3.1 - +0.2	-0.08

Spatial Structure and Diversity

Indices of spatial distribution and diversity have not been developed at the population level. At the ESU level, a diversity index may be used to determine changes in distributions of abundance among the 22 populations and among the 5 geographic regions. The Shannon H diversity index was used to measure diversity of spatial distribution and the results are summarized over 5-year intervals in Table 42. For both distribution among populations and among regions, the diversity is declining, due primarily to the increased abundance of returns to the Whidbey Region,

Table 42 -- Diversity/Spatial Structure of ESU – Shannon Diversity Index

5-year ranges	Diversity Indices	
	Populations	Regions
1985-1989	2.356	0.989
1990-1994	2.416	0.962
1995-1999	2.328	0.890
2000-2004	2.253	0.798
2004-2009	2.232	0.768
Trend	-0.041	-0.061

Population Viability

The Puget Sound TRT provided a minimum viability spawning target for each population in their viability report (Table 1, Ruckelshaus et al 2002 and Table 38 of this report). The TRT report and a Shared Strategy document (Table 1: Chinook Planning Targets and Ranges 5/8/02 on shared Strategy web site) gave parameters for Beverton-Holt spawner recruits developed by the state and tribal comanagers (WDFW&Tribes) using EDT and NMFS properly functioning conditions (Table 38).

The estimated spawner recruit functions were based on survival patterns experienced in the early 1990's. Those survival patterns appear to be relevant to current conditions because marine survival (as measured by returns of hatchery releases) has been relatively low since the mid-1980's.

Recovery spawner recruit curves have been constructed for each population with observed recruit per spawner points superimposed on the graph (Figure 62 -- Figure 67).

Harvest expressed as Adult Equivalent Exploitation Rate (AEQ ER)

Puget Sound Chinook are harvested in Pacific Ocean fisheries, in Puget Sound fisheries, and in terminal fisheries within rivers. They migrate to the north as juveniles, so nearly all ocean fishery impacts occur in off the coasts of Canada and Alaska where they are subject to the Pacific Salmon Treaty. Fisheries within Puget Sound are managed by the state and tribal co-managers under a resource management plan. Fishery impact rates vary widely among regions within Puget Sound primarily because of different terminal area management. Hood Canal and South Sound stocks support relatively intense terminal area fisheries directed at hatchery fish produced largely to support tribal and recreational fisheries.

Cohort exploitation rates, expressed as Adult Equivalent Exploitation Rate (AEQ ER), are estimated separately for each population based on harvest of hatchery indicator stocks and using population specific age estimates applied to the age structure of the population. ESU-level AEQ ER summary data are provided in Table 43 and population specific data are found in Table 46. Estimated trends in exploitation rates from broodyears 1982 to 2006 exhibited a decreasing trend when measured over the five 5-year intervals. However, further examination of the data shows that exploitation was least over the 1992-1996 broodyears and has been increasing over the past 10 years for both ocean and terminal fisheries.

Estimates are based on cohort analysis using harvest rate estimates of hatchery indicator stocks from the CTC and applied, using the appropriate indicator stock(s) to each natural population. However, exploitation rates may also be expressed as calendar year rates (proportion of escapement plus catch in a calendar year that is catch). These estimates were made over all populations within each geographical region and are summarized in Figure 59 and Figure 60 for total and terminal only exploitation rates, respectively. Terminal fisheries are defined as those fishing on the mature portion of the population returning to spawn that year (includes net fisheries in Puget Sound).

Populations from all regions within Puget Sound show a similar pattern of declining exploitation rates in the 1990s and increasing exploitation rates since then. This is primarily a result of Canadian interceptions of Puget Sound Chinook off the West Coast of Vancouver Island (WCVI). During the 1990s Canada sharply reduced fisheries off WCVI in response to depressed stocks. Since then, WCVI stock status has improved somewhat and Canadian managers have changed the temporal pattern of fishing to avoid WCVI stocks. This has resulted in increased impacts on Puget Sound stocks.

Terminal fisheries represented a substantial proportion of the total exploitation rate in the late 1980's and early 1990's. The proportion was lowest during the 1995-1999 period and has been increasing in all areas again since then. The exception is the North Region (Nooksack) where the proportion of terminal fisheries has always been low; however, the most recent five years has the highest proportion (0.10).

Hatchery releases

Hatchery releases of all salmon species except sockeye and steelhead have been trending down in Puget Sound since 1990 (Figure 61). Puget Sound has a mixture of production (for harvest) and conservation (to supplement natural spawning of the natural populations) hatchery releases.

Table 43 -- Brood year adult-equivalent exploitation rate ranges and medians for the five 5-year intervals for ocean (mixed-maturity) and terminal (mature) fisheries and total exploitation rate estimated for each of the 22 populations. Trends over the 5-year intervals are also provided.

	Mix Mat Fishery		Mature Fishery		Total AEQ ER	
BY	pop range	pop median	pop range	pop median	pop range	pop median
1982-1986	0.36-0.72	0.58	0.02-0.39	0.15	0.44-0.9	0.77
1987-1991	0.29-0.65	0.55	0.01-0.29	0.10	0.39-0.84	0.67
1992-1996	0.22-0.56	0.38	0-0.32	0.04	0.23-0.8	0.43
1997-2001	0.29-0.53	0.45	0.01-0.35	0.09	0.31-0.73	0.51
2002-2006	0.09-0.63	0.42	0.02-0.33	0.16	0.12-0.72	0.56
Trend	-0.12 - +0.02	-0.04	-0.03 - +0.01	-0.01	-0.15 - +0.02	-0.05

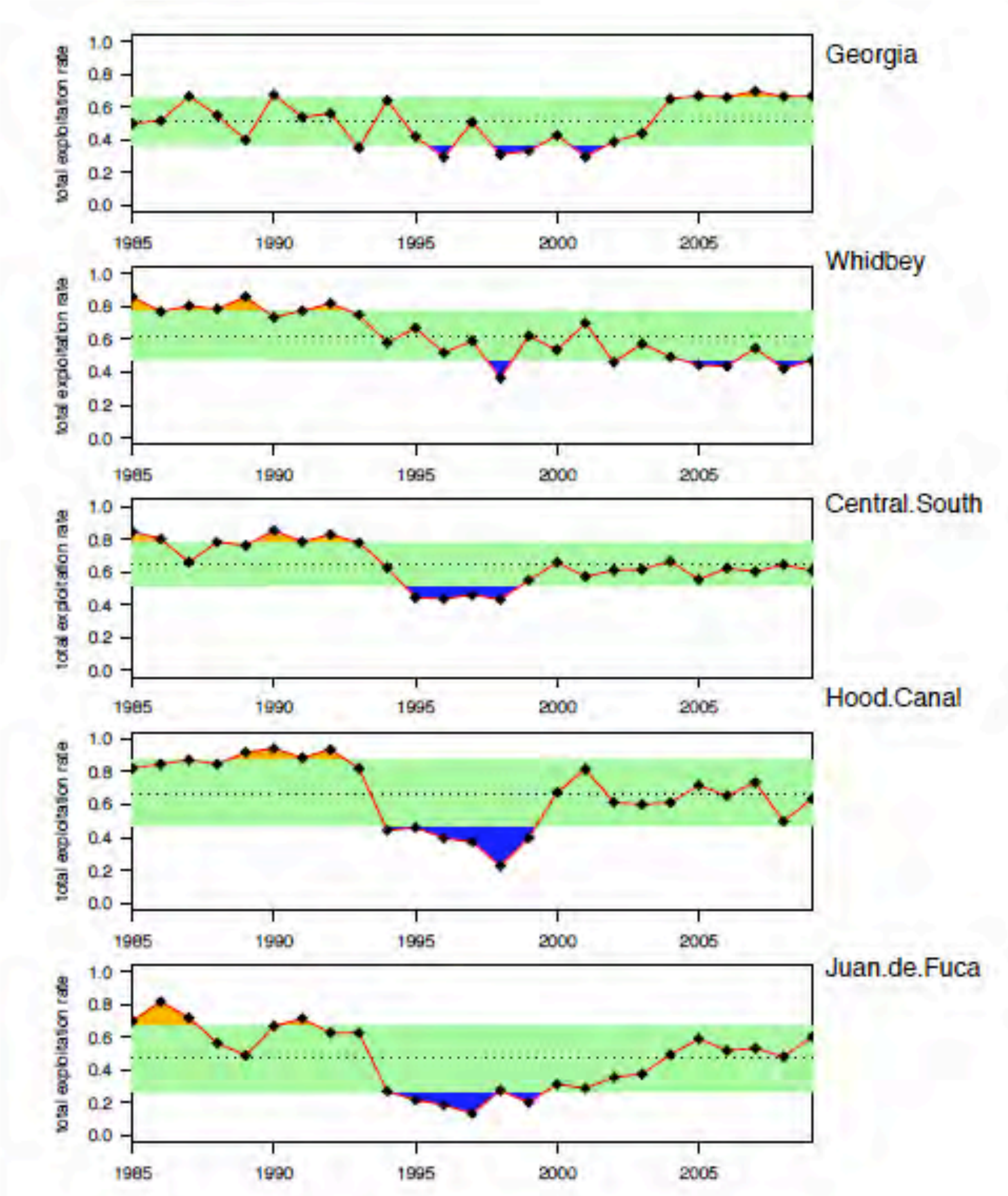


Figure 59 – Trends in Puget Sound salmon total exploitation rates (proportion of total return taken by all fisheries in return year) by calendar year for each major population group.

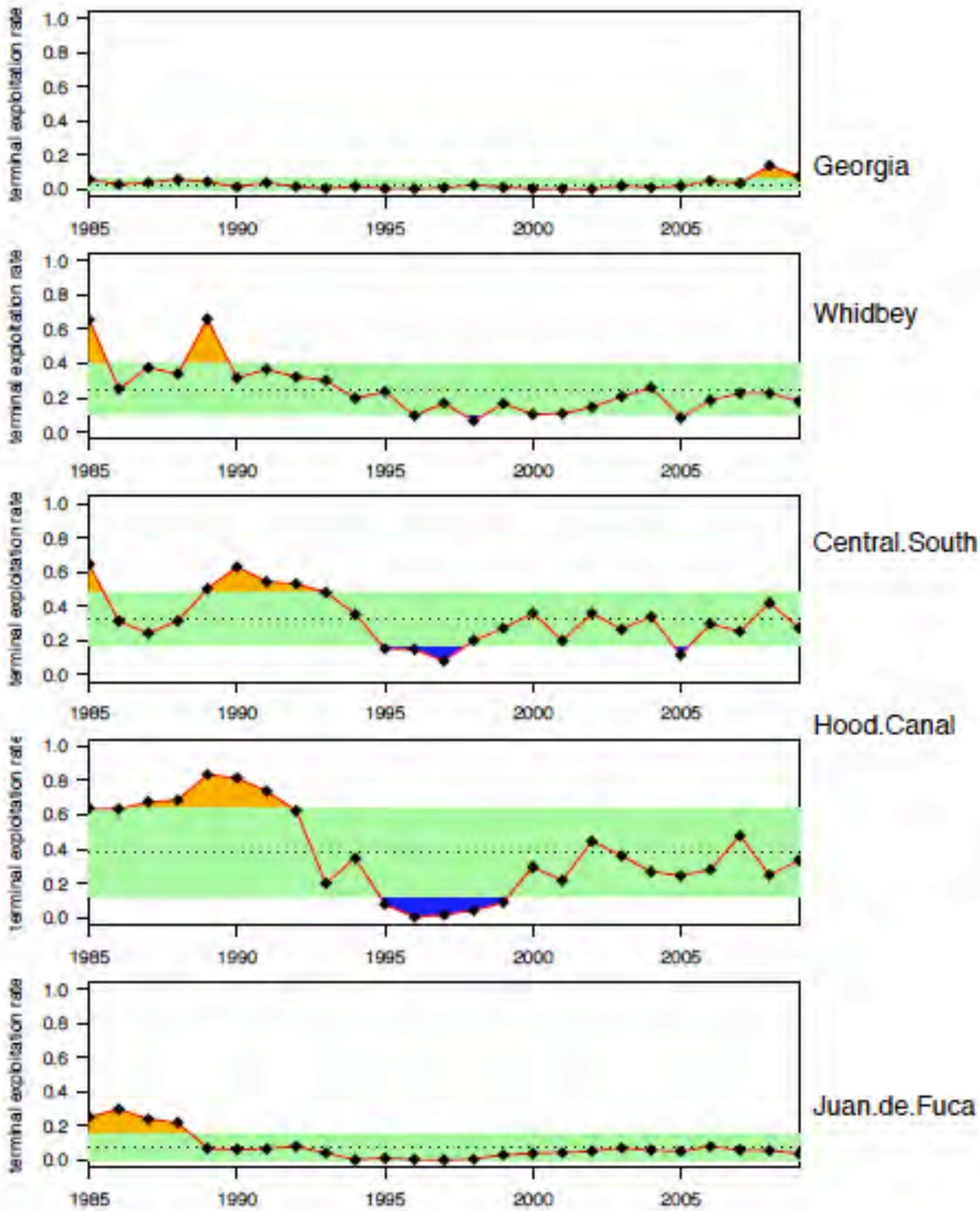


Figure 60 -- Trends in Puget Sound Chinook salmon terminal harvest rates (proportion of terminal run taken by fisheries) by calendar year for each major population group.

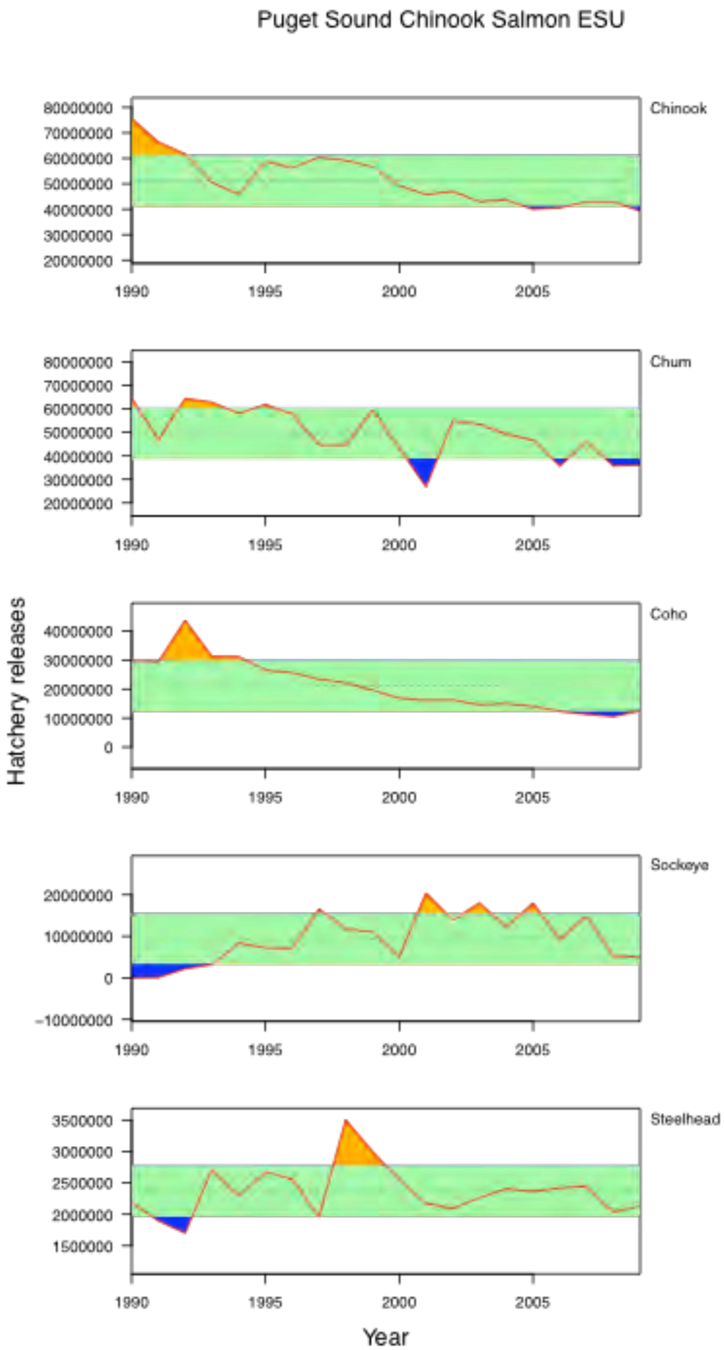


Figure 61 -- Puget Sound hatchery releases. Data source: RMIS.

Puget Sound Chinook salmon: Updated Risk Summary

All Puget Sound Chinook populations are well below the TRT planning range for recovery escapement levels. Most populations are also consistently below the spawner-recruit levels identified by the TRT as consistent with recovery. Across the ESU, most populations have declined in abundance somewhat since the last status review in 2005, and trends since 1995 are mostly flat. Several of the risk factors identified by Good et al. (2005) are also still present, including high fractions of hatchery fish in many populations and widespread loss and degradation of habitat. Many of the habitat and hatchery actions identified in the Puget Sound Chinook recovery plan are expected to take years or decades to be implemented and to produce significant improvements in natural population attributes, and these trends are consistent with these expectations. Overall, the new information on abundance, productivity, spatial structure and diversity since the 2005 review does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good TP, Waples RS, 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., p. 598.

Myers, J. M., R. G. Kope, G. J. Bryant, D. J. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. Lindley, R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-35, 443 p.

Puget Sound Technical Recovery Team (PSTRT). April 30, 2002. Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit. http://www.nwfsc.noaa.gov/trt/puget_docs/trtpopesu.pdf 20pp.

Ruckelshaus, M.H., K.P. Currens, W.H. Graeber, R.R. Fuerstenberg, K. Rawson, N.J. Sands, and J.B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. NOAA Technical Memorandum NMFS-NWFSC-78. 145pp.

Sands, N. J. 2009. A user's guide to the abundance and productivity (A & P) tables as developed for Puget Sound Salmon. From the Puget Sound Technical Recovery Team (PS TRT) Abundance and Productivity (A & P) Workgroup. Fourth draft, 20 April, 2009. (Available from N. J. Sands, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Sands, N. J. 2007. Estimating missing age data for Pacific salmon cohort run reconstruction using the "age engine." Draft, 28 September, 2007. (Available from N. J. Sands, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Shared Strategy 2007. Puget Sound Recovery Plan. Adopted by NMFS January 19, 2007. http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Puget-Sound/PS-Recovery-Plan.cfm

Table 44 -- Puget Sound Chinook average natural (natural origin and hatchery) and natural-origin only spawners and percent hatchery contributions for five-year intervals. Spawning abundance averages are geometric means and hatchery contribution averages are arithmetic.

8/27/2010															
Return Years	1985-1989			1990-1994			1995-1999			2000-2004			2005-2009		
Populations	Nat	%	NOR	Nat	%	NOR	Nat	%	NOR	Nat	%	NOR	Nat	%	NOR
North + Middle Fork Nooksack	268	24%	204	101	47%	52	471	71%	96	3,464	93%	229	1,666	82%	276
South Fork Nooksack	305	11%	309	171	24%	126	217	37%	133	398	38%	235	388	37%	244
Lower Skagit	2,334	4%	2442	1,440	4%	1,385	1,006	4%	968	2,715	3%	2,626	2,163	4%	2,067
Upper Skagit	8,276	4%	8627	5,511	4%	5,304	6,087	2%	5,982	12,109	4%	11,678	10,345	6%	9,724
Upper Cascade	186	2%	202	185	2%	181	208	2%	204	366	2%	359	336	2%	329
Lower Sauk	739	4%	756	391	4%	377	415	4%	397	825	5%	785	777	5%	742
Upper Sauk	913	4%	945	399	4%	384	262	4%	252	420	4%	405	504	4%	486
Suiattle	693	3%	677	298	3%	288	381	3%	368	409	3%	397	259	3%	250
North Fork Stillaguamish	802	2%	836	679	26%	500	904	37%	564	1,173	30%	809	943	46%	478
South Fork Stillaguamish	256	0%	258	298	0%	298	240	0%	240	210	0%	210	99	1%	98
Skykomish	3,334	14%	2967	2,280	27%	1,626	3,228	47%	1,637	4,760	36%	3,030	3,309	28%	2,358
Snoqualmie	888	11%	821	995	15%	839	1,141	33%	710	2,446	13%	2,131	1,592	16%	1,333
Sammamish	348	18%	320	219	33%	131	151	50%	62	244	48%	120	249	77%	56
Cedar	809	8%	810	388	21%	302	345	28%	241	408	34%	268	876	18%	716
Green/ Duwamish	6,676	58%	3569	5,239	56%	2,214	6,792	68%	2,007	6,335	37%	3,921	3,077	56%	1,288
White	46	8%	70	322	25%	230	487	17%	392	1,353	12%	1,184	1,869	30%	1,306
Puyallup	1,206	20%	1094	2,468	16%	2,080	2,287	30%	1,575	1,637	30%	1,137	1,960	60%	775
Nisqually	390	17%	682	779	22%	609	722	20%	576	1,295	32%	875	1,892	69%	566

Skokomish	2,215	48%	1226	895	48%	456	1,046	60%	406	1,479	54%	455	1,109	55%	456
Mid Hood Canal	154	22%	287	110	21%	86	176	16%	148	202	21%	158	81	39%	44
Dungeness	174	83%	34	117	83%	20	104	83%	18	520	84%	71	417	59%	161
Elwha Nat Spawners	2,248	42%	1543	653	35%	417	722	59%	269	424	46%	211	575	66%	185
ESU	33,260	86%	28,680	23,938	75%	17,905	27,392	63%	17,245	43,192	72%	31,294	34,486	69%	23,938

Table 45 -- Puget Sound Chinook population average productivity for five-year intervals measured as recruits per spawner (R/S) and spawners per spawner (S/S). Trend over the five intervals is also given.

Brood Years	1982-1986		1987-1991		1992-1996		1997-2001		2002-2006		Trend	
Populations	**R/S**	**S/S**	**R/S**	**S/S**	**R/S**	**S/S**	**R/S**	**S/S**	**R/S**	**S/S**	**R/S**	**S/S**
North + Middle Fork Nooksack	5.56	2.52	2.83	1.28	0.61	0.39	0.55	0.31	0.32	0.11	-1.28	-0.58
South Fork Nooksack	2.01	0.93	1.30	0.62	1.60	0.99	1.66	0.94	2.99	0.92	0.23	0.03
Lower Skagit	5.34	1.08	1.55	0.39	3.33	1.58	4.80	3.03	0.90	0.66	-0.56	0.18
Upper Skagit	4.93	0.96	2.80	0.79	3.88	1.48	2.81	1.85	1.08	0.68	-0.77	0.05
Upper Cascade	8.02	1.49	2.88	1.08	2.41	1.31	3.21	1.73	1.76	0.86	-1.22	-0.06
Lower Sauk	5.45	1.28	1.54	0.40	4.04	1.82	3.69	2.35	1.43	1.12	-0.59	0.16
Upper Sauk	14.80	1.98	1.52	0.51	1.98	1.07	3.13	1.47	2.56	1.10	-2.29	-0.08
Suiattle	8.12	1.34	1.57	0.62	2.70	1.45	2.49	1.18	1.44	0.63	-1.24	-0.09
North Fork Stillaguamish	14.68	1.67	2.98	0.78	1.88	1.01	1.51	0.67	0.90	0.51	-2.90	-0.24
South Fork Stillaguamish	20.44	2.48	4.16	1.26	1.70	0.96	1.46	0.81	1.20	0.70	-4.12	-0.40
Skykomish	6.54	0.97	2.53	0.43	2.44	0.80	3.47	0.94	2.25	0.56	-0.76	-0.03
Snoqualmie	4.70	0.76	8.09	1.04	3.72	1.52	3.81	1.28	1.78	0.61	-1.01	0.00
Sammamish	2.80	1.00	2.32	0.97	4.35	2.83	1.33	0.69	1.81	0.82	-0.30	-0.06
Cedar	2.92	0.94	2.43	0.75	0.68	0.41	4.01	1.64	3.61	1.56	0.30	0.21

Green/Duwamish	4.69	1.18	1.34	0.23	3.10	0.53	3.58	0.73	3.12	0.29	-0.09	-0.13
White	30.62	17.18	4.12	1.94	1.52	1.08	5.15	2.50	1.50	1.28	-5.72	-3.12
Puyallup	7.85	1.71	5.32	1.15	1.07	0.62	1.82	0.68	1.54	0.53	-1.61	-0.28
Nisqually	42.83	5.66	44.13	3.78	15.05	2.55	3.23	0.81	1.75	0.38	-12.31	-1.35
Skokomish	12.84	1.84	2.70	0.45	0.84	0.51	1.86	0.57	0.93	0.33	-2.47	-0.29
Mid Hood Canal	1.90	0.18	13.57	2.40	7.02	3.39	1.88	0.62	2.00	0.68	-1.15	-0.08
Dungeness	0.58	0.21	0.31	0.11	0.25	0.20	1.67	0.93	0.44	0.18	0.11	0.08
Elwha Nat Spawners	2.92	0.90	1.14	0.17	1.99	0.79	2.37	0.50	1.46	0.27	-0.17	-0.09

Table 46 -- **Puget Sound Chinook Population average AEQ exploitation rates for five-year intervals for both mixed-maturity catch fisheries (mix) and mature catch fisheries (mat). Trends calculated over the five-year intervals are also given.**

8/27/2010													
Brood Years	**1982-1986**		**1987-1991**		**1992-1996**		**1997-2001**		**2002-2006**		**Trend**		
Populations	**Mix**	**Mat**	**Mix**	**Mat**	**Mix**	**Mat**	**Mix**	**Mat**	**Mix**	**Mat**	**Mix**	**Mat**	**Total**
North + Middle Fork Nooksack	0.50	0.03	0.52	0.01	0.37	0.01	0.46	0.01	0.62	0.03	0.02	0.00	0.02
South Fork Nooksack	0.54	0.02	0.51	0.01	0.38	0.00	0.47	0.01	0.63	0.03	0.02	0.00	0.02
Lower Skagit	0.60	0.17	0.62	0.09	0.49	0.03	0.29	0.02	0.19	0.07	-0.12	-0.03	-0.14
Upper Skagit	0.62	0.16	0.64	0.08	0.54	0.03	0.31	0.01	0.19	0.16	-0.12	-0.01	-0.12
Upper Cascade	0.60	0.18	0.56	0.07	0.43	0.02	0.44	0.03	0.28	0.19	-0.08	0.00	-0.08
Lower Sauk	0.63	0.13	0.65	0.08	0.56	0.03	0.31	0.01	0.21	0.02	-0.12	-0.03	-0.15
Upper Sauk	0.60	0.18	0.56	0.07	0.45	0.02	0.48	0.06	0.29	0.17	-0.07	-0.002	-0.07
Suiattle	0.62	0.16	0.58	0.06	0.45	0.02	0.50	0.05	0.33	0.21	-0.07	0.01	-0.06
North Fork Stillaguamish	0.71	0.15	0.54	0.13	0.37	0.05	0.40	0.12	0.41	0.03	-0.07	-0.02	-0.10
South Fork Stillaguamish	0.72	0.14	0.56	0.11	0.38	0.05	0.38	0.12	0.41	0.03	-0.08	-0.02	-0.10
Skykomish	0.68	0.17	0.64	0.15	0.45	0.13	0.53	0.16	0.50	0.18	-0.05	0.005	-0.04
Snoqualmie	0.65	0.18	0.59	0.16	0.46	0.12	0.49	0.18	0.47	0.19	-0.05	0.004	-0.04
Sammamish	0.47	0.18	0.44	0.20	0.27	0.08	0.38	0.12	0.40	0.16	-0.02	-0.01	-0.03
Cedar	0.54	0.14	0.51	0.17	0.31	0.09	0.46	0.11	0.43	0.12	-0.03	-0.01	-0.04
Green/Duwamish	0.58	0.15	0.54	0.17	0.32	0.09	0.48	0.12	0.46	0.16	-0.03	0.00	-0.03
White	0.36	0.08	0.29	0.09	0.27	0.02	0.36	0.04	0.09	0.02	-0.05	-0.02	-0.06
Puyallup	0.58	0.14	0.53	0.17	0.33	0.10	0.49	0.13	0.49	0.16	-0.02	0.00	-0.02
Nisqually	0.51	0.39	0.55	0.29	0.47	0.32	0.38	0.35	0.39	0.33	-0.04	-0.01	-0.05
Skokomish	0.54	0.32	0.62	0.13	0.30	0.04	0.48	0.20	0.45	0.18	-0.03	-0.02	-0.05
Mid Hood Canal	0.55	0.32	0.64	0.16	0.40	0.05	0.46	0.17	0.47	0.17	-0.03	-0.03	-0.06
Dungeness	0.57	0.07	0.55	0.01	0.22	0.01	0.42	0.04	0.57	0.03	-0.01	-0.004	-0.02
Elwha Nat Spawners	0.47	0.06	0.47	0.01	0.24	0.01	0.31	0.03	0.52	0.03	-0.01	0.00	-0.01

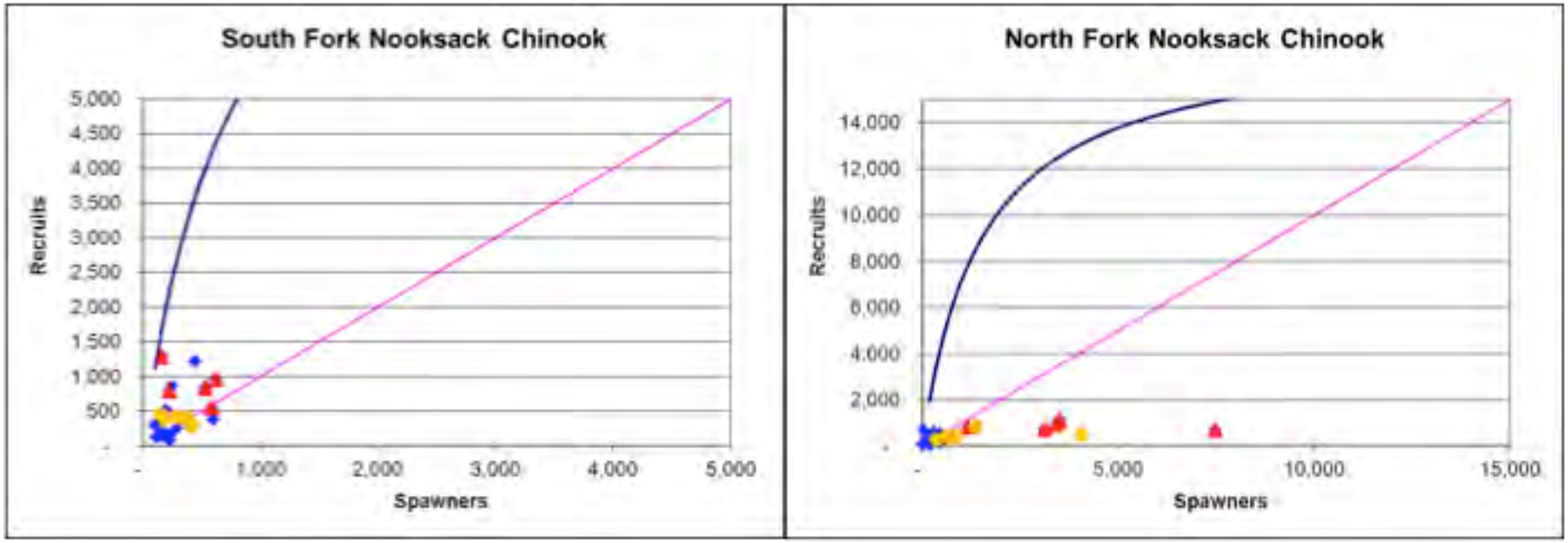


Figure 62 -- Observed returns relative to the estimated recovery spawner recruit relationship for the two populations in the Strait of Georgia region. The most recent five years are indicated by triangles and the previous 5 years by circles.

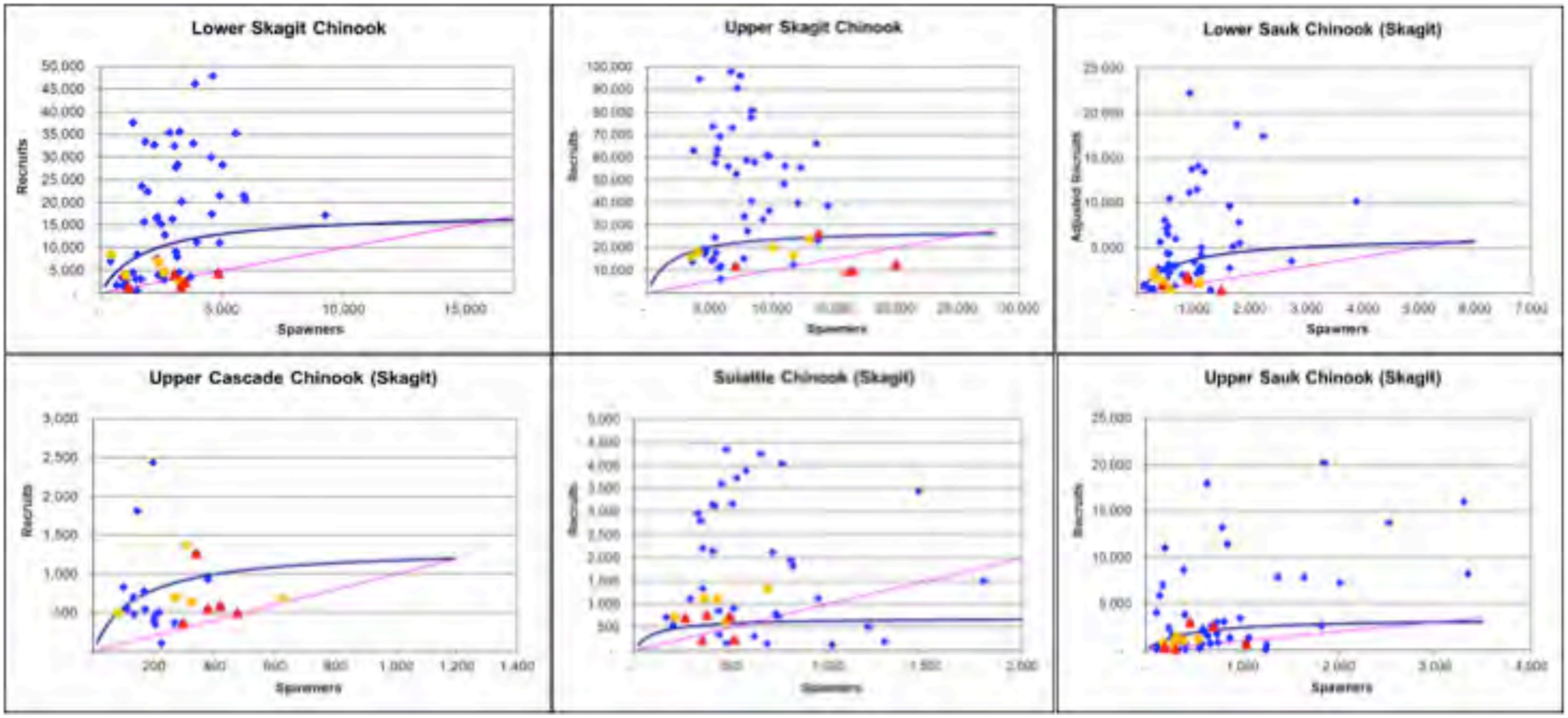


Figure 63 -- Observed returns relative to the estimated recovery spawner recruit relationship for the six of the ten populations in the Whidby Basin region. The top row are the three late-run populations and the bottom row are the three early-run populations in the Skagit River. The most recent five years are indicated by triangles and the previous 5 years by circles. One data point off graph for Upper Sauk (1956 BY 1884 sp produced 32,337 R); nine points off the graph for Suiattle, all occurring prior to 1970.

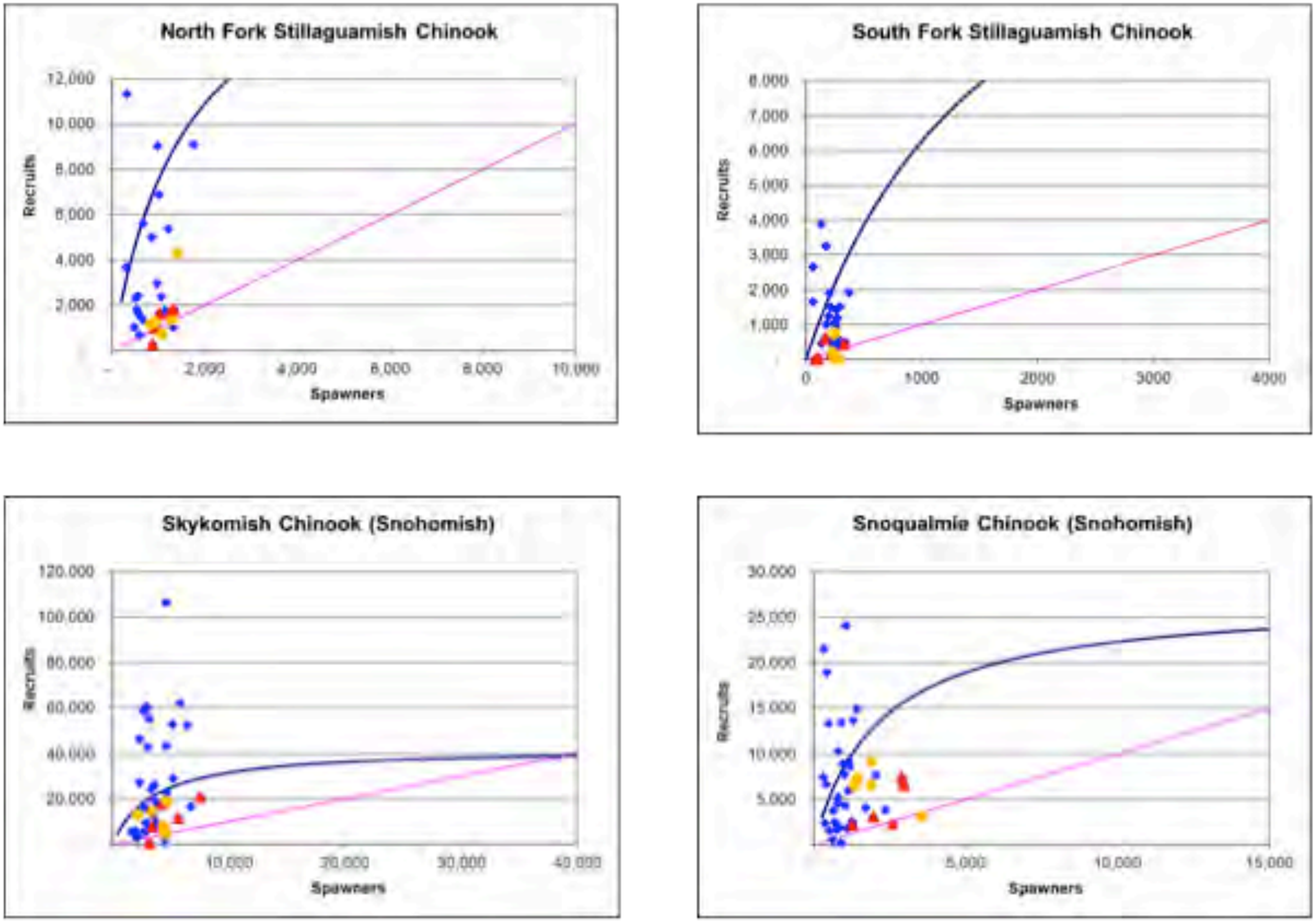


Figure 64 -- Observed returns relative to the estimated recovery spawner recruit relationship for the four of the ten populations in the Whidby Basin region. The most recent five years are indicated by triangles and the previous 5 years by circles.

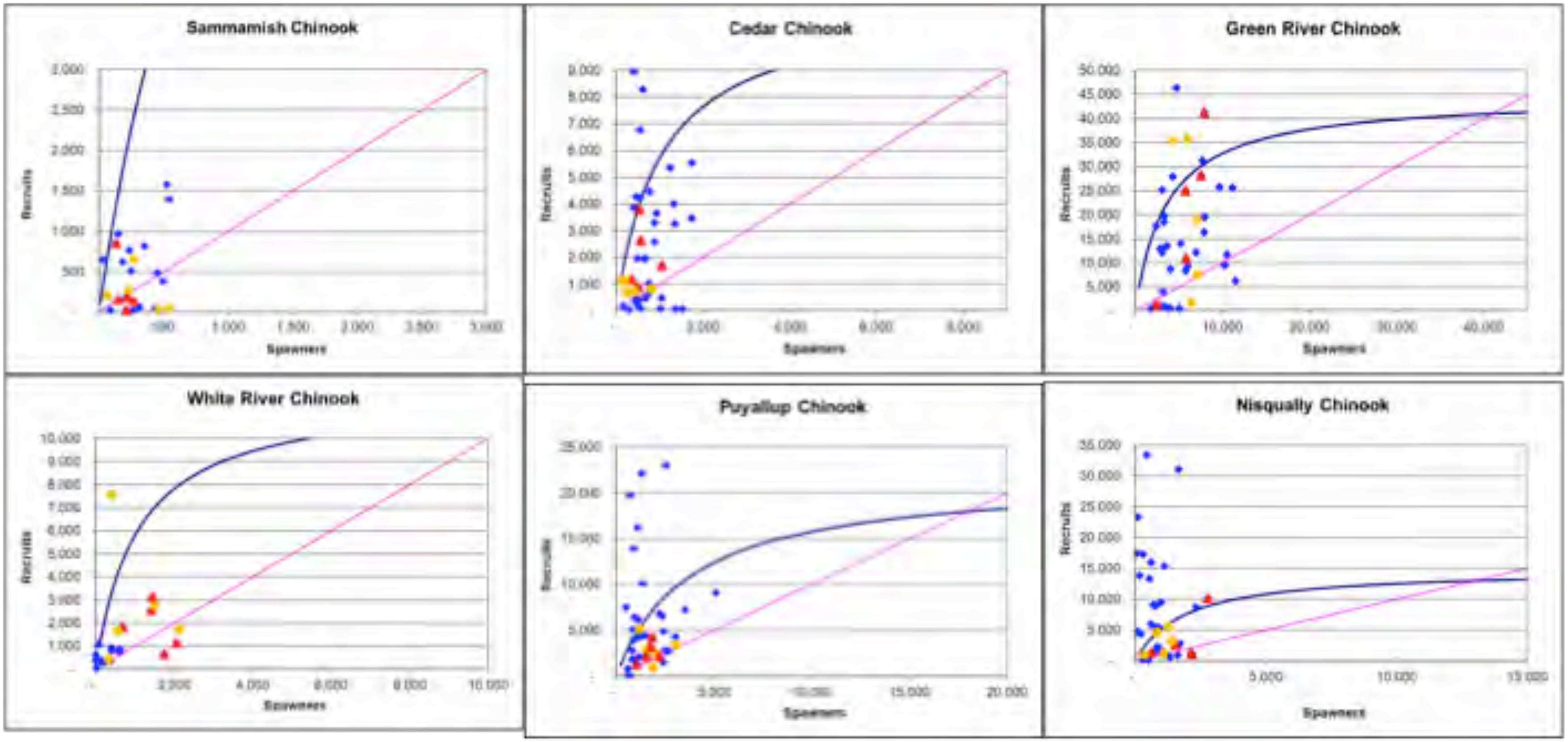
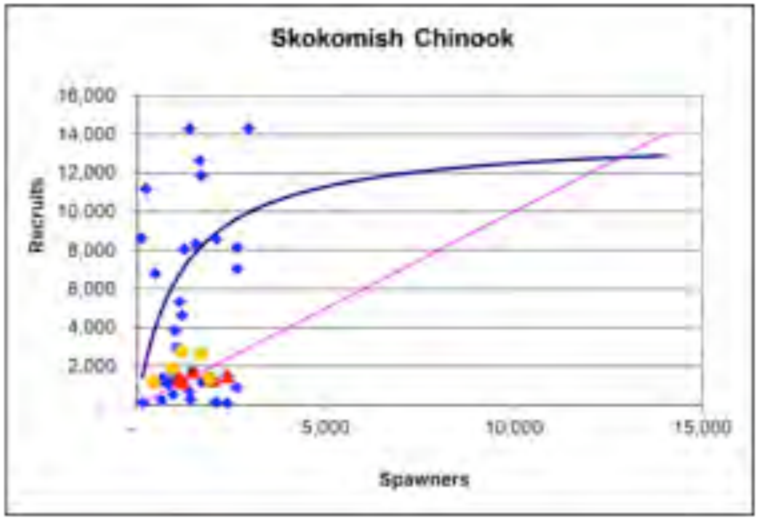


Figure 65 -- Observed returns relative to the estimated recovery spawner recruit relationship for the six populations in the Central/South Sound region. The most recent five years are indicated by triangles and the previous 5 years by circles.



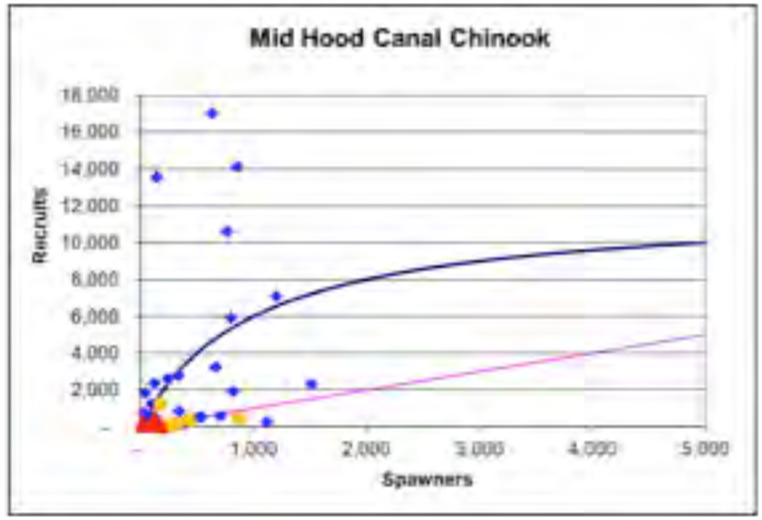
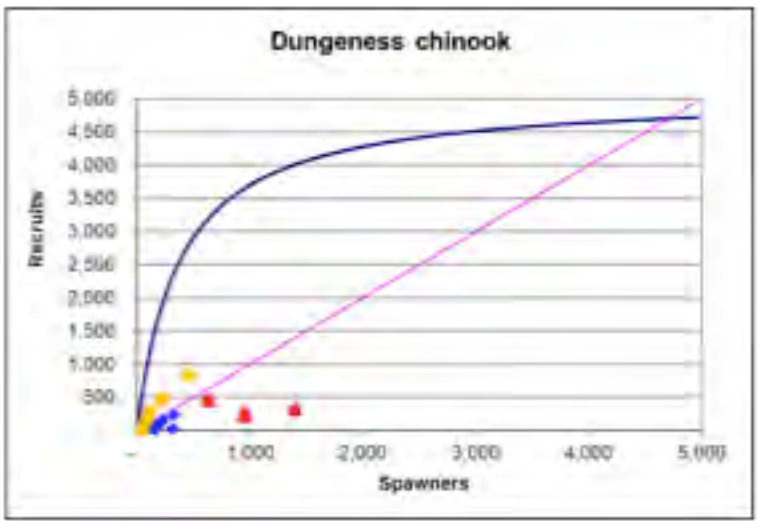


Figure 66 --Observed returns relative to the estimated recovery spawner recruit relationship for the two populations in the Hood Canal region. The most recent five years are indicated by triangles and the previous 5 years by circles



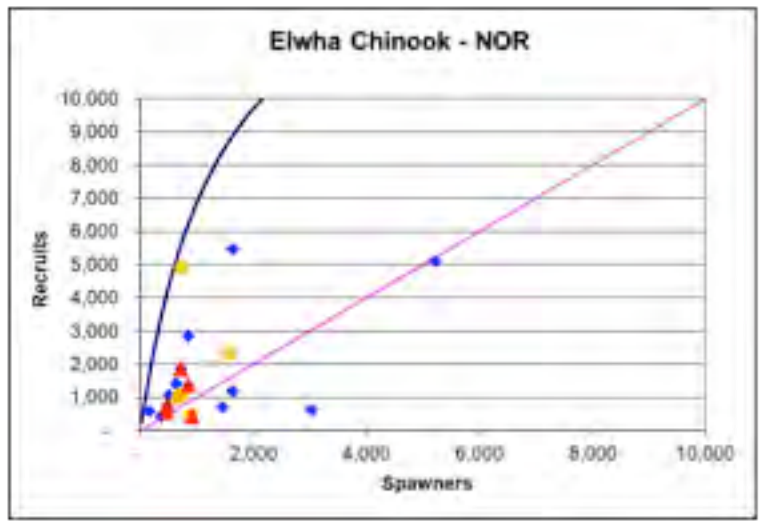


Figure 67 -- Observed returns relative to the estimated recovery spawner recruit relationship for the two populations in the Strait of Juan de Fuca region. The most recent five years are indicated by triangles and the previous 5 years by circles.

Hood Canal summer-run chum salmon[16]

Listed as threatened on March 25, 1999; threatened status reaffirmed on June 28, 2005. The ESU includes all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington, as well as eight artificial propagation programs: the Quilcene NFH, Hamma Hamma Fish Hatchery, Lilliwaup Creek Fish Hatchery, Union River/Tahuya, Big Beef Creek Fish Hatchery, Salmon Creek Fish Hatchery, Chimacum Creek Fish Hatchery, and the Jimmycomelately Creek Fish Hatchery summer-run chum hatchery programs.

Previous Status Reviews and Recovery Documents

At the time of the last status review in 2005 (Good et al. 2005), the Puget Sound TRT had not yet finalized their population designations or viability criteria for this ESU. Most stocks at that time were showing positive growth rates and increased spawning abundance compared to the time of listing. The recovery plan, submitted by the Hood Canal Coordinating Council, was adopted by NMFS May 24th 2007 (HCCC 2007). The Puget Sound TRT population identification and viability document was finalized in 2009 (Sands et al. 2009).

ESU Status at a Glance

Listing status: Threatened.

Historical peak abundance	N/A
Historical spawning aggregations	18
Recent peak run size abundance	259,000 (2000)
Recent peak spawning abundance	66,000 (2004)
Extant populations	2 (one with 4 extant spawning aggregations and one with 10 extant spawning aggregations; some of these are recently reintroduced)
Viable abundance and productivity	Defined by spawner recruit functions – see Figure 71 and Figure 72.
Viable populations needed for ESU	2 with high diversity among spawning aggregations within each population

ESU Structure

The Puget Sound Technical Recovery Team designated two independent populations for the Hood Canal summer chum, one which includes the spawning aggregations from rivers and creeks draining into the Strait of Juan de Fuca and one which includes spawning aggregations within Hood Canal proper (see Table 47). Since each population consists of several spawning

[16] Section author: Norma Sands

aggregations, spatial structure and diversity can be measured using a diversity index to measure population distribution among spawning areas.

Table 47 – Current populations of summer-run chum salmon in the Hood Canal chum salmon ESU and their associated historical spawning aggregations. Updated from Sands et al. (2009). Note that WDFW considers salmon/Snow one stock and Big and Little Quilcene as one stock (T. Johnson, WDFW pers.comm. 10/29/10). Note that reintroduction programs started 3-5 years before natural spawning returns are noted.

Stock	Status
Strait of Juan de Fuca Summer Chum Population	
Dungeness River	Unknown <5 annually recently
Jimmycomelately Creek	Extant
Salmon Creeks	Extant
Snow Creek	Extant
Chimacum Creek	Extinct but reintroduced with natural spawning reported starting in 1999
Hood Canal Summer Chum Population	
Big Quilcene Rivers	Extant
Little Quilcene Rivers	Extant
Dosewallips River	Extant
Duckabush River	Extant
Hamma Hamma River	Extant
Lilliwaup Creek	Extant
Big Beef Creek	Extinct but reintroduced with returns reported starting in 2001
Anderson Creek	Extinct
Dewatto Creek	Extinct, no returns mid 1990's, some natural recolonization apparent but numbers remain low (<70 annually)
Tahuya River	Extinct but reintroduced with increased returns reported starting 2006
Union River	Extant
Skokomish River	Extinct, no spawning reported prior to 2001, very low numbers (<40 annually) reported in recent years
Finch Creek	Extinct

New Data and Updated Analyses

Escapement data, total natural spawners and hatchery contribution, age distribution of the natural origin escapement, and broodstock take are recorded per spawning aggregation (also referred to as subpopulation) and catch is available per fishery area; most data are available from 1971 to 2009 (Sands et al. 2009 and T.Johnson, WDFW, per.comm.). Age data from scale samples are available from 1992 to 2009; estimates are made for earlier years. Each spawning aggregation or subpopulation appears to have its own age distribution so that age distribution for each population is weighted by the relative abundance of the component subpopulations. Hatchery contributions to the spawning grounds are estimated to have begun in 1995 from the hatchery supplementation program and estimates were provided by WDFW (Johnson, per comm) through 2009. Hatchery contribution varies greatly from subpopulation to subpopulation. Catch data are proportioned out to spawning aggregates based on area of the fish catch in relation to the spawning tributaries as determined by the comanagers (WDFW&PNPTT 2003). Cohort run reconstruction is then done for each population to determine recruits per spawner, the measure of productivity using the PS TRT Abundance & Productivity Excel Files (Sands 2009).

Relative abundances of subpopulations within each population is used to estimate the Shannon Diversity index, used as an indicator of spatial structure and diversity, two of the viable salmon population factors.

Abundance

Spawning abundance is available from 1968 for the Hood Canal population and from 1971 for the Strait of Juan de Fuca population (Figure 68). Escapement estimates prior to 1974 are less precise than those afterwards (WDFW & PNPTC 2000) due to sampling procedures.

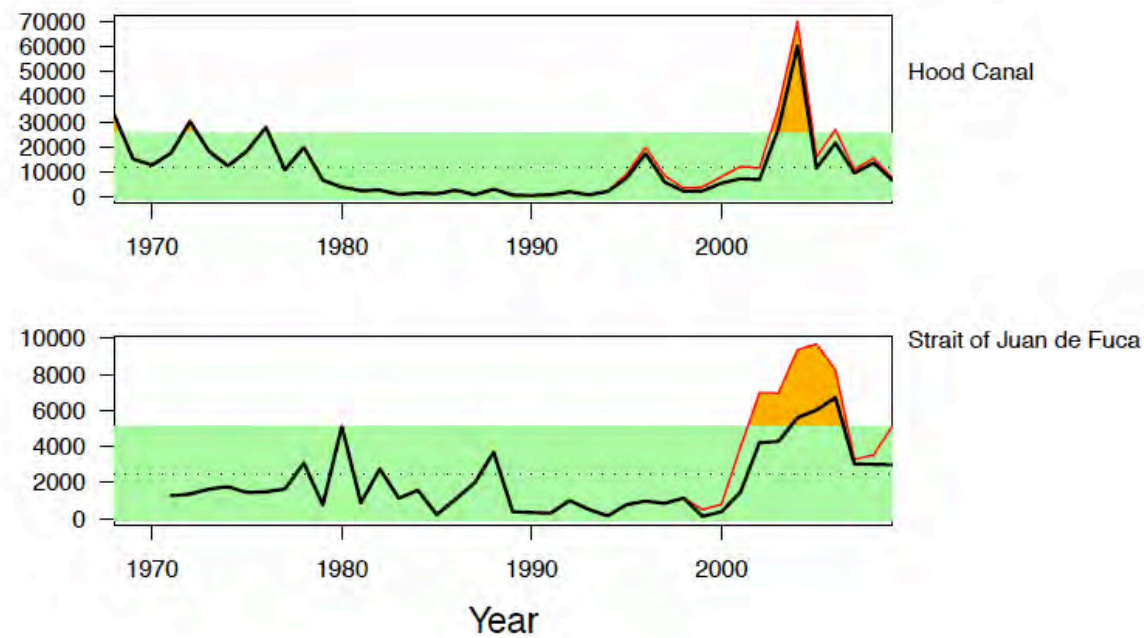


Figure 68 -- Spawning abundance of Hood Canal summer chum. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

Average escapements (geometric means) for five-year intervals are given in Table 48 as well as estimates of trends [exp[trend(ln(esc))]] over the intervals for all natural spawners and for natural-origin only spawners. Abundance was lowest for the mid period (1985-1999) and greatest for the most recent 10 years. The overall trend is positive for both all natural spawners and natural-origin only spawners.

Table 48 -- Five-geometric means of all spawners and natural-origin spawners only for the two Hood Canal ESU summer chum populations. Trend over the 5-year intervals is also given.

	All Spawners	Natural-Origin Spawners
Strait of Juan de Fuca Population		
71-74	1502	1502
75-79	1528	1528
80-84	1861	1861
85-99	936	936
90-94	386	386
95-99	822	629
00-04	4279	2254
05-09	5433	4057
Trend	2.72	2.30

Hood Canal Population		
71-74	18473	18473
75-79	14757	14757
80-84	1973	1973
85-99	1306	1306
90-94	979	979
95-99	7224	5170
00-04	19407	13425
05-09	13903	11513
Trend	2.68	2.48

Short and long term trends (exp[trend(ln(esc))]) and growth rates (lambda) as estimated by the SPAZ program are given in Table 49. The SPAZ programs gives estimates of lambda for both assumptions of hatchery fish having zero success on the spawning grounds and 100% success. The only abundance trend that appears to be positive is that for the Juan de Fuca population for the short time spawn (1995-2009). None of the average growth rate (lambda) estimates indicate positive average growth rates.

Table 49 -- Short and long term population trend and growth rate estimates for the Hood Canal ESU summer chum populations.

			Hatchery Fish Success =0		Hatchery Fish Success =1	
Popu-lation	Years	Trend Nat Sp w/CI	Lambda w/CI	p>1	Lambda w/CI	p>1
Hood Canal	1995-2009	1.075 (0.964 - 1.198)	1.041 (0.108 - 10.016)	0.57	0.958 (0.114 - 8.026)	0.42
	1968-2009	0.989 (0.956 - 1.022)	0.989 (0.786 - 1.244)	0.46	0.962 (0.775 - 1.195)	0.34
Juan de Fuca	1995-2009	1.184 (1.06 - 1.324)	1.139 (0.242 - 5.365)	0.76	1.009 (0.255 - 3.989)	0.53
	1971-2009	1.013 0.984 - 1.043)	1.028 (0.872 - 1.211)	0.65	0.99 (0.867 - 1.129)	0.43

Productivity

Five year averages of recruits per spawner are given in Table 50 and annual estimates are given in Table 51 and Table 52. Productivity in the last 5-year period has been very low, especially compared to the relatively high productivity in the 5-10 previous years.

Table 50 -- 5-year arithmetic mean of Recruits per Spawner for the populations and ESU

BYs	Strait	Canal	ESU
71-76	1.19	3.64	3.45
77-81	2.44	2.66	2.33
82-86	3.98	9.18	6.20
87-91	1.27	7.05	4.70
92-96	2.63	14.37	9.54
97-01	4.23	10.06	9.41
02-06	0.55	2.02	1.49
Trend	0.01	0.54	0.41

Table 51 -- Escapement, catch, and broodstock take data for the Stait of Juan de Fuca Summer Chum population and the estimates of diversity, progeny recruits, and recruits per spawner (R/S).). Recruits and R/S for brood-year 2006 are estimated by forecasting the returns of age 4 fish.

BY	Nat Esc	% NOR	NOR Esc	Harvest	Broodstock Take (NOR)	Diversity	Progeny Recruits	BY R/S
1971	1,281	100%	1,281	180	0	1.03	1371	1.07
1972	1,362	100%	1,362	159	0	1.09	2000	1.47
1973	1,648	100%	1,648	164	0	1.07	1490	0.90
1974	1,768	100%	1,768	218	0	1.06	2260	1.28
1975	1,448	100%	1,448	299	0	1.02	2995	2.07
1976	1,494	100%	1,494	179	0	1.08	532	0.36
1977	1,644	100%	1,644	166	0	1.07	6335	3.85
1978	3,080	100%	3,080	161	0	1.01	124	0.04
1979	761	100%	761	140	0	0.95	4542	5.97
1980	5,109	100%	5,109	465	0	0.93	191	0.04
1981	884	100%	884	256	0	1.04	2055	2.32
1982	2,751	100%	2,751	789	0	1.03	27	0.01
1983	1,139	100%	1,139	78	0	0.89	2066	1.81
1984	1,579	100%	1,579	128	0	1.02	2349	1.49
1985	232	100%	232	179	0	0.84	3827	16.50
1986	1,087	100%	1,087	129	0	1.01	101	0.09
1987	1,991	100%	1,991	190	0	1.01	737	0.37
1988	3,690	100%	3,690	439	0	1.02	268	0.07
1989	388	100%	388	407	0	0.86	1739	4.48
1990	341	100%	341	187	0	0.78	330	0.97
1991	309	100%	309	115	0	0.82	139	0.45
1992	1,008	100%	1,008	324	62	0.75	1346	1.34
1993	521	100%	521	71	52	0.61	855	1.64
1994	154	100%	154	36	24	0.39	1395	9.06
1995	786	100%	786	43	53	0.73	701	0.89
1996	975	100%	975	22	109	0.58	226	0.23
1997	852	100%	852	23	110	0.53	1087	1.28
1998	1,148	100%	1,148	47	121	0.40	1900	1.65
1999	502	26%	131	1	23	0.50	4628	9.22
2000	801	49%	391	2	116	0.46	6293	7.86
2001	3,955	37%	1,473	11	134	0.91	4594	1.16
2002	6,970	60%	4,215	16	88	0.68	7703	1.11
2003	6,959	62%	4,283	36	99	0.68	3234	0.46
2004	9,341	60%	5,597	12	22	1.04	4475	0.48
2005	9,682	62%	6,012	32	24	1.05	2790	0.29
2006	8,245	81%	6,709	29	31	1.06	3256	0.39
2007	3,290	92%	3,031	23	54	1.32		

2008	3,521	85%	3,010	35	39	1.19
2009	5,118	58%	2,987	30	17	1.15

Table 52 -- Escapement, catch, and broodstock take data for the Hood Canal summer chum population and the estimates of diversity, progeny recruits, and recruits per spawner (R/S). Recruits and R/S for brood-year 2006 are estimated by forecasting the returns of age 4 fish.

	Nat Esc	% NOR	NOR Esc	Harvest	Broodstock Take (NOR)	Diversity	Progeny Recruits	BY R/S
1971	17,412	100%	17,412	10857	0	1.90	38312	2.20
1972	30,079	100%	30,079	10859	0	1.66	184126	6.12
1973	18,107	100%	18,107	19771	0	1.81	89813	4.96
1974	12,281	100%	12,281	1941	0	1.70	57375	4.67
1975	18,248	100%	18,248	10866	0	1.91	53168	2.91
1976	27,715	100%	27,715	46506	0	2.00	26750	0.97
1977	10,711	100%	10,711	5977	0	1.92	20208	1.89
1978	19,709	100%	19,709	5635	0	1.80	25321	1.28
1979	6,554	100%	6,554	2960	0	1.57	13061	1.99
1980	3,777	100%	3,777	9249	0	1.98	7438	1.97
1981	2,374	100%	2,374	3501	0	1.78	14645	6.17
1982	2,623	100%	2,623	5708	0	1.77	18480	7.05
1983	899	100%	899	2646	0	1.98	9103	10.13
1984	1,414	100%	1,414	1959	0	2.12	20181	14.27
1985	1,109	100%	1,109	3314	0	1.77	13539	12.21
1986	2,552	100%	2,552	5281	0	1.03	5700	2.23
1987	757	100%	757	3214	0	1.24	819	1.08
1988	2,967	100%	2,967	2713	0	1.95	12743	4.29
1989	598	100%	598	3877	0	0.93	3396	5.68
1990	429	100%	429	1135	0	1.06	5485	12.79
1991	747	100%	747	1452	0	1.70	8528	11.42
1992	1,945	100%	1,945	1000	432	1.55	53943	27.73
1993	707	100%	707	115	49	1.74	26950	38.12
1994	2,044	100%	2,044	530	385	1.63	8483	4.15
1995	8,971	83%	7,448	429	326	1.37	6194	0.69
1996	19,707	87%	17,202	494	638	1.30	23165	1.18
1997	8,419	70%	5,859	278	381	0.54	18963	2.25
1998	3,404	63%	2,158	171	307	1.19	10855	3.19
1999	3,884	59%	2,279	243	133	0.89	38507	9.91
2000	7,987	67%	5,384	573	390	1.16	252752	31.65
2001	12,044	60%	7,173	789	288	1.55	39620	3.29
2002	11,454	60%	6,852	1022	350	1.82	72809	6.36
2003	35,696	77%	27,319	249	221	1.53	28349	0.79
2004	69,995	86%	60,328	21570	236	1.54	47426	0.68

2005	15,840	72%	11,373	293	271	1.85	28363	1.79
2006	26,754	80%	21,385	2107	209	1.94	12578	0.47
2007	10,781	87%	9,407	1745	205	2.15		
2008	15,332	88%	13,522	1907	221	2.04		
2009	7,416	88%	6,537	1122	92	1.92		

Spatial structure and diversity

Spatial distribution is measured using the Shannon diversity index (Table 53).

Table 53 -- Table 5. Five Year Arithmetic Averages of Diversity Index for the two populations and trend measured over the 5-year averages. Note the first average is for four years only. Trend is measured as the slope of the linear trend line.

Years	Strait	Hood Canal
71-74	1.06	1.77
75-79	1.03	1.84
80-84	0.98	1.92
85-99	0.95	1.38
90-94	0.67	1.54
95-99	0.55	1.06
00-04	0.75	1.52
05-09	1.15	1.98
Trend	-0.03	-0.03

Higher diversity values indicate a more uniform distribution of the population among spawning sites, which provides greater robustness to the population. Values were generally lower in the 1990s for both populations, indicating that most of the abundance occurred at a few of the spawning sites, The overall linear trend appears to be negative, which is not desirable, however, the last five years has shown the highest average value for both populations. This is partly the result of the addition of one reintroduced spawning aggregation in the Strait of Juan de Fuca population and two reintroduced spawning aggregations in the Hood Canal population. The distribution of spawning aggregations, number and relative abundance, within the populations is shown in Figure 69 and Figure 70.

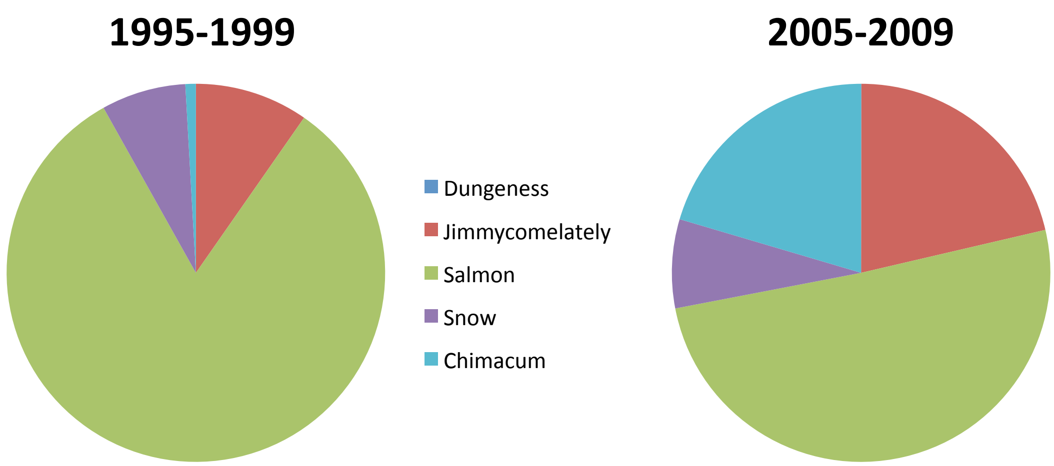


Figure 69 -- Relative abundance for the spawning aggregations of the Strait of Juan de Fuca summer chum population for the most recent five years of data and the five years prior to listing in 1999.

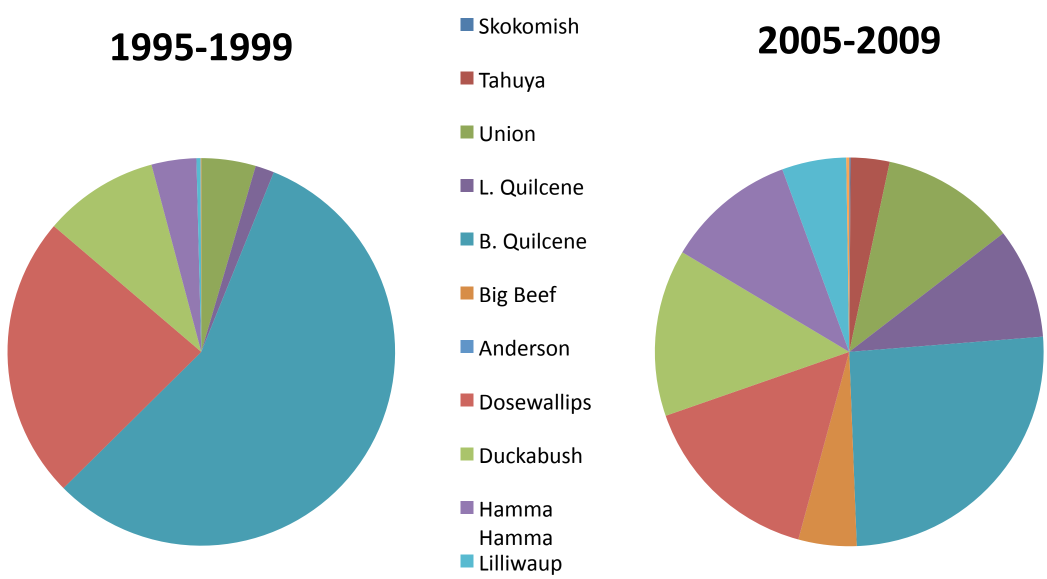


Figure 70 -- Relative abundance for the spawning aggregations of the Hood Canal summer chum population for the most recent five years of data and the five years prior to listing in 1999.

Viability

The TRT defined the abundance & productivity viability criteria for the Hood Canal summer chum populations using both 1) the assumption of density independence and replacement growth factor of 1:1 and 2) the assumption of density dependence which provides a series of viable spawner recruit functions (Sands et al. 2009). Brood year data used in these analyses were 1974-2001. The minimum viability levels assuming density independence were 12,500 for the Strait of Juan de Fuca population (this has not been attained in the years 1971 to present) and 24,700 for the Hood Canal population (this has been attained four times since 1971, twice since 2003).

Viable abundance and productivity were also expressed as intrinsic productivity and capacity from Beverton-Holt spawner recruit functions representing a recovered state; different functions were given for different levels of desired harvest exploitation after attaining recovery. These two figures from the 2009 report (Sands et al. 2009) are reproduced below (Figure 71 and Figure 72) with current estimates of capacity abundance, intrinsic productivity, and average exploitation rate for three over lapping time periods. These three points all fall within the non-viable section of the graph for both populations. The time periods were chosen to examine difference in estimates using sorter time span of data as well as the full range (1971-2006).

Viability for spatial distribution and diversity was expressed as a need to maintain a diverse aggregation of subpopulations within each population (Sands et al. 2009). If current relatively high diversity index values were to be maintained over time, this would go a long ways to satisfying that criteria.

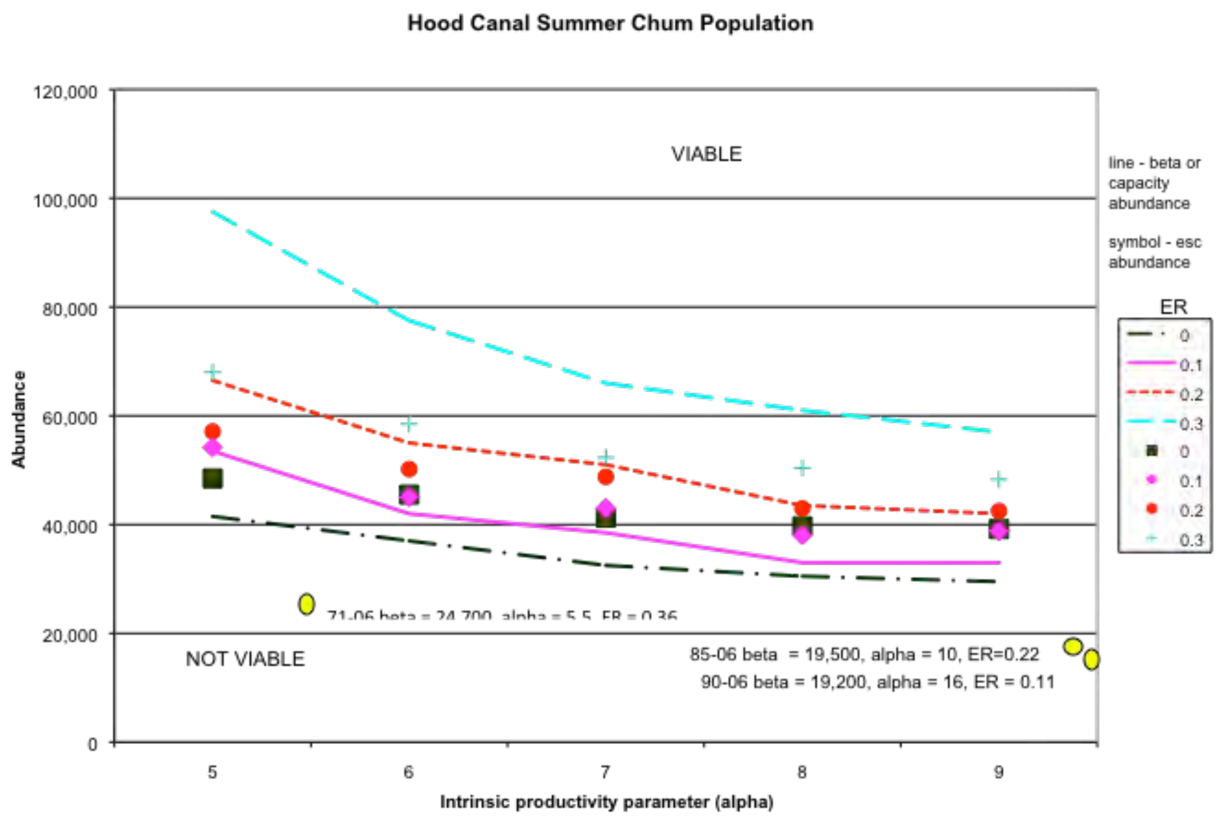


Figure 71 -- Viability curves for the Hood Canal summer chum population for no harvest and three levels of harvest (lines) using the ≤5% probability of extinction over 100 years. Capacity abundance and intrinsic productivity (beta and alpha parameters of the Beverton-Holt spawner recruit function) are plotted. To be viable, function parameters from current data should lie above the line for the associated exploitation rate. Point estimates from three time periods (brood years 1971-2006, 1985-2006, and 1990-2006) are plotted and all fall below the curve for zero harvest, indicating the population is not currently viable. Also plotted are corresponding points for each point in each curve of average values of spawning escapement (from 1000 simulated runs). (Adapted from Sands et al. 2009).

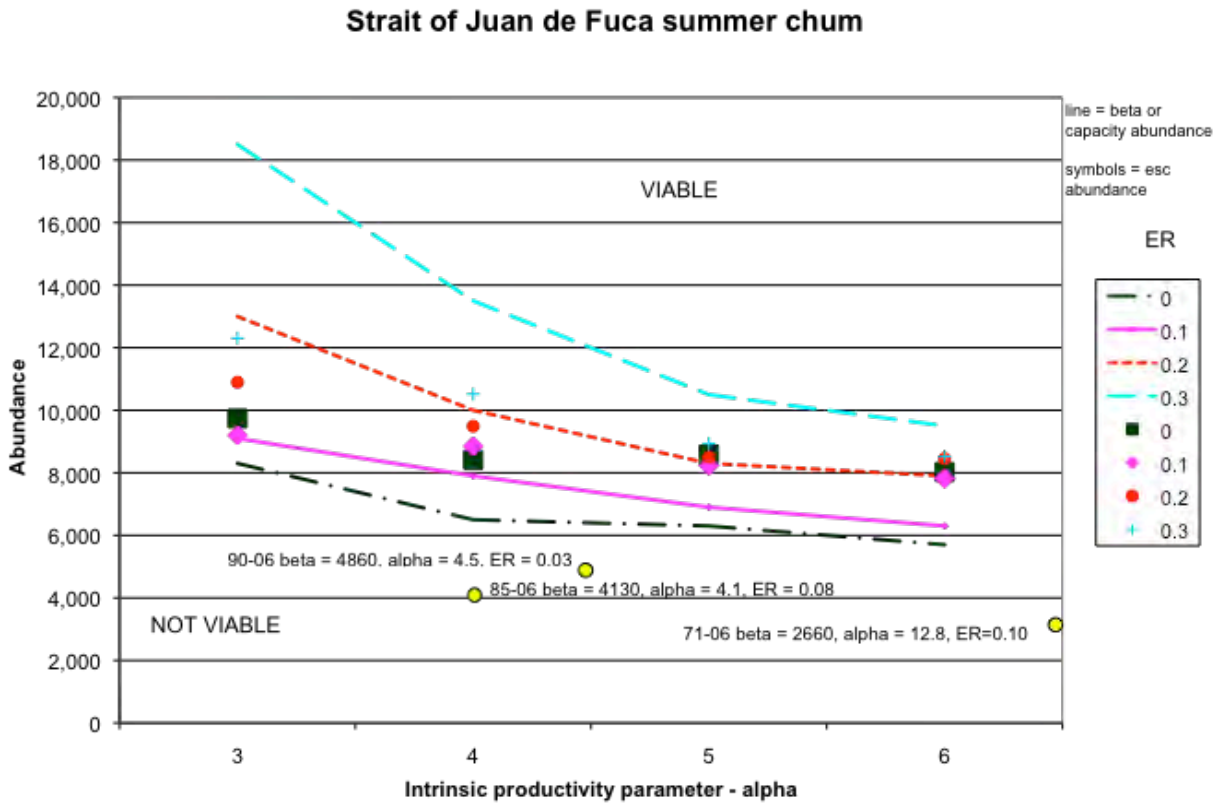


Figure 72 -- Viability curves for the Strait of Juan de Fuca summer chum population for no harvest and three levels of harvest (lines) using the ≤5% probability of extinction over 100 years. Capacity abundance and intrinsic productivity (beta and alpha parameters of the Beverton-Holt spawner recruit function) are plotted. To be viable, function parameters from current data should lie above the line for the associated exploitation rate. Point estimates from three time periods (brood years 1971-2006, 1985-2006, and 1990-2006) are plotted and all fall below the curve for zero harvest, indicating the population is not currently viable. Also plotted are corresponding points for each point in each curve of average values of spawning escapement (from 1000 simulated runs). (Adapted from Sands et al. 2009).

<u>Harvest</u>

There are no directed fisheries on Hood Canal summer chum. However, they are taken in fisheries directed at other species in the Strait of Juan de Fuca and in Hood Canal. Because the populations from the Eastern Strait of Juan de Fuca (Elwha River through Discovery Bay) are not subject to fisheries in Hood Canal directed at Chinook and coho salmon, they experience lower overall harvest rates in general. Historically, the populations in the Eastern Strait of Juan de Fuca experienced harvest rates on the order of 20% with rates as high as 50% in individual years. Populations in Hood Canal proper were subject to harvest rates that were typically on the order of 50% to 70% with rates in individual years approaching 90%.

In response to severely depressed runs of summer-run chum salmon, in the early 1990s, the State of Washington and the Western Washington Treaty Tribes took measures to curb the incidental harvest of summer chum and harvest rates fell dramatically (Figure 73). The co-managers have continued to constrain harvest impacts as runs have returned to historic levels, leading to escapements that exceed historic levels

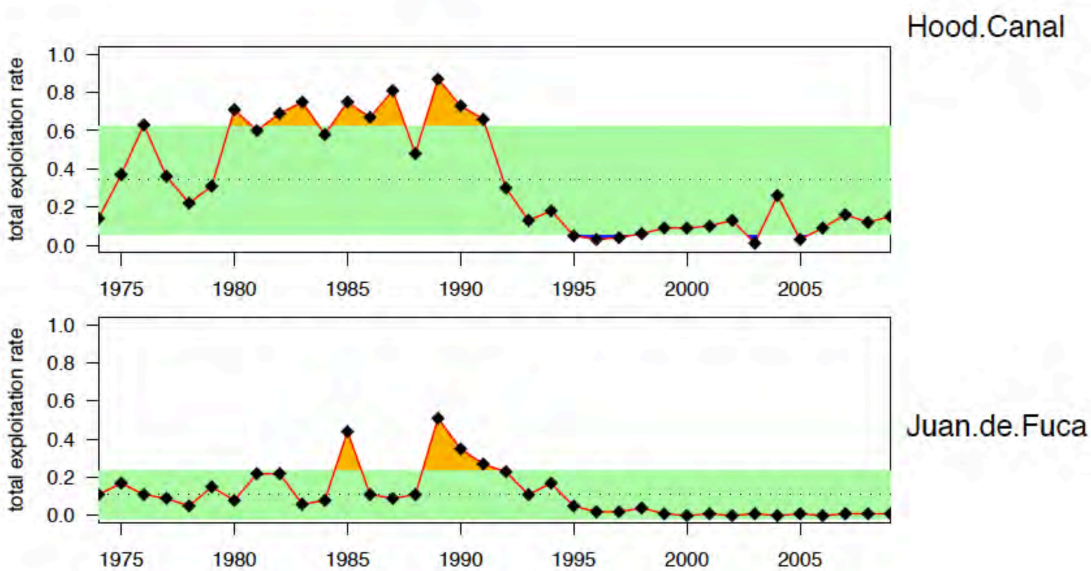


Figure 73 -- Total exploitation rate on the combined Hood Canal/Strait of Juan de Fuca summer chum salmon ESU. Data from WDFW run reconstruction (1974-2007 data from http://wdfw.wa.gov/fish/chum/chum-5e.htm; 2008 and 2009 data from Valerie Tribble, WDFW, personal communication).

Hatchery releases

Hatchery releases of chum, Chinook, and coho within the Hood Canal summer chum ESU spawning and rearing areas have generally declined since 2005, while steelhead releases have remained fairly flat and relatively low; all hatchery releases have generally declined since the mid-1990s (Figure 74). Chum hatchery releases are primarily fall run stocks (not part of the summer chum ESU).

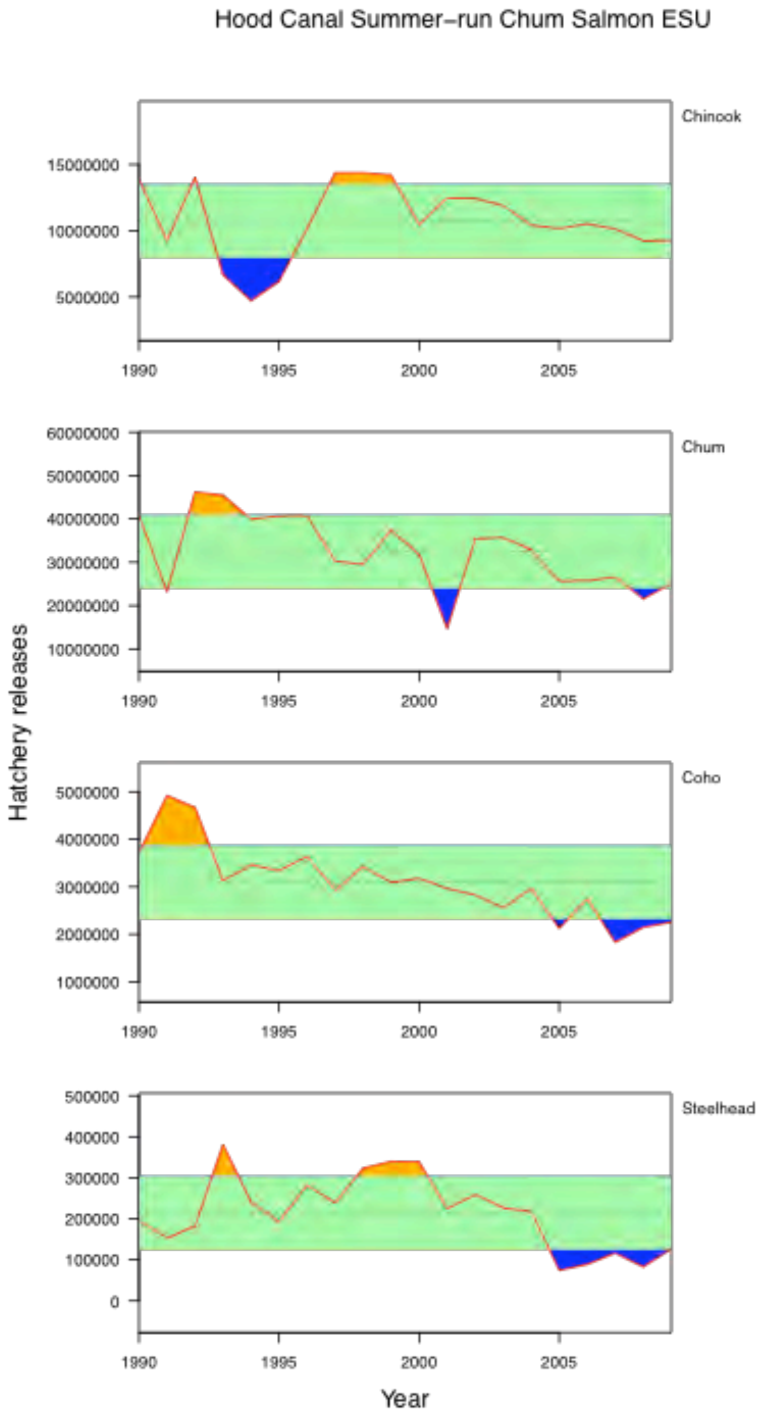


Figure 74 – Summary of total hatchery releases per species within the spawning and rearing areas of Hood Canal summer chum salmon (note that most chum releases in are fall run chum). Dotted line indicates the long-term mean and shaded areas the long-term standard deviation. Data source: RMIS.

Hood Canal summer chum salmon: Updated Risk Summary

The spawning abundance of this ESU has clearly increased since the time of listing, although the recent abundance is down from the previous 5-years. While spawning abundances have remained relatively high compared to the low levels in the early 1990's, productivity has decreased significantly for the last 5 brood years, being lower for brood years 2002-2006 than any previous 5-year average since 1971. This is a concern for future production. Since abundance is increasing and productivity is decreasing, this suggests that improvements in habitat and ecosystem function is needed. Diversity is increasing from the low values seen in the 1990s due both to the reintroduction of spawning aggregates and the the more uniform relative abundance between populations; this is a good sign for viability in terms of spatial structure and diversity. Spawning survey data shows that the spawning distribution within most streams has been extended further upstream as abundance has increased (WDFW and PNPTT 2007. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good TP, Waples RS, 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., p. 598.

Hood Canal Coordinating Council. 2007. Hood Canal & Eastern Strait of Juan de Fuca Summer Chum Salmon Recovery Plan. Adopted by NMFS May 24, 2007. http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Puget-Sound/HC-Recovery-Plan.cfm

Johnson, O. W., W. S. Grant, R. G. Kope, K. Neely, F. W. Waknitz, and R. S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-32.

Sands, N. J. 2009. A user's guide to the abundance and productivity (A & P) tables as developed for Puget Sound Salmon. From the Puget Sound Technical Recovery Team (PS TRT) Abundance and Productivity (A & P) Workgroup. Fourth draft, 20 April, 2009. (Available from N. J. Sands, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Sands, N.J. K. Rawson, K.P. Currens, W.H. Graeber, M.H. Ruckelshaus, R.R. Fuerstenberg,4 and J.B. Scott. 2009. Determination of Independent Populations and viability Criteria for the Hood Canal summer Chum salmon Evolutionarily Significant Unit. NOAA Technical Memorandum NMFS-NWFSC-101. 71 pp.

Washington Department of Fish and Wildlife and Point No Point Treaty Tribes (WDFW and PNPTT). 2000. Summer Chum Salmon Conservation Initiative. Washington Department of Fish and Wildlife and Point No Point Treaty Tribes, Olympia, WA. 423 pages + appendices. Available at http://wdfw.wa.gov/fish/chum/library/

Washington Department of Fish and Wildlife (WDFW) and Point No Point Treaty Tribes (PNPTT). 2003. Report on summer chum salmon stock assessment and management activities for 2001 and 2002. Supplemental Report No. 4 Summer Chum Salmon Conservation Initiative: An implementation plan to recovery summer chum in the Hood Canal and Strait of Juan de Fuca Region. 219pp.

Washington Department of Fish and Wildlife (WDFW) and Point No Point Treaty Tribes (PNPTT). 2007. Report on summer chum salmon stock assessment and management activities for 2006. Supplemental Report No. 7 Summer Chum Salmon Conservation Initiative: An implementation plan to recovery summer chum in the Hood Canal and Strait of Juan de Fuca Region.

Puget Sound coho salmon[17]

Description of Puget Sound/ Strait of Georgia ESU

The Puget Sound/Strait of Georgia was originally designated in 1994 during the West Coast coho salmon status review (Weitkamp et al. 1995); other than in the earlier section of this report, its boundaries have not been reconsidered since that time. The ESU includes coho salmon from drainages of the Salish Sea, which include Puget Sound and Hood Canal, the eastern Olympic Peninsula (east of Salt Creek, Strait of San Juan de Fuca), and the from the eastern side of Vancouver Island (north to and including Campbell River) and the British Columbia mainland (north to and including Powell River) (Strait of Georgia), excluding the upper Fraser River above Hope (Figure 1).

Summary of Previous BRT Conclusions Puget Sound/Strait of Georgia Coho Salmon ESU

The 1994 Status Review

In addition to delineating ESU boundaries, the 1994 BRT examined the status of all coho salmon ESUs along the West Coast (Weitkamp et al. 1995). For the Puget Sound/Strait of Georgia, the BRT noted that although population abundance in 1994 was near historical levels and recent trends in overall population abundance were not downward, there was substantial uncertainty relating to several of the risk factors considered. These risk factors included 1) widespread and intensive artificial propagation, 2) high harvest rates, 3) extensive habitat degradation, 4) a recent dramatic decline in adult size, and 5) unfavorable ocean conditions. Concerns associated with declining adult size included reduced fecundity, greater likelihood that redds would be destroyed by winter storms due to their shallower depth, the inability of salmon to successfully ascend challenging river reaches, and genetic changes such that populations would permanently lose the ability to produce large individuals; taken together, these would result in lower population productivity.

The BRT's overall conclusion for the ESU was that if present trends continued, the ESU was likely to become endangered in the foreseeable future, although it also recommended that further information would likely clarify some of these uncertainties (Weitkamp et al. 1995).

The 1995 Status Review

When it revisited the Puget Sound/Strait of Georgia in 1995, many of the questions the 1994 BRT raised about the status of natural populations were answered to varying degrees. For example, it was determined that the majority of natural production and spawning escapement in Puget Sound occurred in basins managed for natural escapement and production (Skagit, Stillaguamish, Snohomish Rivers, and South and Central Hood

---

[17] Section author: Laurie Weitkamp. Puget Sound coho are not listed under the ESA. However, they are a species of concern (69FR19975) so we have included a brief review of this ESU in our report.

Canal), and these natural populations appeared to be stable. Hatchery influence was considerably less in these areas than in those managed for hatchery production, where hatchery production was extensive (10s of millions of fry and smolts released annually). Harvest rates on these natural stocks were generally lower than on stocks in areas managed for hatchery production.

Size of adults in this ESU increased slightly in the 1994 and 1995 return years, although they were still generally smaller than they were in 1990. Limited data on the size of natural spawners indicated downwards trends, although they did not appear to be declining as steeply as some hatchery stocks.

As of 1995, overall abundance of coho salmon, including both natural and artificial production, was much higher in this ESU than in any of the other coho salmon ESUs. In the U.S. portion alone, estimated run size was approximately a half million fish. Three drainages that were dominated by natural production had spawning escapements in excess of 10,000 fish, led by the Snohomish River with a geometric mean of over 75,000.

On the other hand, the 1995 status review found that there continued to be several reasons for concern about the health of natural populations of coho salmon in this ESU. First, the 1995 BRT lacked detailed information for coho salmon in the Canadian portion of this ESU, but available data indicated that natural populations in British Columbia declined substantially during the early 1990's. Second, artificial propagation of coho salmon was conducted on an immense scale in both the Canadian and U.S. portions of this ESU. Large geographic areas of Puget Sound (e.g., the Nooksack River and all the southern drainages) were managed for hatchery production, and little natural production was expected (or encouraged) from streams in these areas. Finally, the decline in adult size of coho salmon was dramatically sharper in Puget Sound than in other areas of the Pacific Northwest.

After weighing these various factors, the majority of the 1995 BRT concluded that this ESU was neither at risk of extinction nor likely to become so in the foreseeable future. A minority felt that the ESU was likely to become endangered. A key factor was the presence of several relatively large populations in natural production areas in north Puget Sound, which suggested that the ESU as a whole was not at significant extinction risk. However, the BRT was very concerned that these natural populations were few in number and concentrated in a relatively small portion of the ESU.

The 1995 status review (Weitkamp et al., 1996) was never finalized due to a request by co-managers for further review and comment. At present, Puget Sound coho salmon are not listed on the Endangered Species List, but remain a species of concern (Species of Concern 4/15/04 (69FR19975).

New Data and Updated Analyses

Because the Puget Sound/Strait of Georgia ESU has not been formally evaluated since 1995, there is a wide variety of new or updated information available for coho salmon within the ESU. For purposes of this review, we have focused on updating key data series used in the previous reviews to provide insight into the overall status of the Puget Sound portion of the ESU, in order to address whether the ESUs overall status has likely changed since the 1995 status review. Accordingly, we examined updated data series of harvest rates, abundance (spawner abundance and run size), adult size, marine survival rates, and smolt production. If examination of this information leads to the conclusion that ESU status has greatly deteriorated, then a wider range of information will be considered as part of a formal status review.

Abundance and trends

The abundance of coho salmon in Puget Sound remains quite high. For Puget Sound as a whole, there returned a geometric mean of 483,000 spawners and a total run size of 851,000 during the period of 2000-2008 (PFMC 2010). The single largest natural population (Snohomish River) has a geometric mean of 122,000 spawners during 2000-2008, reaching 252,000 fish in 2004 (PSC 2010). Trends in spawning abundance in the major natural production areas are fairly flat since 2005, but are down from the peaks seen in 2002-2004 (Figure 75). Current spawning escapement is similar to levels in the 1990's.

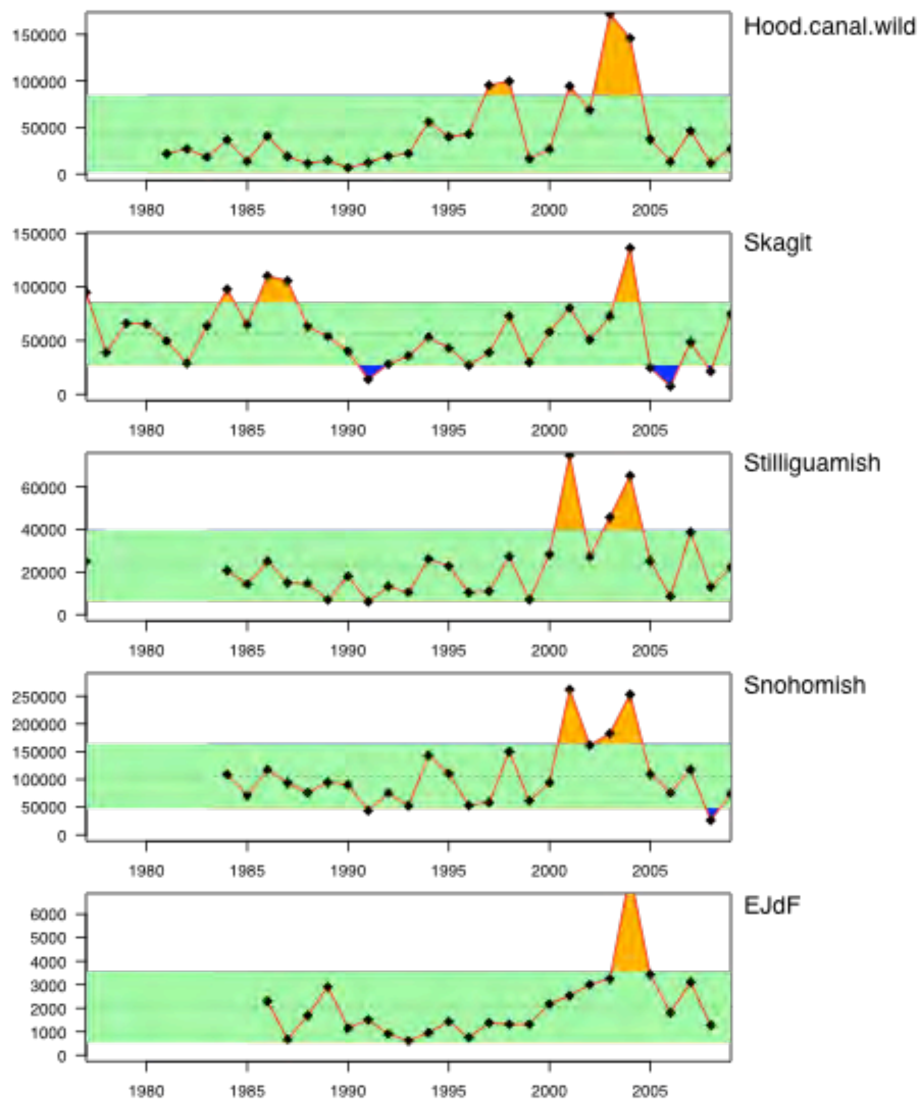


Figure 75 -- Spawning escapement trends in the major wild population areas of for Puget Sound coho salmon. Data compiled from WDFW.

Table 54 – Short and long-term trends for the major natural production stocks of Puget Sound coho salmon.

Stock	Geometric mean spawners[1]	Short-term trend (95% CI)[2]	Long-term trend (95% CI)[3]
Hood Canal	23490	0.946 (0.849 - 1.052)	1.036 (0.999 - 1.074)
Skagit	27074	0.984 (0.897 - 1.08)	0.983 (0.962 - 1.006)
Snohomish	71800	0.99 (0.911 - 1.076)	1.007 (0.978 - 1.037)
Stillaguamish	18864	1.028 (0.936 - 1.13)	1.029 (0.995 - 1.066)
E Strait of Juan de Fuca	2859	1.077 (0.999 - 1.161)	1.044 (1.007 - 1.082)

[1]2005 – 2009 for all except ESJF, which is 2004-2008. [2] Trend from 1995. [3] Trend from 1981 (Hood Canal), 1977 (Skagit), 1984 (Snohomish, Stillaguamish), and 1986 (ESJF). Based on data compiled from WDFW.

Harvest

Puget Sound coho salmon are taken primarily in Puget Sound fisheries. Historically, Canadian coho fisheries off of WCVI and in the Strait of Georgia had very high impacts on Puget Sound coho as well and member of the ESU are take in northern BC, southeast Alaska, and in ocean fisheries off the coast of Washington. Within Puget Sound, fisheries in the south Sound, and Hood Canal are managed for hatchery production, and fisheries in the Strait of Juan de Fuca and northern and central Puget Sound are managed for natural production. Differences in exploitation patterns reflect these differences in management strategy (Figure 76). Exploitation rates in the vicinity of 80% in the late 1980s fell dramatically on stocks managed for natural production within Puget Sound as a result of severe restrictions on Canadian fisheries to protect upper critically depressed Fraser River coho salmon. US fisheries in Washington waters have also been constrained by limits on upper Fraser coho salmon negotiated through the Pacific Salmon Treaty. Recreational fisheries and ocean commercial fisheries in Washington and Oregon waters also switched over to mark-selective fishing beginning in 1999. As a result, total exploitation rates on the Puget Sound coho stocks managed for natural production have been relatively stable since 2000 in the range of 40% or less.

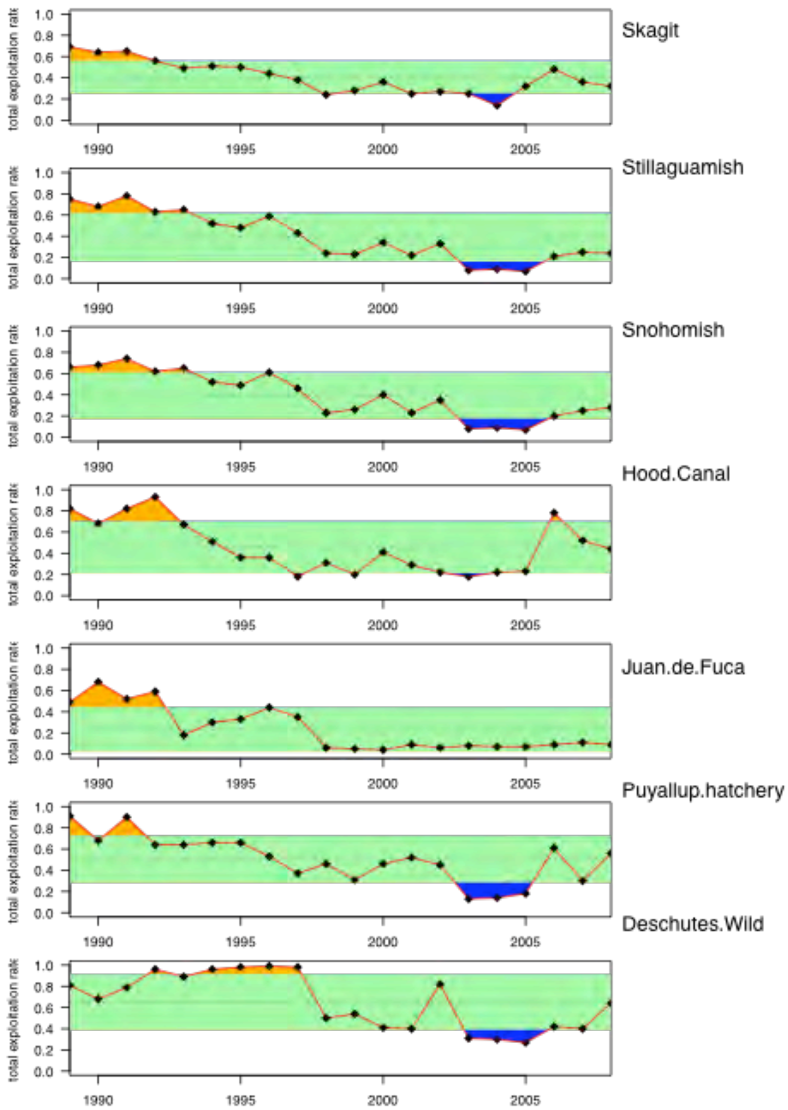


Figure 76 -- Total exploitation rates on Puget Sound coho stocks. Data 1989-1997 based on coded-wire-tag analysis, and 1998-2008 from Fishery Regulation Assessment Model validation runs (Larrie LaVoy, NMFS, personal communication)

Artificial Propagation (Hatcheries)

In both the 1994 and 1995 status review, the BRT had concerns about the level of hatchery influence in the ESU as a whole. Many of the concerns about hatchery influence in basins managed for natural production were addressed in the 1995 review, with the general feeling that natural production areas had limited hatchery influence. Current information indicates that hatchery influence is still substantial in the Puget Sound portion of the ESU as a whole, although it has declined substantially since 1995 (Figure 78) as the number of coho salmon released annually has declined. For example, Puget Sound terminal run size was composed of 62% hatchery fish during years 1981-1996, but decreased to 43% during the period from 1997-2008 (Figure 77; PFMC 2010). Similarly, the percent of spawners that were of hatchery origin decreased from 47% during the earlier period (1981-1996) to 35% after 1996. Hatchery influence in basins managed for natural production (Skagit and Stillaguamish-Snohomish) remains low (19 and 21% for run size and 19% and 8% for spawners, respectively, for years 2000-2008). Overall coho hatchery production in Puget Sound has declined from an average of 35 million fish released annually in the 1980's to ~12 million annually during the period 2005-2009.

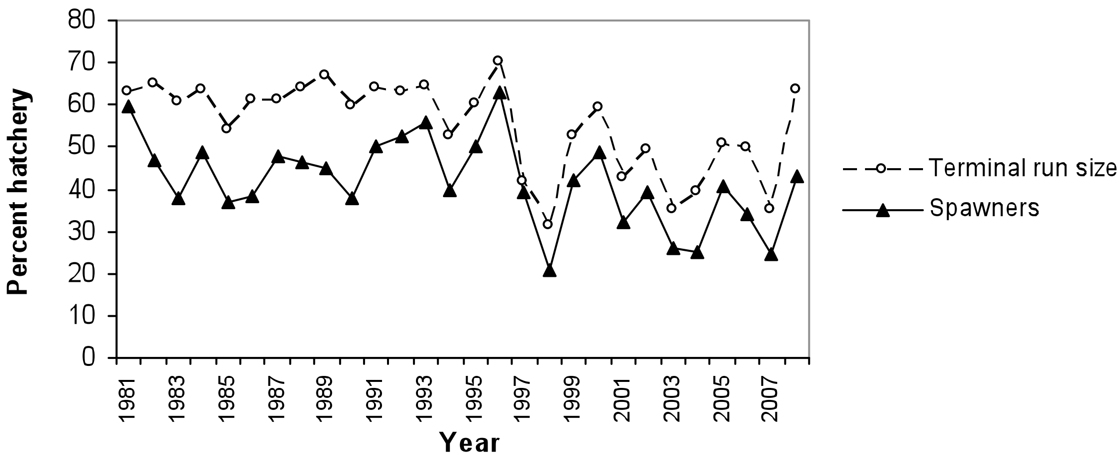


Figure 77 -- Percent of Puget Sound coho salmon of hatchery origin estimated for both terminal run size (before terminal harvest) and for spawners. Data from PFMC 2010.

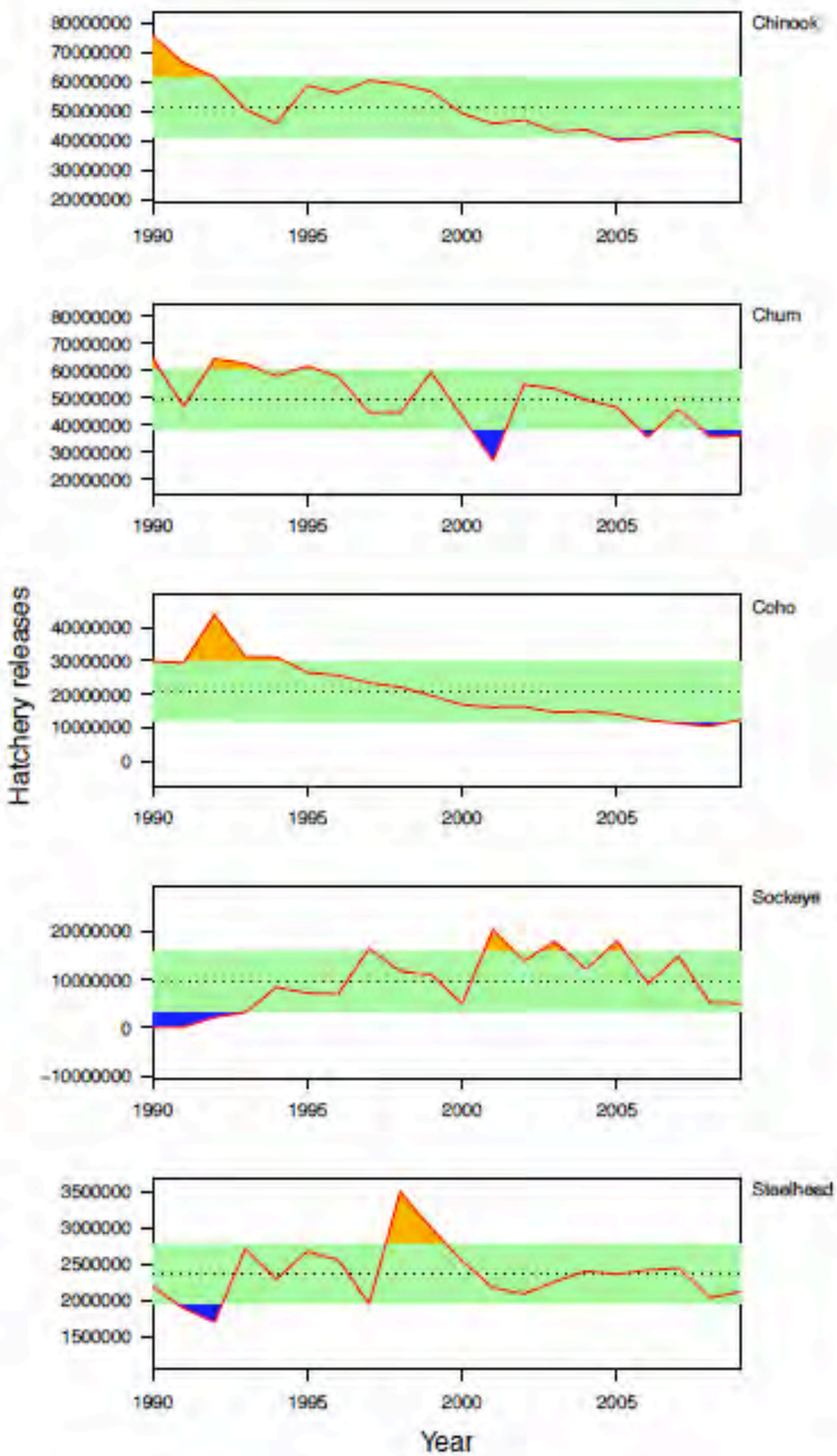


Figure 78 -- Summary of hatchery releases within the Puget Sound coho ESU spawning and rearing areas. Source: RMIS.

Other Factors

Marine survival

Marine survival rates are estimated annually for four wild Puget Sound coho salmon populations based on coded wire tags: Big Beef Creek, Deschutes River, South Fork Skykomish, and Baker (Table 55, Figure 79; Zimmerman 2009). Big Beef Creek has consistently had the highest marine survival rate (16.0% during 1978-2008), Deschutes and SF Skykomish have been intermediate (11.8% and 13.5%, respectively) and Baker River the lowest (8.1%). Baker marine survival rates were not estimated prior to 1992, at a time when rates were generally high (mean 18.4%) compared to the period since 1992 (9.8%). For all populations, trends in marine survival rates have been declining, at rates of -0.25%/year (SF Skykomish) to -0.94%/year (Deschutes River). Part of this downward trends comes from consistently low survival rates for coho salmon returning in 2006 (mean = 3.0%) and 2008 (mean = 3.7%). However, as recently as 2004 marine survival rates were still quite high (mean = 13.7%), with Big Beef Creek reaching an impressive 24.4% marine survival rate (Zimmerman 2009).

Table 55 -- Marine survival rate information for wild Puget Sound coho salmon populations. Regression slopes that are statistically significant at $p \leq 0.05$ are in bold. Data from Zimmerman 2009.

	Attribute			
Population	Years for estimate	Average marine survival (%)	Slope	Regression r^2
Big Beef Creek	1978-2008	15.96	**-0.36**	0.191
Deschutes River	1980-2008	11.81	**-0.94**	0.677
SF Skykomish	1979-2008	13.5	**-0.25**	0.155
Baker River	1992-2008	8.10	**-0.34**	0.298

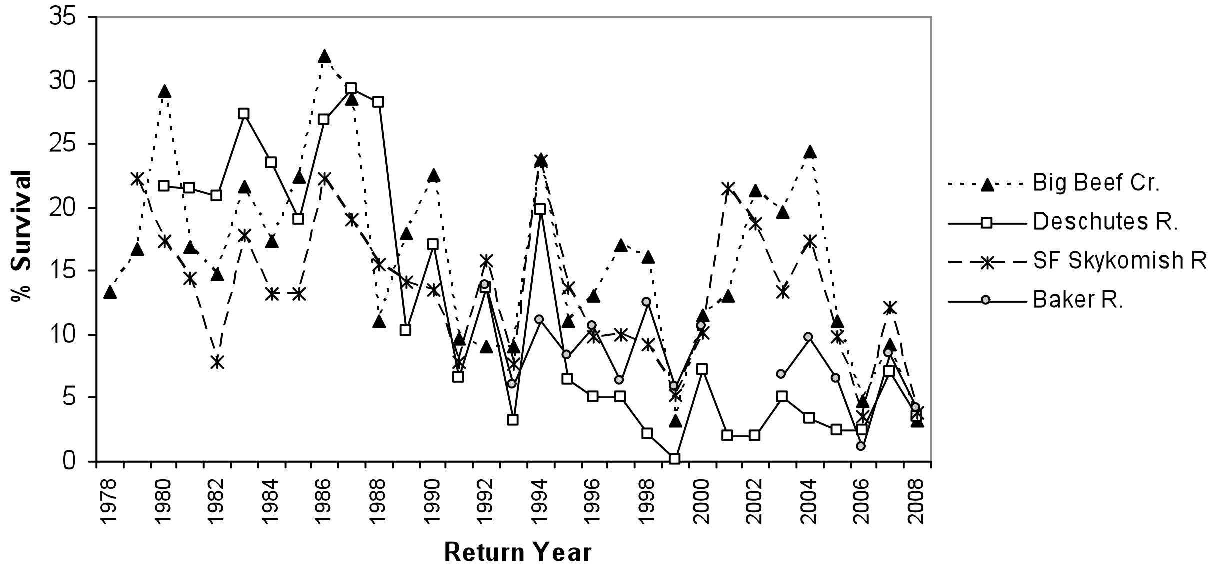


Figure 79 -- Marine survival rates for wild coho salmon populations in Puget Sound. Data from WDFW 2010.

Smolt production

The number of smolts produced in numerous major and minor rivers in Puget Sound is estimated each year (Zimmerman 2009). Rivers for which there are recent smolt production estimates include Dungeness, Skagit, Cedar, Green, and Deschutes Rivers and Big Beef Creek, with a single (2009) estimate for the Nisqually River (135, 512) (Zimmerman 2010). Of these systems, the Skagit produces the most smolts (averaging 1,037,119 annually since 1990), followed by the Green River (79,701), Cedar (50,759), Deschutes (48,144), Dungeness (25,038) and Big Beef Creek (27,015) (Fig. SP).

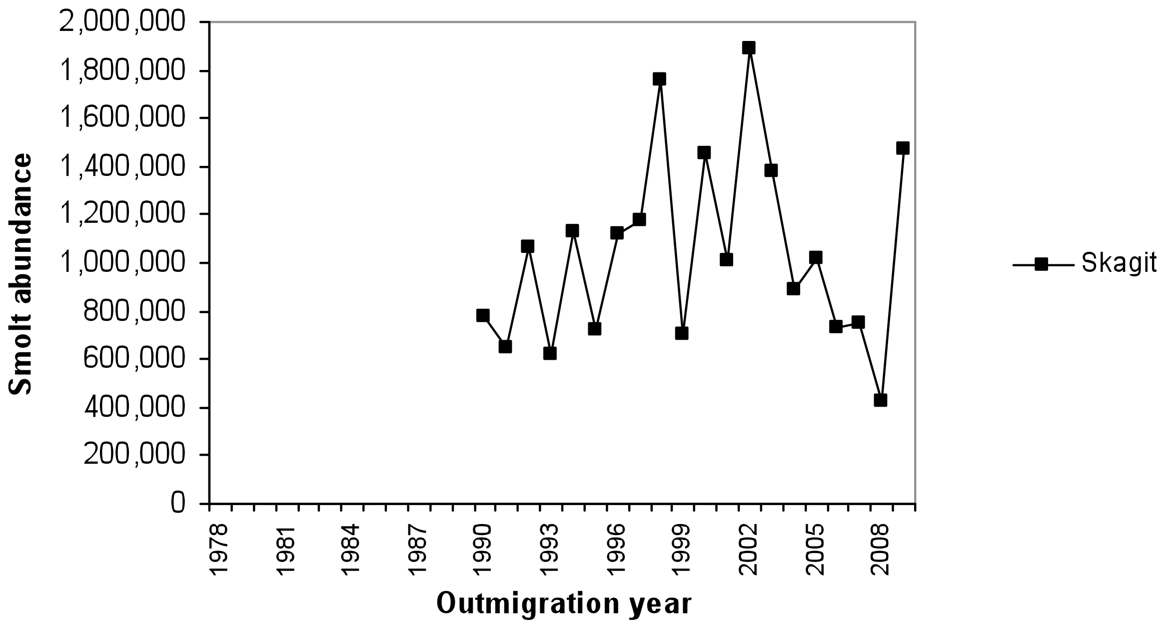
Analysis of the trends of smolt production over time indicate that only the Deschutes River had a significant trend ($p < 0.05$) with a declining slope of -2842 smolts/year (Table 56). The slopes of smolt production over time for other basins were a mix of positive (Skagit, Big Beef Creek) and negative (Dungeness, Cedar, Green River), but none were statistically meaningful ($p > 0.10$). For many populations, smolt production was low in 2007 and 2008, but rebounded in 2009 such that three basins (Skagit, Cedar, Big Beef Creek) had above average production that year, including the highest smolt production from the Skagit (1,475,065 smolts) since the 2000 outmigration (Figure 80).

Table 56 -- Smolt production estimates for Puget Sound populations. Data from M. Zimmerman, WDFW.

Population	Years	Average smolt production	Slope of smolts over time*	Regression r^2
Dungeness	2005-2009	35,038	-7522	0.60

Skagit	1990-2009	1,037,119	+7826	0.01
Cedar River	1999-2009	50,759	-1994	0.08
Big Beef Creek	1978-2009	27,015	231	0.05
Green River	2000-2009	79,701**	-5651	0.08
Nisqually	2009	135,512	--	--
Deschutes	1979-2009	48,144	**-2943**	0.43

*Slopes that are statistically significantly at $p < 0.05$ are indicated in bold.
**Smolt production estimates were not available for smolt outmigration years 2004, 2005 and 2008.



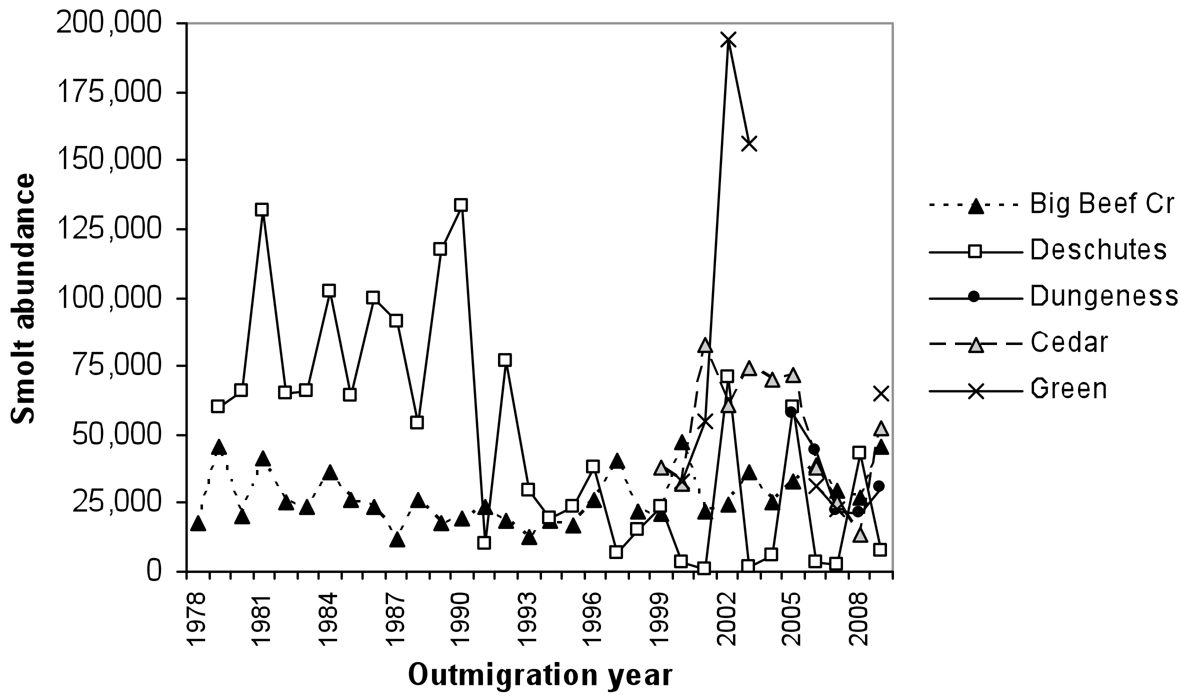


Figure 80 -- Estimated smolt abundances for various Puget Sound coho salmon populations.

Adult size

One of the concerns of previous reviews of Puget Sound coho salmon was the rapid decline in adult size, discussed above. Updated data on the size of coho salmon collected in fisheries, upon return to hatcheries (from the coded wire tag database), or measured at weirs all indicate that adult size reached minimum levels in the mid 1990s and has since increased (Figure 81, Figure 82, Figure 83). For most data series examined, the size of coho salmon in the last few years is comparable to that in the 1970s and 1980s, before the rapid decline. Accordingly, while 1994 status review provided evidence that trends in Puget Sound adult size were declining and most were statistically significant ($p < 0.05$; Weitkamp et al. 1995), updated trends indicate both fewer negative slopes (only 10 of 26 time series examined), of which few only 4 were statistically significant, while most trends were positive (16 of 26) including three statistically significant positive trends (Table 57).

Although we did not examine trends in fecundity, we have no reason to assume that increasing trends in adult size are not accompanied by a concurrent increase in fecundity. Perhaps most importantly, recent increases in size clearly indicate that Puget Sound coho salmon have not lost the ability to produce large adults when the conditions are right.

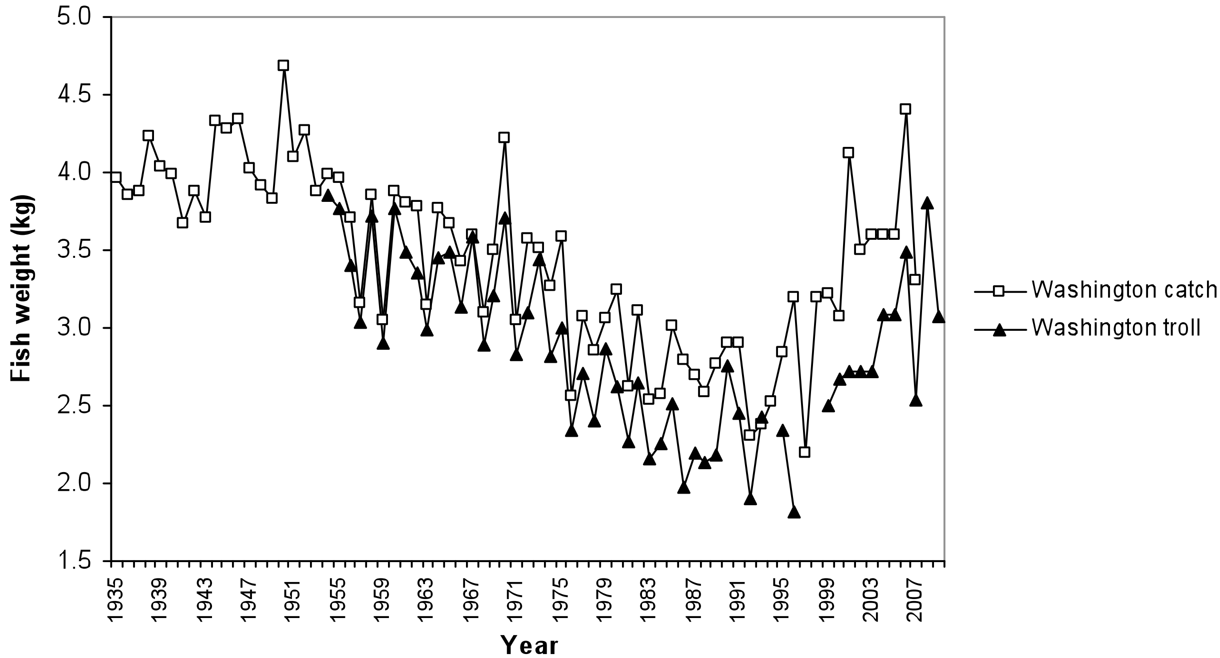


Figure 81 -- Long term trends in estimated weight of coho salmon caught in Washington commercial fisheries ("Washington catch") or Washington commercial troll fisheries ("Washington troll"). Data from Wright 1970, WDF 1985, WDF 1996, and PFMC 2009.

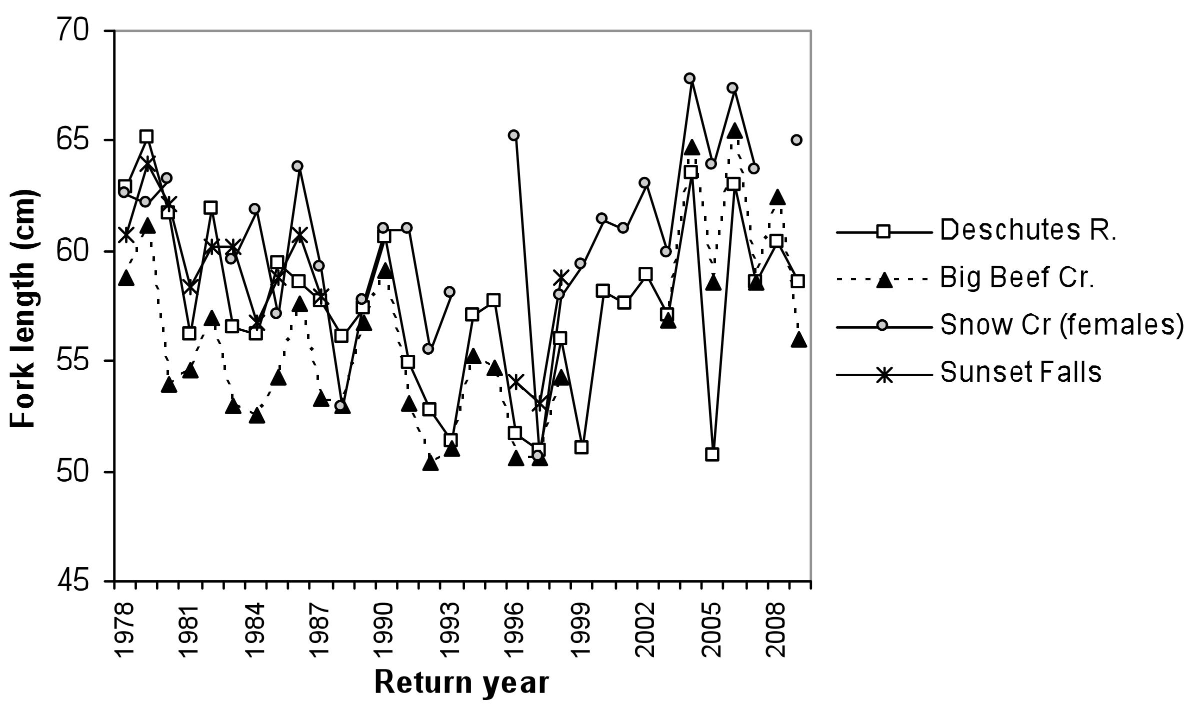


Figure 82 -- Trends of adult coho salmon size from monitored wild populations in Puget Sound. Data from M. Zimmerman, WDFW, 2010.

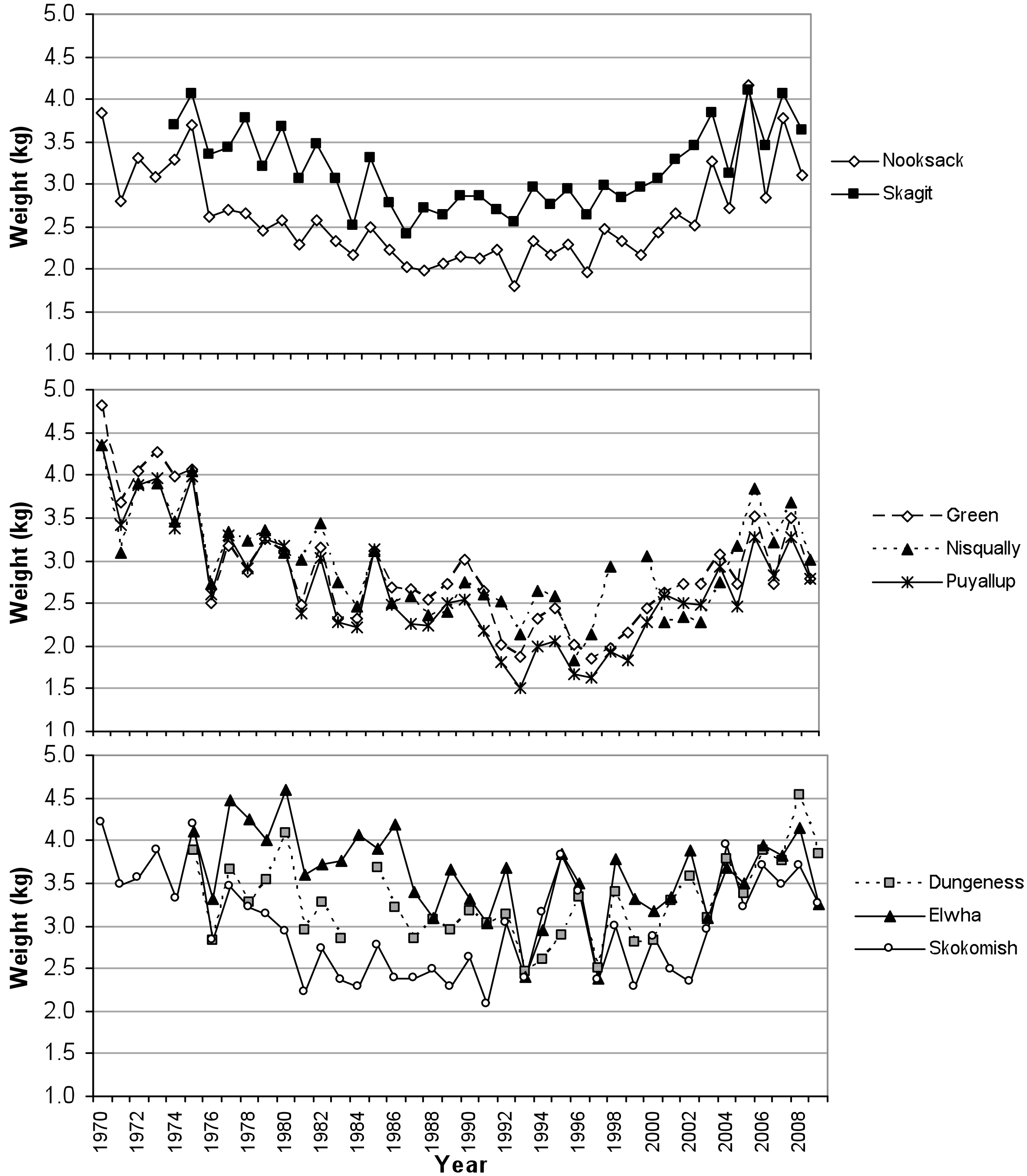


Figure 83 -- Trends of adult size for salmon caught in in river fisheries in north (top) and central (middle) Puget Sound and Hood Canal and the Strait of Juan de Fuca (bottom). Data from WDFW 2010.

Table 57 -- Regression statistics for changes in adult size over time. Included are years considered and slopes reported in our earlier analysis (Weitkamp et al. 1995). Slopes that are statistically significant at $p<0.05$ are in bold font.

Population/Fishery	Measurement source	Measurement type	Current years	Previous years	Current Slope	Previous slope	Source
Washington commercial catch	all	weight	35-07	35-91	**-0.02**	**-0.03**	1
Washington commercial troll	troll	weight	54-09	54-92	**-0.02**	**-0.04**	2
Big Beef Creek	spawners	length	78-98, 03-09	78-91	0.14	-0.43	3
Deschutes River	spawners	length	78-09	78-92	-0.08	**-0.96**	3
Nooksack	in river	weight	70-09	77-93	0.00	**0.03**	4
Nooksack	hatchery returns	length	76-08		0.15		4
Skagit	in river	weight	74-09	78-93	0.00	**-0.06**	4
Skagit	hatchery returns	length	74-08		**0.16**		4
Skagit	test fishery	length	84-08		**0.18**		5
Snohomish (Wallace R)	hatchery returns	length	74-08		0.14		4
Snohomish (Issaquah Cr)	hatchery returns	length	74-05		0.06		4
Duwamish/Green	in river	weight	70-09	72-93	**-0.03**	**-0.09**	4
Duwamish/Green	hatchery returns	length	74-08		-0.02		4
Puyallup	in river	weight	70-09	72-93	**-0.03**	**-0.09**	4
Puyallup	hatchery returns	length	75-08		0.02		4
Nisqually	in river	weight	70-09	72-93	-0.02	**-0.08**	4
Nisqually	hatchery returns	length	80-08		0.31		4
Minter Creek	hatchery returns	length	73-08		0.04		4
Purdy Creek	hatchery returns	length	74-08		0.10		4
Big Quilcene	hatchery returns	length	80-08		0.08		4
Skokomish	in river	weight	70-09	79-90	-0.01	-0.04	4
Snow Creek (females only)	spawners	length	78-09 (incomplete)		0.12		3
Dungeness	in river	weight	75-09	75-83	0.01	-0.06	4
Dungeness	hatchery returns	length	75-08		-0.11		4
Elwha	in river	weight	75-09	77-93	-0.02	**-0.08**	4
Elwha	hatchery returns	length	80-08		0.09		4

Sources are: 1—WDF 1985, PFMC 2010; 2—Wright 1970, WDF 1985, PFMC 2010; 3—M. Zimmerman (WDFW), unpublished data; 4—WDFW 2010; 5—B. Hayman (Skagit Cooperative), unpublished data.

Puget Sound coho salmon: Updated Risk Summary

The available information suggests that the status of the Puget Sound coho salmon ESU is similar, or perhaps improved, from its status at the time of the last formal status review in 1995. Some of the risk factors identified in the earlier status review, in particular the declining trend in adult size, have reversed. Abundance in the northern populations managed for natural escapement remains as high or higher than it was at the time of the last status review. Harvest rates on natural origin Puget Sound coho salmon have generally declined since 1995. Total hatchery releases of coho salmon in the ESU have declined, although the southern portion of the ESU continues to have large number of hatchery returns. This review did not specifically evaluate trends in habitat quality, but many of actions taken as a result of the Chinook and steelhead listings likely provide some benefit to coho salmon as well. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

NMFS (National Marine Fisheries Service) 1996. Factors for decline: A supplement to the notice of Determination for West Coast Steelhead. NMFS Protected Species Branch, Portland, OR. Online at http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Reports-and-Publications/upload/stlhd-ffd.pdf.

NMFS (National Marine Fisheries Service) 1998. Factord contributing to the decline of West Coast Chinook salmon: An addendum to the 1996 West Coast Steelhead Factors for Decline Report. NMFS Protected Species Branch, Portland, OR. Online at: http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Reports-and-Publications/upload/chnk-ffd.pdf

Pacific Fisheries Management Council (PFMC). 2010. Review of the 2009 ocean fisheries. Available from PFMC, pcouncil.org.

Pacific Salmon Commission (PSC). 2010. 1986-2008 Period Report. Report TCCoho (xx)-x. Draft version provided by WDFW.

Puget Sound Salmon Recovery Plan

Washington Department of Fisheries (WDF). 1985. Annual Fisheries Statistics. WDF, Olympia, Washington.

Washington Department of Fish and Wildlife (WDFW). 2010. Information on Puget Sound coho salmon provided to Laurie Weitkamp.

Weitkamp, L.A., T.C. Wainright, 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. Dep. Commer. NOAA Tech. Memo. NMFS-NWFSC-24, 258 p.

Weitkamp, L.A., P. Adams, G. Bryant, P.Busby, R.Emmett, J.Hard, O.Johnson, R.Iwamoto, R. Kope, C.Mahnken, G. Matthews, M. Schiewe, D.Teel, T. Wainwright, W.Waknitz, R. Waples, J.Williams, G Winans, 1996. Draft Status review of coho salmon from Washington, Oregon, and California. Available from Dr. Laurie Weitkamp, NMFS 2032 SE OSU Drive, Newport, OR 97365

Wright, S. 1970. Size, age, and maturity of coho salmon in Washington's ocean troll fisheries. Wash. Dep. Fisheries, Fisheries Research Papers 3(2): 63.

Zimmerman, M. 2009. 2009 Wild Coho Forecasts for Puget Sound, Washington Coast, and Lower Columbia. Wash. Dep. Fish. Wildlife Rep. 2009-01-28.

Zimmerman, M. 2010. Smolt production and adult size and abundance data provided to L. Weitkamp. WDFW.

Lake Ozette Sockeye salmon[18]

Listed as a threatened species on March 25, 1999; threatened status reaffirmed on June 28, 2005. The ESU includes all naturally spawned populations of sockeye salmon in Lake Ozette and streams and tributaries flowing into Lake Ozette, Washington, as well as two artificial propagation programs: the Umbrella Creek and Big River sockeye hatchery programs. Since then, the ESA salmon recovery plan was finalized for Lake Ozette sockeye May 29, 2009 and the Puget Sound Technical Recovery Team (TRT) finalized analyses on population identification (Currens et al. 2009) and population/ESU viability (Rawson et al. 2009) for this ESU. The Lake Ozette sockeye salmon ESU was determined to consist of only one population which consists of both beach and tributary spawners.

Lake Ozette sockeye were an important contributor to fisheries of the Makah and Quileute Tribes in the first half of the 1900s. Estimates of Makah Tribes annual harvest of Lake Ozette sockeye reach 17,000 in 1949; harvest declined sharply in the 1960's due to declining returns; commercial harvest ended in 1974 and all harvest ended by 1982. Harvest records are our best indicators of population abundance in past years. Estimation of returns to the lake are attempted using a weir at the mouth of the Ozette River; however, functioning of the weir and interpretation of the weir counts has been difficult. However, they do indicate that returns to this system have not recovered.

Previous Status Reviews and Recovery Documents

The three most recent status reviews of Lake Ozette sockeye (Gustafson et a. 1997; NMFS 1998; Good et al. 2005) all agreed that overall abundance is low; but collection/monitoring methods need to be improved to get a better idea of abundance trends.

Five-year geometric means from the three reviews are:

1992-1996, 700 adult sockeye and declining by 10% per year (Gustafson et al. 1997).

1994-1998, 580 adult sockeye and declining by 2% per year (NMFS 1998).

1997-2001, 2,267 adult sockeye and increasing by 28% per year (Good et al. 2005).

The increased numbers in the 2005 review could be in part due to changes in methods of counting data through the weir.

The hatchery supplementation program was developed in 1982 to plant fry in Umbrella Creek and Big Creek with the intent of starting spawning in the tributaries to augment the traditional beach spawning by the population. Beach spawning seems to be declining, due in part to loss of quantity and quality of adequate beach spawning habitat. Spawning in Umbrella Creek has become self-sustaining as indicated by estimates of natural origin spawners to the tributary. The current hatchery program is limited to releases through 2012, at which time it will be re-evaluated.

The recovery plan for Lake Ozette sockeye was adopted by NMFS in 2009 (NMFS 2009) and population identification and viability were determined by the Puget Sound TRT also in 2009 (Currens et al. 2009 and Rawson et al. 2009, respectively).

---

[18] Section author: Norma Sands

New Data and Updated Analyses

ESU Status at a Glance

Historical peak catch levels	15,000–18,000 (1949-1951)
Historical populations	1
Extant populations	1
Current 5-yr average escapement	2,679 (NOR)
Viable population structure	1 population with multiple beach and tributary spawners
Viable min. spawning abundance	35,500

ESU Structure

The Puget Sound TRT considers the Lake Ozette sockeye salmon ESU to be composed of one historical population (Currens et al. 2009), with substantial substructuring of individuals into multiple spawning aggregations. The primary existing spawning aggregations occur in two beach locations— Allen's and Olsen's beaches, and in two tributaries, Umbrella Creek and Big River (both tributary-spawning groups were initiated through a hatchery introduction program).

New Data and Updated Analyses

New data for Lake Ozette sockeye are from the annual resource management reports from the Makah Tribe (Peterschmidt & Hinton 2005, 2006, 2008 and Peterschmidt et al. 2007). Escapement data are available from 1077-2007, although the escapement weir data from 2004 was not expanded in the reports. Estimates of sockeye returning to Lake Ozette are generally made based on weir counts and represent the returns to the lake before pre-spawning mortality such as in-lake predation. Estimation of returns and of spawners has been difficult; weir operation has been problematic and the method for expanding weir counts has changed periodically. The lack of reliable spawning estimates makes it difficult to assess the status or any changes that might be occurring over time for this population.

There is no harvest on Lake Ozette sockeye since 1982; there were only minor terminal catches from 1977 to 1982.

Age of beach spawners are assumed to be all age 4 while the age distribution of tributary spawners is estimated at a weir at the mouth of Umbrella Creek and are provided in the resource management reports

Cohort run reconstruction is done using the PS TRT Abundance & Productivity Excel Table (Sands 2009).

Abundance and Productivity Estimates

Estimating spawning abundance and hatchery contributions remains difficult for the population. Various reports give slightly different estimates and weir counts have not been expanded by the comanagers since 2003. For this report we expand the weir counts based on average expansion factors used in the past; these data are considered highly imprecise and are included here to utilize the information that is available for these recent years. Estimates used here differ somewhat from those used by the TRT in their viability report (Rawson et al 2009) based on data provided in the annual Resource Management Plan Reports from Makah Fisheries Management for 2004-2007.

The abundance data used are provided in Table 58 and Figure 84. Escapement numbers that are italic in the table are estimated missing values, or in the case of 2004 to 2007, expanded weir counts based on average expansions, not year specific expansions. These number have high uncertainty but we expect these estimates to be updated by tribal biologists in the future.

Table 58 -- Natural spawning escapement (includes natural origin and hatchery origin fish), natural origin (NOR) fish, the percent of natural escapement that is hatchery origin, the percent of natural spawners that occur in the tributaries

Year	Total[1]	Natural origin	Hatchery %	% Tributary Spawners	Harvest	Broodstock Take
1977	2,752	2752	0%	0%	84	0
1978	2,398	2398	0%	0%	30	0
1979	1,335	1335	0%	0%	30	0
1980	1,054	1054	0%	0%	30	0
1981	858	858	0%	0%	0	0
1982	4,131	4131	0%	0%	29	0
1983	*814*	814	0%	0%	0	14
1984	2,447	2447	0%	0%	0	0
1985	*2,014*	2014	0%	0%	0	40
1986	*1,592*	1592	0%	0%	0	43
1987	*5,579*	5579	0%	0%	0	123
1988	9,577	9098	5%	5%	0	193
1989	1,671	1587	5%	5%	0	6
1990	699	664	5%	5%	0	33
1991	1,780	1691	5%	5%	0	175
1992	4,058	3873	5%	5%	0	109
1993	*357*	328	8%	10%	0	32
1994	964	894	7%	10%	0	54
1995	*363*	230	37%	57%	0	94
1996	3,931	4063	5%	9%	0	200
1997	1,346	1052	22%	47%	0	263
1998	1,882	1714	9%	24%	0	88
1999	2,620	2248	16%	55%	0	29
2000	4,851	4208	13%	71%	0	213
2001	4,151	3846	7%	85%	0	164
2002	3,822	3344	12%	45%	0	168
2003	4,876	4830	1%	36%	0	199
2004	*4,917*	4368	11%	90%	0	218
2005	*2,260*	1753	22%	98%	0	192
2006	*2,288*	1934	15%	43%	0	86
2007	*510*	509	0%	10%	0	45

[1]Total natural spawning estimates are taken from the Limiting Factors Analysis report accompanying the Lake Ozette Recovery Plan, except for italic numbers which are estimated by various methods of filling in missing data. For 1983, 1986, 1993, 1995, values were given in an earlier version of the LFA report; all estimates given in the later report were expanded numbers; these four years are expanded by the average expansion value. For 1985 and 1987 the average of the preceding and following year was used. For 2004 to 2007 only raw weir counts were supplied in Tribal annual reports; these weir counts were expanded by the average expansion used from 1997 to 2003.

Average escapement over five-year intervals is given in Table 59 as well as estimates of trends [exp[trend(ln(esc))]] over the intervals. No trend is notable, with the years 1993-1997 having relatively low abundances and 1998-2002 having relatively high abundances.

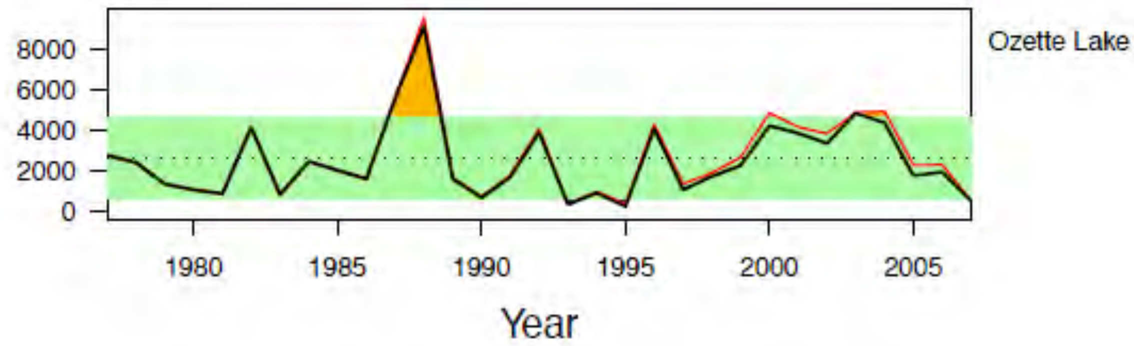


Figure 84 – Trend in spawning abundance of Lake Ozette sockeye salmon. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

Table 59 -- Five-year geometric mean escaapments for natural origin spawners and natural spawners (natural and hatchery origin) for Lake Ozette sockeye and trend over the 5-year intervals. Note the first year range includes 6 years to include the start of available data.

Years	Natural origin	Total
77-82	1,790	1,790
83-87	2.044	2.044
88-92	2,289	2,407
93-97	766	921
98-02	2,899	3,280
03-07	2,052	2,291
Trend	1.05	1.02

Short and long term trends [exp[trend(ln(esc))]] and growth rates (lambda) as estimated by the SPAZ program are given in Table 60. Although the SPAZ programs gives estimates of lambda for both assumptions of hatchery fish having zero success on the spawning grounds and 100% success, the hatchery fish in Lake Ozette are having a degree of success. These fish are from the conservation hatchery program that is introducing spawners in the tributaries; the hatchery fish have been successfully spawning and establishing spawning aggregates in the tributaries. Neither the trend nor growth rate shows any indication of increasing population growth.

Table 60 -- Short and long term population trend and growth rate estimates for the Lake Ozette sockeye population.

	Hatchery Fish Success =0	Hatchery Fish Success =1

Years	Trend Nat Sp w/CI	Lambda w/CI	p>1	Lambda w/CI	p>1
1995 - 2007	1.041 (0.893 - 1.213)	1.022 (0.328 - 3.19)	0.5769	0.995 (0.329 - 3.006)	0.4816
1977 - 2007	1.004 (0.969 - 1.041)	1.005 (0.861 - 1.173)	0.5306	0.991 (0.85 - 1.156)	0.4421

Productivity is measured in terms of recruits from natural spawners. Most Lake Ozette sockeye are age 4, but there are estimates of a few age 5 spawners on the beaches and both age 3- 5 spawners returning to the tributaries. Using the age data, cohort run reconstruction is done to provide recruit per spawner (R/S) estimates for brood years 1977-2003. As is normal for salmon, productivity various greatly from year to year. However, the most recent brood years (1999-2003) have the lowest average R/S (Table 61).

Table 61 -- Recruits per spawner for Lake Ozette sockeye brood years 1977-2003.

Brood Year	R/S
1977	0.32
1978	1.74
1979	0.61
1980	2.34
1981	2.39
1982	0.40
1983	7.11
1984	3.76
1985	0.78
1986	0.43
1987	0.34
1988	0.41
1989	0.20
1990	1.38
1991	0.17
1992	0.98
1993	3.60
1994	1.88
1995	6.22
1996	1.12
1997	2.96
1998	1.85
1999	1.92
2000	0.93
2001	0.45
2002	0.52
2003	0.11
5-year arithmetic averages	
BY 79-83	2.57
BY 84-88	1.15
BY 89-93	6
BY 94-98	2.81
BY 99-03	0.79
Trend	-0.19

Spatial structure and diversity

Spatial structure and diversity are important factors in determining viability of salmon populations. These viability factors for Lake Ozette sockeye are measured using spawning location as the indicator. It is, therefore, important to be monitoring the spawning distribution of this population, not only between beach and tributary spawners, but among location sites within each of these spawning types. There is currently a weir at the mouth of Umbrella Creek where there is a hatchery introduction program that monitors escapement to that tributary. However, there is currently no successfully quantitative program to monitor beach spawning or spawning at other tributaries.

Hatchery releases
Hatchery releases started in 1983 into Umbrella Creek with the purpose of introducing tributary spawners into this sockeye ESU (Table 62). The hatchery program will be re-evaluated in 2012 to see if it has accomplished its purpose and will be stopped, or whether it should be continued. The program does seem to have produced natural spawners returning to these two creeks and to a lesser extent in other tributaries. Because of the reduced quality and quantity of beach spawning habitat, these tributary spawners will be an important contribution to overall ESU viability.

Table 62 -- Hatchery releases into Umbrella Creek and Big Creek.

Year	Hatchery releases
1995	45,220
1996	266,295
1997	187,756
1998	69,328
1999	36,660
2000	194,076
2001	246,210
2002	228,549
2003	117,071
2004	231,508
2005	170,698
2006	95,830
2007	50,748

Harvest
Ocean fisheries do not significantly impact Lake Ozette sockeye salmon. Both Lake Ozette and the Ozette River, connecting the lake with the ocean, are closed to salmon fishing.

Lake Ozette sockeye salmon: Updated Risk Summary
Estimates of population data for Lake Ozette sockeye remain highly variable and uncertain. This makes it impossible to detect changes in abundance trends or in productivity in recent years. It is obvious, though, that population levels remain very low compared to historical levels when harvest on these stocks was plentiful. Assessment methods must improve in order to evaluate the status of this population/ESU and its responses to recovery actions. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Currens, K.P., R.R. Fuerstenberg, W.H. Graeber, K. Rawson, M.H. Ruckelshaus, N.J. Sands, and J.B. Scott. 2009. Identification of an independent population of sockeye salmon in Lake Ozette, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-96, 18 p. NTIS number PB2009-108060.

Good TP, Waples RS, 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., p. 598.

Gustafson, R. G., T. C. Wainwright, G. A. Winans, F. W. Waknitz, L. T. Parker, R. S. Waples. 1997. Status review of sockeye salmon from Washington and Oregon. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-33, 282 p.

NMFS (National Marine Fisheries Service). 1998. Proposed rule: Endangered and threatened species: Proposed threatened status and designated critical habitat for Ozette Lake, Washington sockeye salmon. Federal Register [Docket 980219043-8043-01, 10 March 1998] 63(46):11750–11771.

NMFS. 2009. Lake Ozette Sockeye Recovery Plan. Adopted by NMFS May 29, 2009. http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Puget-Sound/Lake-Ozette-Plan.cfm

Peterschmidt, C. and J. Hinton. 2005. Resource management plan report for Lake Ozette sockeye 2004. Makah Fisheries Management Report June 2005. 10pp.

Peterschmidt, C. and J. Hinton. 2006. Resource management plan report for Lake Ozette sockeye 2005. Makah Fisheries Management Report 2006. 11pp.

Peterschmidt, C.,J. Hinton and C. Eggleston. 2007. Resource management plan report for Lake Ozette sockeye 2006. Makah Fisheries Management Report 2007. 10pp.

Peterschmidt, C. and J. Hinton. 2008. Resource management plan report for Lake Ozette sockeye 2007. Makah Fisheries Management Report June 2008. 10pp.

Rawson, K. et al. 2009. Viability criteria for the Lake Ozette sockeye salmon evolutionarily significant unit. NOAA Tech. Memo. NMFS-NWFSC-99. 53 pp.

Sands, N. J. 2009. A user's guide to the abundance and productivity (A & P) tables as developed for Puget Sound Salmon. From the Puget Sound Technical Recovery Team (PS TRT) Abundance and Productivity (A & P) Workgroup. Fourth draft, 20 April, 2009. (Available from N. J. Sands, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Puget Sound steelhead[19]

Listed ESU/DPS
This report covers the Distinct Population Segment (DPS) of Puget Sound steelhead (*Oncorhynchus mykiss*). These fish are the anadromous form of *O. mykiss* that occur in rivers, below natural barriers to migration, in northwestern Washington State that drain to Puget Sound, Hood Canal, and the Strait of Juan de Fuca between the U.S./Canada border and the Elwha River, inclusive.

ESU/DPS Boundary Delineation The DPS boundary delineation for Puget Sound steelhead has not been reviewed since the Biological Review Team's (BRT) 2007 status review of this DPS (Hard et al. 2007). The Puget Sound Technical Recovery Team (TRT) considered genetic and life history information from steelhead on the Olympic Peninsula and Washington coast but concluded that there is no compelling evidence to alter the DPS boundaries described above.

Summary of Previous BRT Conclusions
The initial review of this DPS—then called the Puget Sound Evolutionarily Significant Unit (ESU)—by a BRT was completed in 1996 in response to two listing petitions received by NOAA in 1993 and 1994 (Busby et al. 1996). Subsequent to that BRT review, NOAA issued a determination that listing of Puget Sound steelhead was not warranted (61 FR 41451). In response to a petition to list Puget Sound steelhead received in September 2004, a newly convened BRT completed its report summarizing the status of the Puget Sound steelhead DPS in June 2007 (Hard et al. 2007). Subsequent to the BRT review, NOAA issued its final determination to list the Puget Sound steelhead DPS as a threatened species under the ESA on 11 May 2007 (72 FR 26722); the effective date of the listing was 11 June 2007.

Brief Review of Technical Recovery Team Documents and Findings

The Puget Sound Steelhead Technical Recovery Team (TRT) was formed in March 2008. It has not yet finalized its viability criteria for the Puget Sound steelhead DPS; the TRT is still conducting analyses of these data to identify Demographically Independent Populations (DIPs) and Major Population Groups (MPGs) within the DPS. The TRT expects to complete its report summarizing these criteria in early 2011. Consequently, this report focuses on assessing viability of populations in the DPS for which demographic data are available, and which might reflect a *draft* set of putative DIPs and MPGs thought to represent historical population structure within the DPS. The viability assessment incorporates 1) basic analyses of abundance and trend, followed by 2) a set of simple Population Viability Analyses (PVAs) for these draft DIPs and MPGs within the DPS.

New Data and Updated Analyses

Abundance and trends

---

[19] Section author: Jeff Hard

The data considered in this report include estimates of steelhead natural escapement and/or total run size, as calculated from redd count and catch statistics obtained from the Washington Department of Fish and Wildlife. These data are for winter-run steelhead primarily (the sole summer-run exception is from the Tolt River), and date from 1985. At this point, these populations are considered by the Technical Recovery Team to be potential DIPs; however, they do not include all potential DIPS under consideration by the TRT, so the populations evaluated herein should be considered *draft* DIPs. We present basic analyses of natural escapement data in Table 63 - Table 65 below; these analyses focus on a) data from the entire time series, b) data since 1995, and c) from the most recent five years.

a) Data from the entire series

Since 1985, Puget Sound winter-run steelhead abundance has shown a widespread declining trend over much of the DPS (Table 1). Only four of the 16 populations evaluated exhibit estimates of long-term population growth rate ($\lambda = R_0 = e^r$, where is R_0 is the net birth rate and r is the intrinsic geometric growth rate) that are positive (East Hood Canal, Port Angeles, Samish River, and West Hood Canal), and only one of these is significantly ($P < 0.05$) greater than one (indicating positive population growth): West Hood Canal. These four populations are all small. The highest growth rates over the entire series occur in East Hood Canal, the Green River, Port Angeles, the Samish and Skagit rivers, and West Hood Canal; the lowest rates occur in the Elwha River, Lake Washington, and the Stillaguamish, Nisqually, and Puyallup rivers. Trends could not be calculated for south Puget Sound tributaries.

Table 63 -- Estimates of exponential trend in the natural logarithm (ln) of natural spawners (λ) for several winter-run populations of steelhead in the Puget Sound DPS over the entire data series (1985-2009). NC, not calculated.

Population	Exp. Trend ln(nat. spawners) (95% CI)
South Sound tributaries winter-run	NC
Dungeness River winter-run	0.926 (0.909 - 0.943)
East Hood Canal winter-run	1.022 (0.997 - 1.048)
Elwha River winter-run	0.840 (0.749 - 0.943)
Green River winter-run	0.992 (0.969 - 1.016)
Lake Washington winter-run	0.807 (0.770 - 0.845)
Nisqually River winter-run	0.914 (0.890 - 0.940)
Port Angeles winter-run	1.016 (0.983 - 1.050)
Puyallup River winter-run	0.919 (0.899 - 0.938)
Samish River winter-run	1.008 (0.972 - 1.045)
Skagit River winter-run	0.969 (0.954 - 0.985)
Skokomish River winter-run	0.956 (0.932 - 0.979)
Snohomish River winter-run	0.963 (0.941 - 0.985)

Stillaguamish River winter-run	0.910 (0.887 - 0.934)
West Hood Canal winter-run	1.101 (1.046 - 1.160)
White River winter-run	0.938 (0.923 - 0.952)

b) Data since 1995

Since 1995, Puget Sound winter-run steelhead abundance has also shown a widespread declining trend over much of the DPS (Table 2). Only three of the 16 populations evaluated exhibit point estimates of growth rate that are positive (East Hood Canal, Skokomish River, and West Hood Canal), and only one of these is significantly greater ($P < 0.05$) than one (positive population growth): West Hood Canal. These four populations are all small. The highest growth rates over the entire series occur in East Hood Canal, the Skokomish River, and the Samish and Skagit rivers; the lowest rates occur in the Elwha and Dungeness rivers, Lake Washington, and the Stillaguamish, Nisqually, and Puyallup rivers. Trends could not be calculated for south Puget Sound tributaries.

Table 64 -- Estimates of exponential trend in the natural logarithm (ln) of natural spawners (λ) for several winter-run populations of steelhead in the Puget Sound DPS since 1995 (1995-2009). NC, not calculated.

Population	Exp. Trend ln(nat. spawners) (95% CI)
South Sound tributaries winter-run	NC
Dungeness River winter-run	0.919 (0.786 - 1.075)
East Hood Canal winter-run	1.033 (0.976 - 1.092)
Elwha River winter-run	0.750 (0.020 - 28.503)
Green River winter-run	0.953 (0.892 - 1.019)
Lake Washington winter-run	0.731 (0.656 - 0.815)
Nisqually River winter-run	0.935 (0.876 - 0.997)
Port Angeles winter-run	0.964 (0.899 - 1.031)
Puyallup River winter-run	0.902 (0.850 - 0.957)
Samish River winter-run	0.966 (0.934 - 0.998)
Skagit River winter-run	0.978 (0.931 - 1.029)
Skokomish River winter-run	1.006 (0.958 - 1.057)
Snohomish River winter-run	0.961 (0.878 - 1.050)
Stillaguamish River winter-run	0.879 (0.820 - 0.943)
West Hood Canal winter-run	1.101 (1.046 - 1.160)
White River winter-run	0.933 (0.905 - 0.963)

c) Data from the most recent five years

Over the most recent five years (2005-2009), Puget Sound winter-run steelhead abundance has been low over much of the DPS, with a geometric mean less than 250 fish annually for all but eight populations of the 15 evaluated (Table 57). Four of these are in northern Puget Sound (Samish, Skagit, Snohomish and Stillaguamish rivers), three are in southern Puget Sound (Nisqually, Puyallup, and White rivers), and one is on the Olympic Peninsula (Skokomish River). Only three populations have a geometric mean greater than 500 fish—Green, Skagit and Samish rivers—and two of these are in northern Puget Sound. The Elwha River, Lake Washington, and South Sound tributaries populations all have very low recent mean abundances (< 15 fish).

Table 65 -- Geometric means of natural spawners for several winter-run populations of steelhead in the Puget Sound DPS over the most recent five years (2005-2009). NC, not calculated.

Population	Geometric mean (95% CI)
South Sound tributaries winter-run	NC
East Hood Canal winter-run	213 (122 - 372)
Elwha River winter-run	NC
Green River winter-run	986 (401 - 2428)
Lake Washington winter-run	12 (3 - 55)
Nisqually River winter-run	402 (178 - 908)
Port Angeles winter-run	147 (53 - 405)
Puyallup River winter-run	326 (178 - 596)
Samish River winter-run	534 (389 - 732)
Skagit River winter-run	4648 (2827 - 7642)
Skokomish River winter-run	355 (183 - 686)
Snohomish River winter-run	4573 (500 - 41865)
Stillaguamish River winter-run	327 (100 - 1067)
West Hood Canal winter-run	208 (118 - 366)
White River winter-run	265 (206 - 342)

Collectively, these data indicate relatively low abundance (4 of 15 populations with fewer than 500 spawners annually) and declining trends (6 of 16 populations) in natural escapement of winter-run steelhead throughout Puget Sound, particularly in southern Puget Sound and on the Olympic Peninsula.

Supplementary analyses

We present several additional analyses of steelhead abundance data that rely on multivariate auto-regressive state-space models (MARSS; Holmes and Ward 2010) to estimate quasi-extinction risk metrics from estimates of total natural run size. The MARSS analyses were conducted in R, version 2.10 (RDCT 2009). These stochastic models evaluate linear univariate or multivariate time series to estimate future trend. They have a distinct advantage in evaluating ecological applications such as time series of abundance because they can accommodate missing data and consider both process (e.g., demographic stochasticity) and non-process (e.g., measurement error) errors in the data (Holmes and Ward 2010, Ward et al. 2010). They also do not require an assumption of a specific underlying demographic structure (e.g., a specific spawner-recruit relationship). The MARSS models are fit iteratively to the data via maximum likelihood, using a Kalman-filtered Expectation-Maximization (EM) algorithm. This algorithm is especially well suited to dynamic systems where hidden random variables occur in the model. The Kalman filter, which is widely used in the analysis of time series, uses diffusion approximation methods to solve for the expected values of the hidden states (of the multivariate auto-regressive processes), conditioned on the data over the entire time series. This approach is appropriate for steelhead abundance data for Puget Sound because these data include primarily observed redd counts, often from index stream reaches, and creel census data, which are taken using conventional protocols but often involve missing or inconsistent catch information.

The PVAs were based on estimates of natural run size (or an index of run size) for most of the Puget Sound steelhead populations; these estimates were obtained from WDFW by adding unexpanded estimates of natural escapement (which were often based on redd counts from index reaches) to estimates of natural fish caught in tribal and sport fisheries between 1985 and 2009. The PVAs provide estimates of process and measurement error, and probabilities of extinction risk and associated confidence intervals are computed from the estimates of abundance trends and process error. The PVAs estimated by MARSS do not account for density dependent effects on productivity and abundance, but this is a typical assumption of PVA when applied to small or declining populations. If habitat capacity is changing or if Allee effects expressed at low abundance are important influences on population trends, they are not detected by these methods. Although missing data are not strictly limiting to the approach (so long as sufficient data are present in the time series), the PVAs do assume that a population is stationary through time, i.e., trends are linear and environmental conditions affecting mortality and production (including harvest) are constant. Because it is a state-space approach, a MARSS analysis can provide more precision in estimates of trend because observation error is explicitly included in the analysis (ignoring observation error tends to lead to inflated estimates of process variance). The state-space framework partitions the total variance into process and observation variance, which can yield more constrained, realistic estimates of process variance and, as a result, more precise estimates of viability metrics.

The following three graphs (Figure **85** - Figure 87) examine the trends in estimated natural run size for Puget Sound winter-run steelhead over the entire data series (1985-2009), for populations combined into three *draft* putative MPGs in the DPS: Northern Cascades, South Sound, and Olympic. In each case, the graphs plot the maximum-likelihood estimate of log(total no. natural steelhead) for the candidate populations in the MPG against the observed data, assuming that 1) each population time series follows a single MPG trajectory and are simply scaled up or down relative to it, and 2) variances in the observation errors for each time series are multivariate normal but are allowed to be unique for each population. The estimate of the log(total MPG count) (solid black curve) has been scaled relative to the first population at the top of the legend (i.e., Samish River for the Northern Cascades MPG, Lake Washington for the South Sound MPG, and Elwha River for the Olympic MPG). The 95% confidence intervals (CI) around the total MPG estimate are given by the red dashed curves (note: these are not the confidence intervals around the observed data, which are expected to fall outside the CI depending on the degree of population-specific non-process error, but are instead around the composite estimate; Holmes and Ward 2010). The approximate CIs were computed using either a numerically estimated Hessian matrix (a square matrix of second-order partial derivatives of the function) or via parametric bootstrapping. The relatively tight CIs arise because the estimate of process variance is small and because all the time-series data are fit to a single "population" trajectory. The total MPG estimate accounts for the bias estimated for the first population time series.

The Northern Cascades MPG shows a clearly declining trend in wild abundance (Figure **85**). The average long-term MPG growth rate (u est, equivalent to ln(λ); see Tables 55 and 56) is estimated from the slope of the regression. This growth rate is negative (-0.039), corresponding to an estimated loss in abundance of 3.9% per year and a λ of 0.962. The process variance (Q est), which is the temporal variability in population growth rate arising from demographic stochasticity, is estimated from the variance of residuals around the regression line, and is 0.024. The South Sound MPG also shows a clearly declining trend in wild abundance (Figure 86). Its estimated long-term MPG growth rate is negative, with a loss of 6.9% per year (λ = 0.933), and its estimated process variance is < 0.001. The Olympic MPG shows a negative long-term population growth rate of 1.3% per year (λ = 0.987), with an estimated process variance of 0.096 (Figure 87).

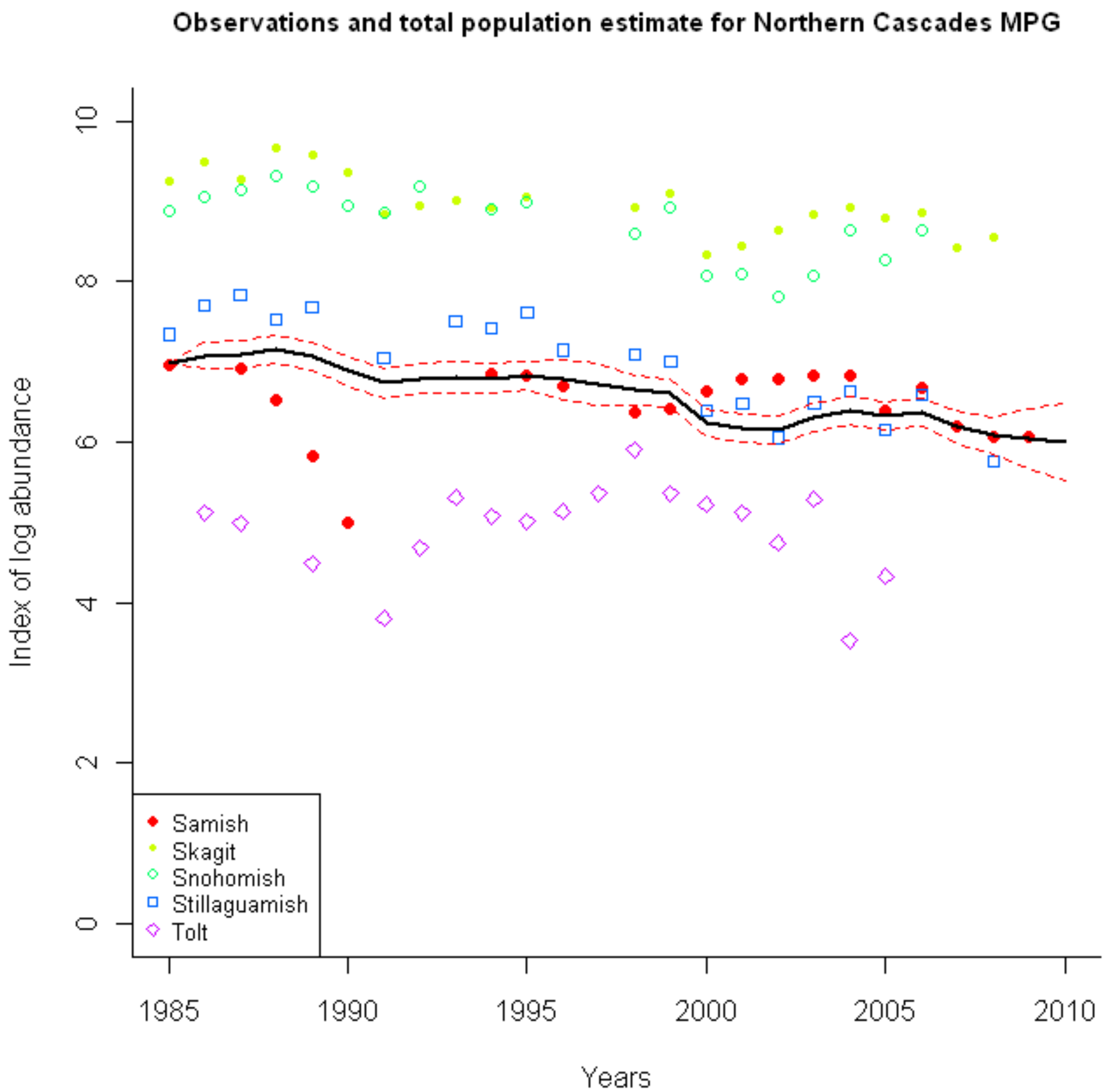


Figure 85 **-- Plot of the estimate of total Puget Sound winter-run steelhead for a putative Northern Cascades Major Population Group (MPG). The graph plots the maximum-likelihood estimate of log(total no. steelhead) in the MPG against the observed data, assuming a single-population model for the MPG. The estimate of the log(total MPG count) (solid black line) has been scaled relative to the Samish River population. The 95% confidence intervals around the total MPG estimate are given by the red dashed lines (note: these are not the confidence intervals around the observed data, which are expected to fall outside the CI, depending on population-specific non-process error). See text for details. No suitable data were available for Nooksack River steelhead.**

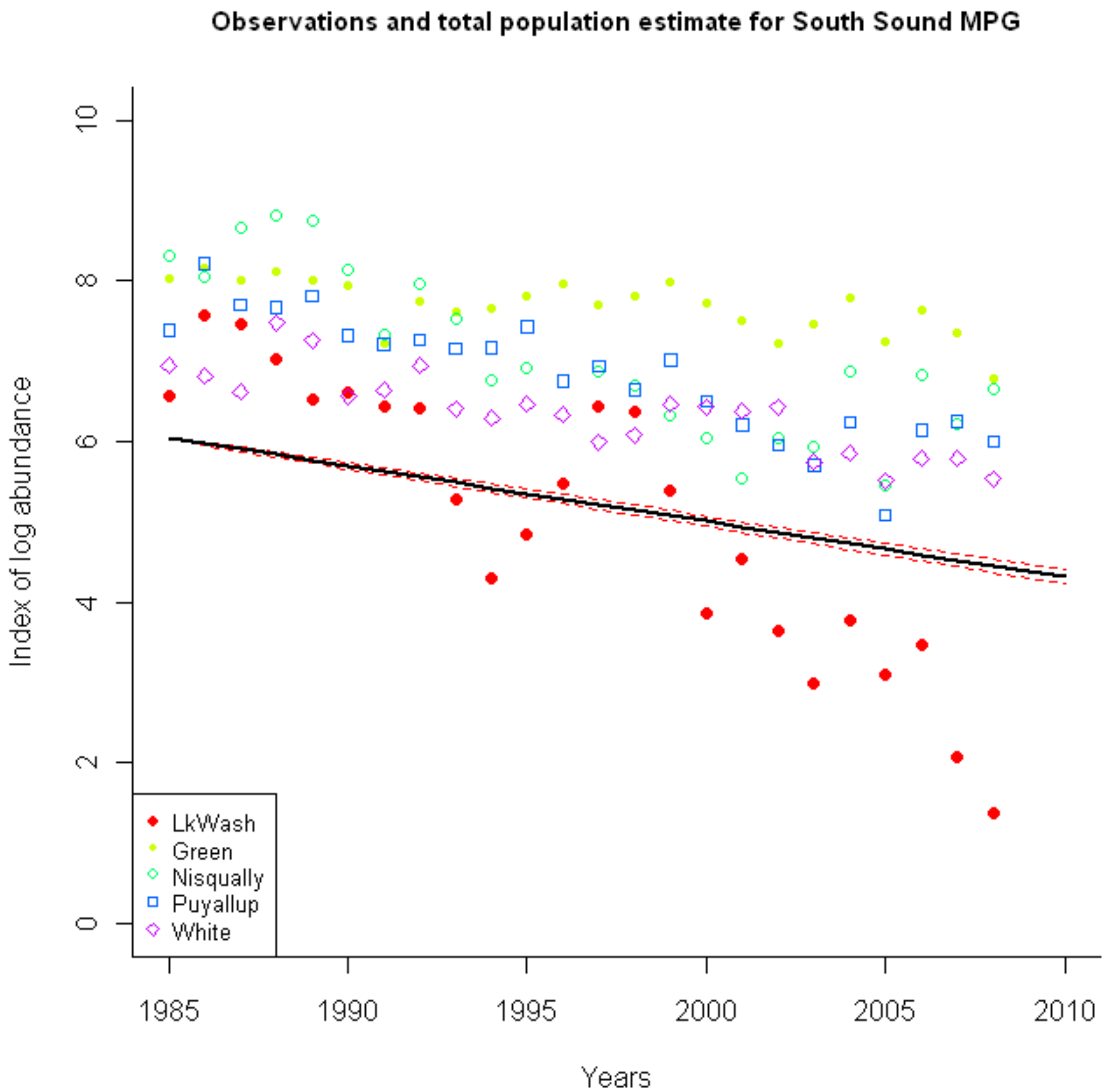


Figure 86 -- Plot of the estimate of total Puget Sound winter-run steelhead for a putative South Sound Major Population Group (MPG). The graph plots the maximum-likelihood estimate of log(total no. steelhead) in the MPG against the observed data. The estimate of the log(total MPG count) (solid black line) has been scaled relative to the Lake Washington population. The 95% confidence intervals around the total MPG estimate are given by the red dashed lines (note: these are not the confidence intervals around the observed data, which are expected to fall outside the CI, depending on population-specific non-process error). See text for details. No suitable data were available for South Sound tributaries steelhead.

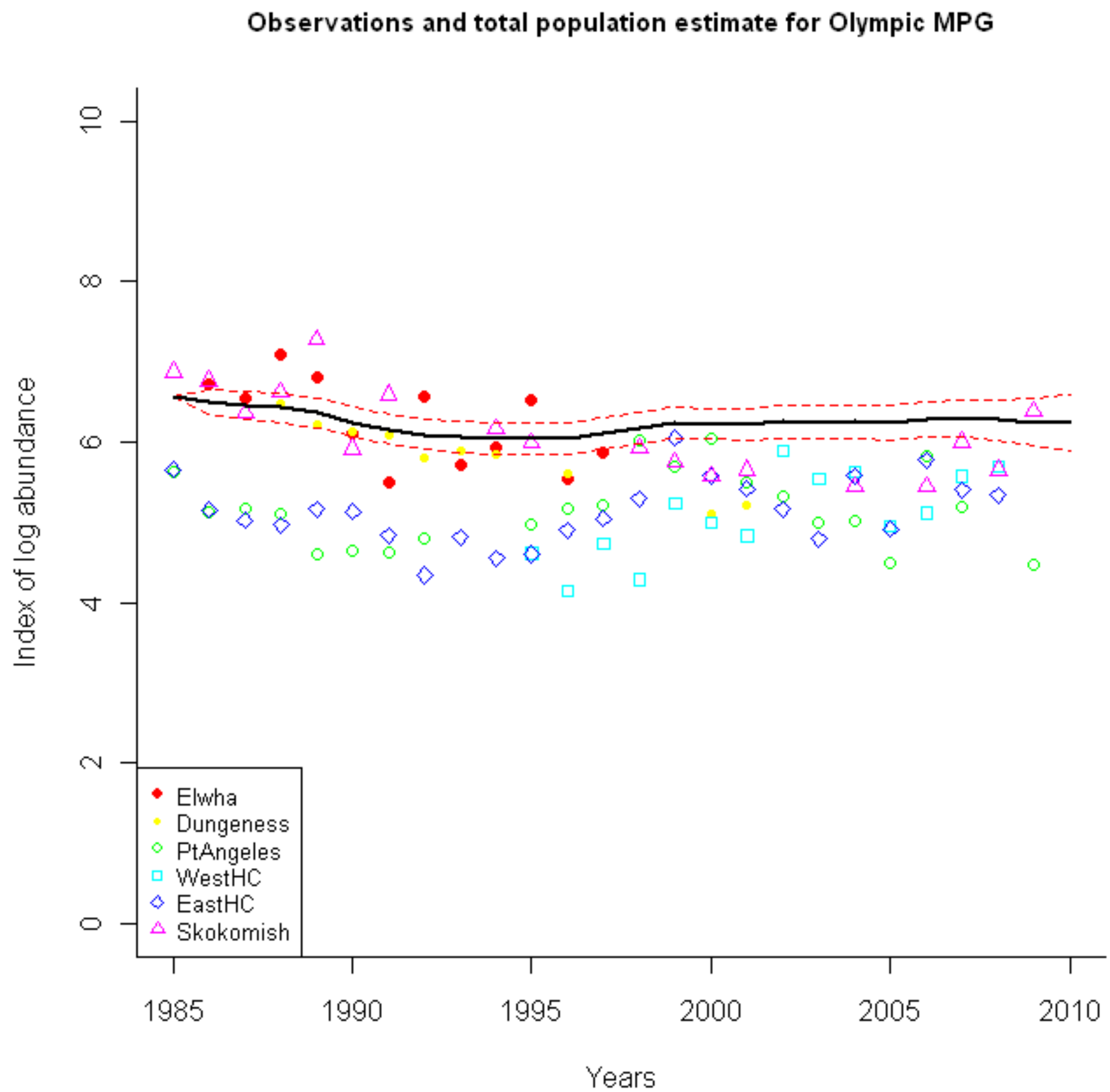


Figure 87 -- Plot of the maximum-likelihood estimate of total Puget Sound winter-run steelhead for a putative Olympic Major Population Group (MPG). The graph plots the estimate of log(total no. steelhead) in the MPG against the observed data. The estimate of the log(total MPG count) (solid black line) has been scaled relative to the Elwha River population. The 95% confidence intervals around the total MPG estimate are given by the red dashed lines (note: these are not the confidence intervals around the observed data, which are expected to fall outside the CI, depending on population-specific non-process error). See text for details.

The next several sets of multi-plots (starting with Figure 88) summarize MARSS analyses that evaluate the trends in estimated wild abundance for *draft* putative DIPs of Puget Sound steelhead over the entire data series (1985-2009; typically, these population estimates are taken from a combination of observed redd counts from index reaches and observed catches), project population trends 100 years into the future, and where possible evaluate these projections against specified viability criteria. For each population, the graphs provide up to six plots summarizing the population viability analyses (PVAs). The top left panel plots the observed counts against year, giving the MARSS maximum-likelihood estimate of fit to the abundance data (red curve), the estimated long-term population growth rate (u est, equivalent to ln(λ)), and the process variance (Q est). The top right panel plots the probability that the population will reach a quasi-extinction threshold (QET) abundance equal to 10% of its current abundance over the next 100 years (with approximate 95% confidence intervals). The middle left panel plots the probability density of the time in years to reach QET given that it is reached within 100 years, and the middle right panel depicts the probability of reaching QET in 100 years, given as a function of the number of individuals at the end of the projection. The bottom left panel plots several of the sample population projections estimated by MARSS. Finally, the bottom right panel depicts the regions of high certainty and uncertainty surrounding the population projections (an extinction risk "envelope"). The green region is where the upper 95% CIs of the projections do not exceed P = 0.05—i.e., where the probability of the specified population decline is < 5%. The red region is where the lower 95% CIs of the projections exceed P = 0.95—i.e., where the probability of the specified population decline is > 95%. The grey regions define less certain areas of parameter space between these extremes, with the dark grey region representing the region of highest uncertainty. Note that not all plots and corresponding estimates could be constructed for each population. For example, we were not able to calculate PVA estimates for putative winter-run steelhead Demographically Independent Populations (DIPs) in the Nooksack River or in South Puget Sound tributaries, nor were we able to do so for any summer-run steelhead populations in the Puget Sound DPS except for that in the Tolt River.

Figure 88 depicts population trends for Samish River winter-run steelhead. Steelhead counts in the Samish River have declined sharply in recent years. Assuming that these counts are a reasonable reflection of spawner abundance, the estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 43 fish) is high—about 80% within 25 years. With an estimated mean population growth rate (u est) of -0.037 ($\lambda = 0.964$) and process variance (Q est) of 0.140, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 5-10 years, and that a 99% decline will not occur within the next 15 years. However, beyond the next 25 years we are highly uncertain about the precise level of risk.

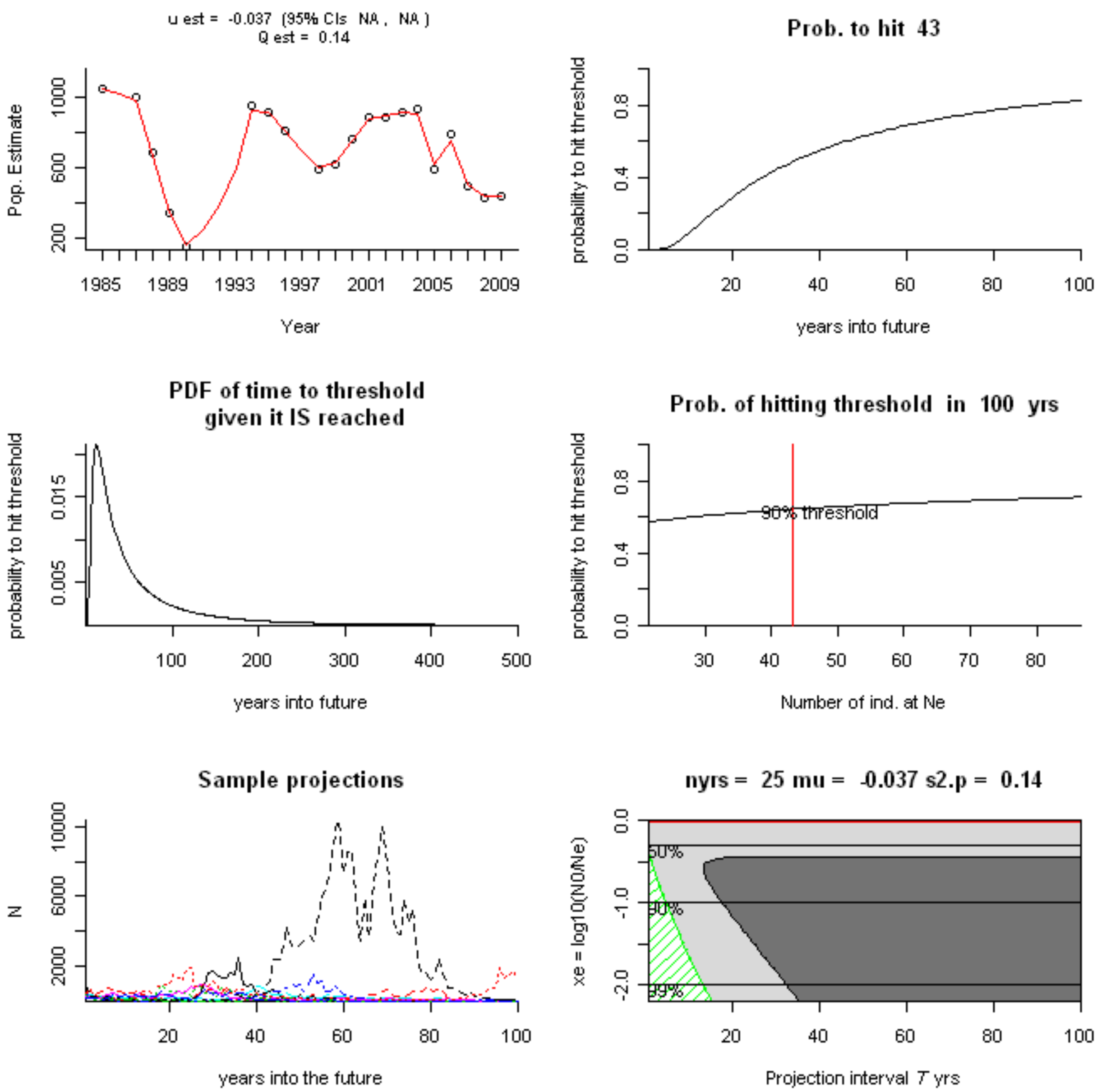


Figure 88 -- Population Viability Analysis (PVA) for Samish River winter-run steelhead. See text for description.

Figure 89 depicts population trends for Skagit River winter-run steelhead. Steelhead counts in the Skagit River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 504 fish) is high—about 80% within 75 years. With an estimated mean population growth rate of -0.037 ($\lambda = 0.964$) and process variance of 0.005, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 30 years, and that a 99% decline will not occur within the next 60 years. However, beyond the next 50 years we are highly uncertain about the precise level of risk.

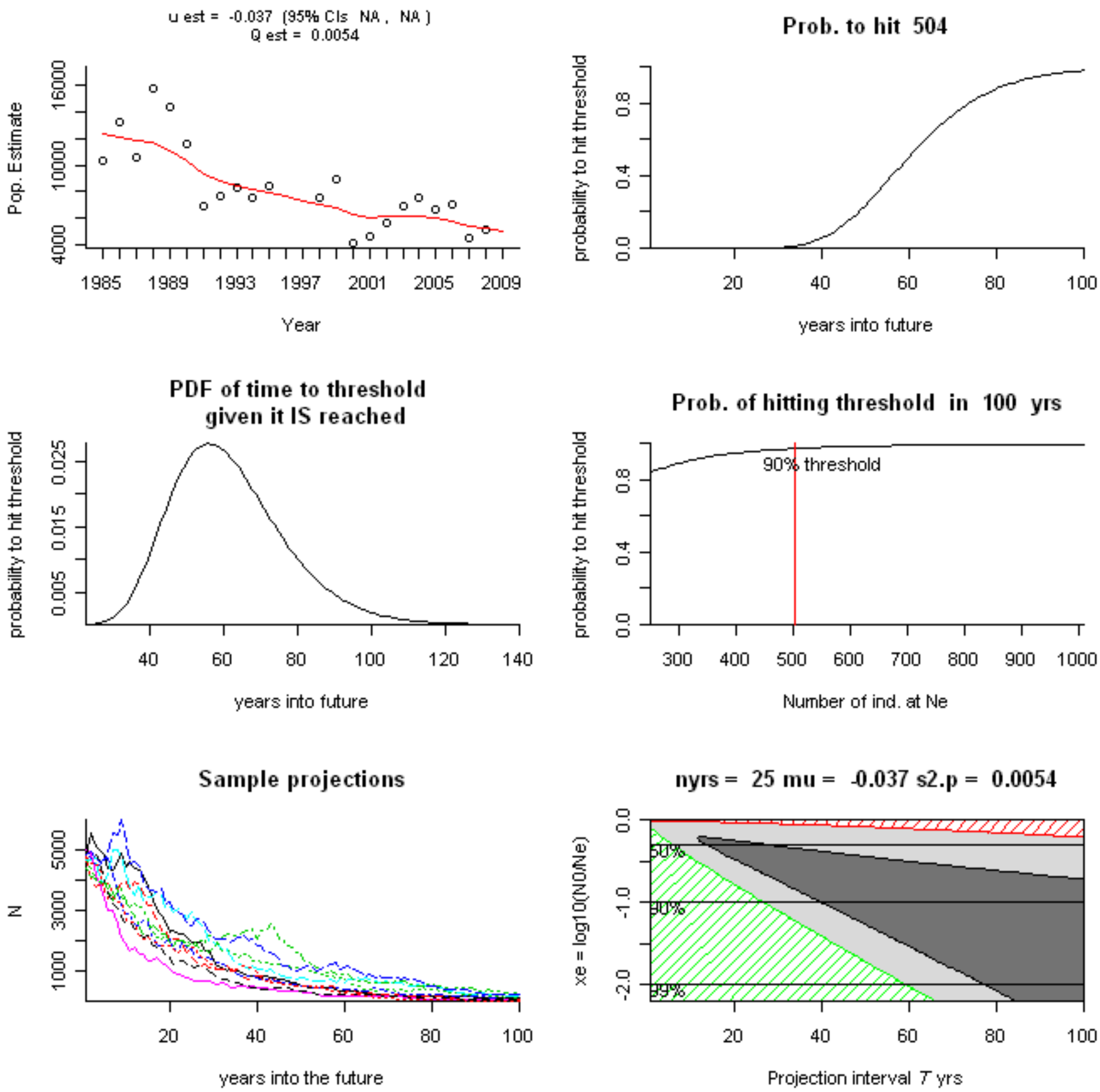


Figure 89 -- Population Viability Analysis (PVA) for Skagit River winter-run steelhead. See text for description.

Figure 90 depicts population trends for Stillaguamish River winter-run steelhead. Steelhead counts in the Stillaguamish River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 37 fish) is high—about 90% within 60 years. With an estimated mean population growth rate of -0.071 ($\lambda = 0.931$) and process variance of 0.016, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 15 years, and that a 99% decline will not occur within the next 30 years. However, a 50% decline is highly likely within 100 years. Beyond the next 30-40 years, we are highly uncertain about the precise level of risk.

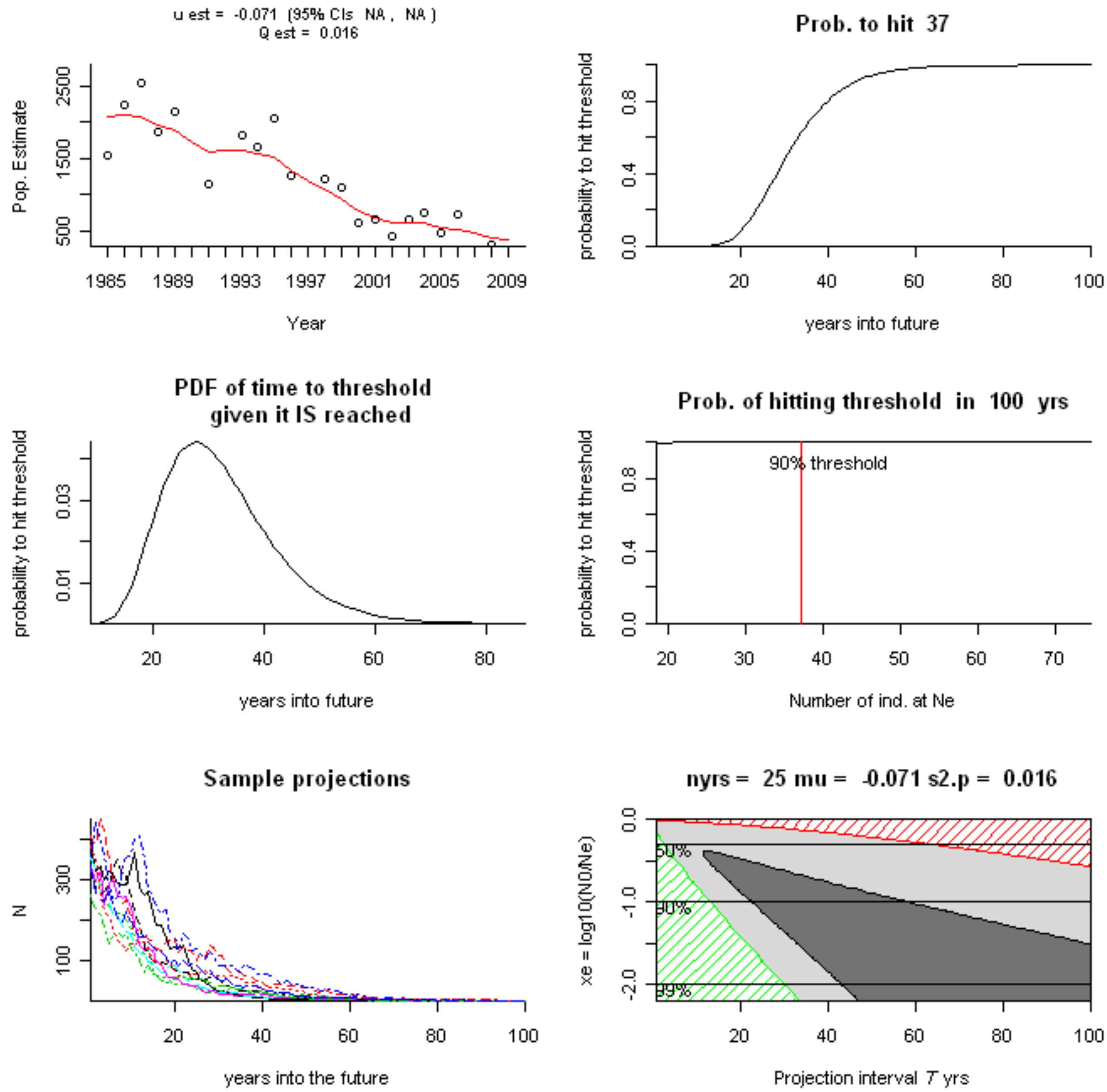


Figure 90 -- Population Viability Analysis (PVA) for Stillaguamish River winter-run steelhead. See text for description.

Figure 91 depicts population trends for Snohomish River winter-run steelhead. Steelhead counts in the Snohomish River have declined since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 445 fish) is moderately high—about 50% within 100 years. With an estimated mean population growth rate of -0.024 (λ = 0.976) and process variance of 0.033, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 15 years, and that a 99% decline will not occur within the next 35 years. However, beyond the next 40-50 years we are highly uncertain about the precise level of risk..

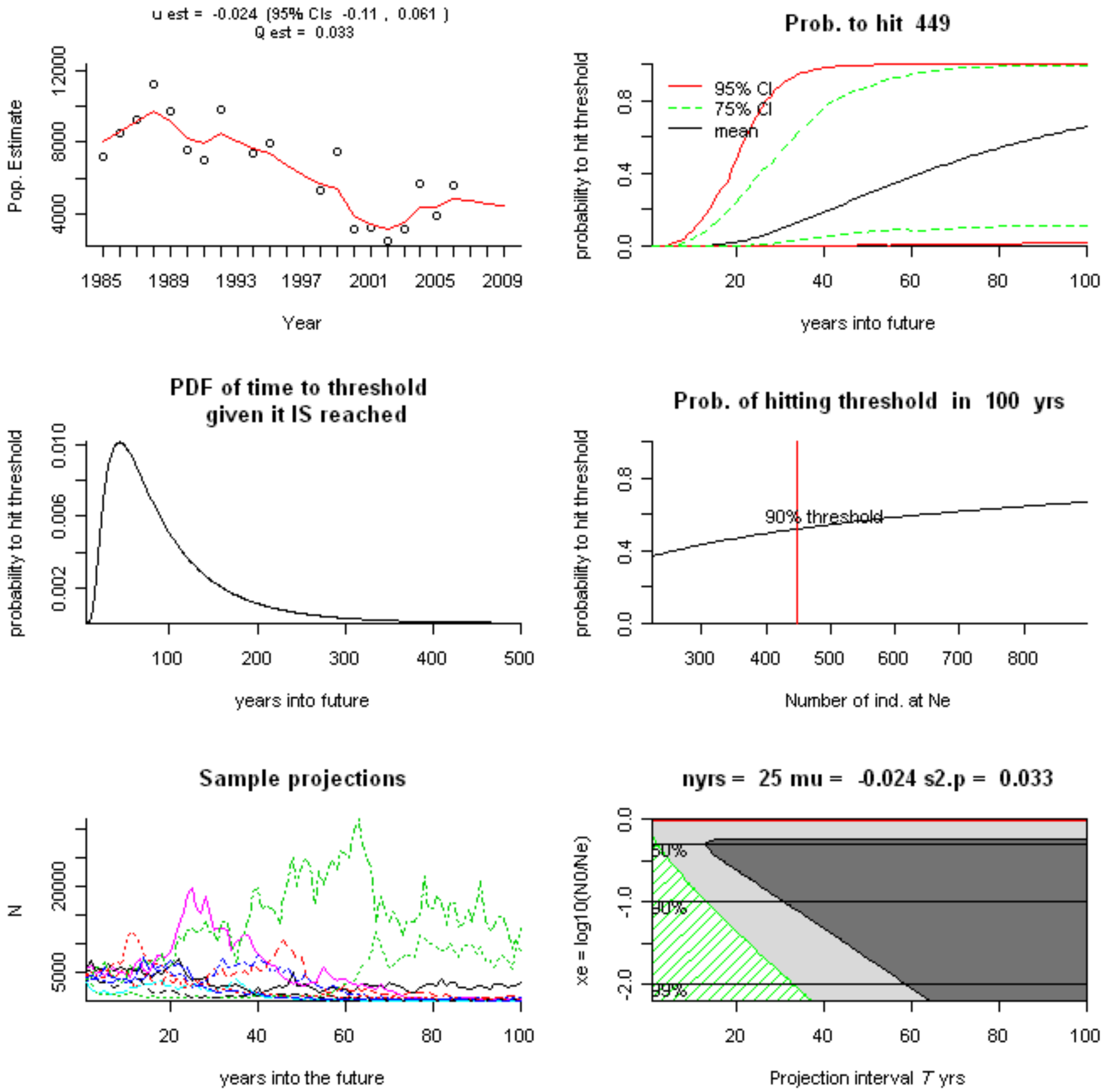


Figure 91 -- Population Viability Analysis (PVA) for Snohomish River winter-run steelhead. See text for description.

Figure 92 depicts population trends for Lake Washington winter-run steelhead. The counts have been very low since 2000. The estimated mean population growth rate is -0.23 (λ = 0.794) and process variance is 0.380. The estimated probability that the Lake Washington steelhead population would decline to 10% of its current estimated abundance (< 1 fish) is high—~ 90% within 40 years. An extinction risk envelope could not be calculated for this population from the data.

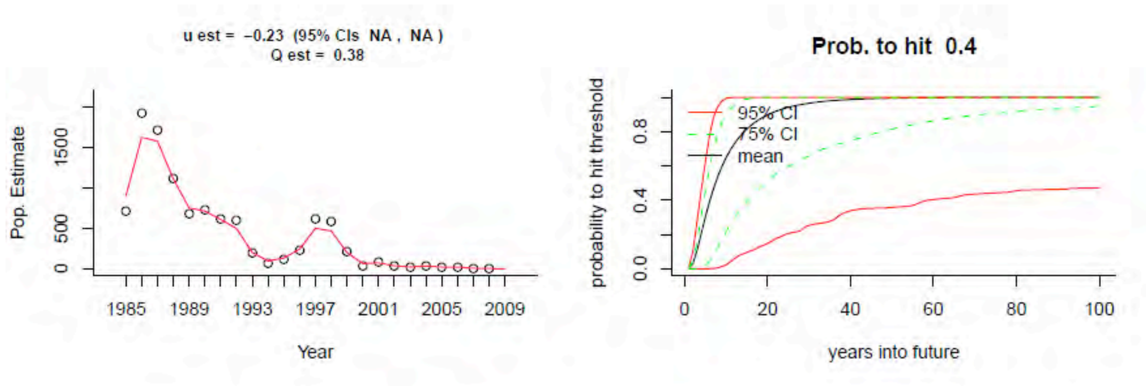


Figure 92 -- Population Viability Analysis (PVA) for Lake Washington winter-run steelhead. See text for description.

Figure 93 depicts population trends for Green River winter-run steelhead. Steelhead counts in the Green River have declined steadily since the 1980s and most sharply since 2005. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 45 fish) is high—about 90% within 80 years. With an estimated mean population growth rate of -0.042 (λ = 0.959) and process variance of 0.001, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 20 years, and that a 99% decline will not occur within the next 45 years. However, beyond the next 50 years we are highly uncertain about the precise level of risk.

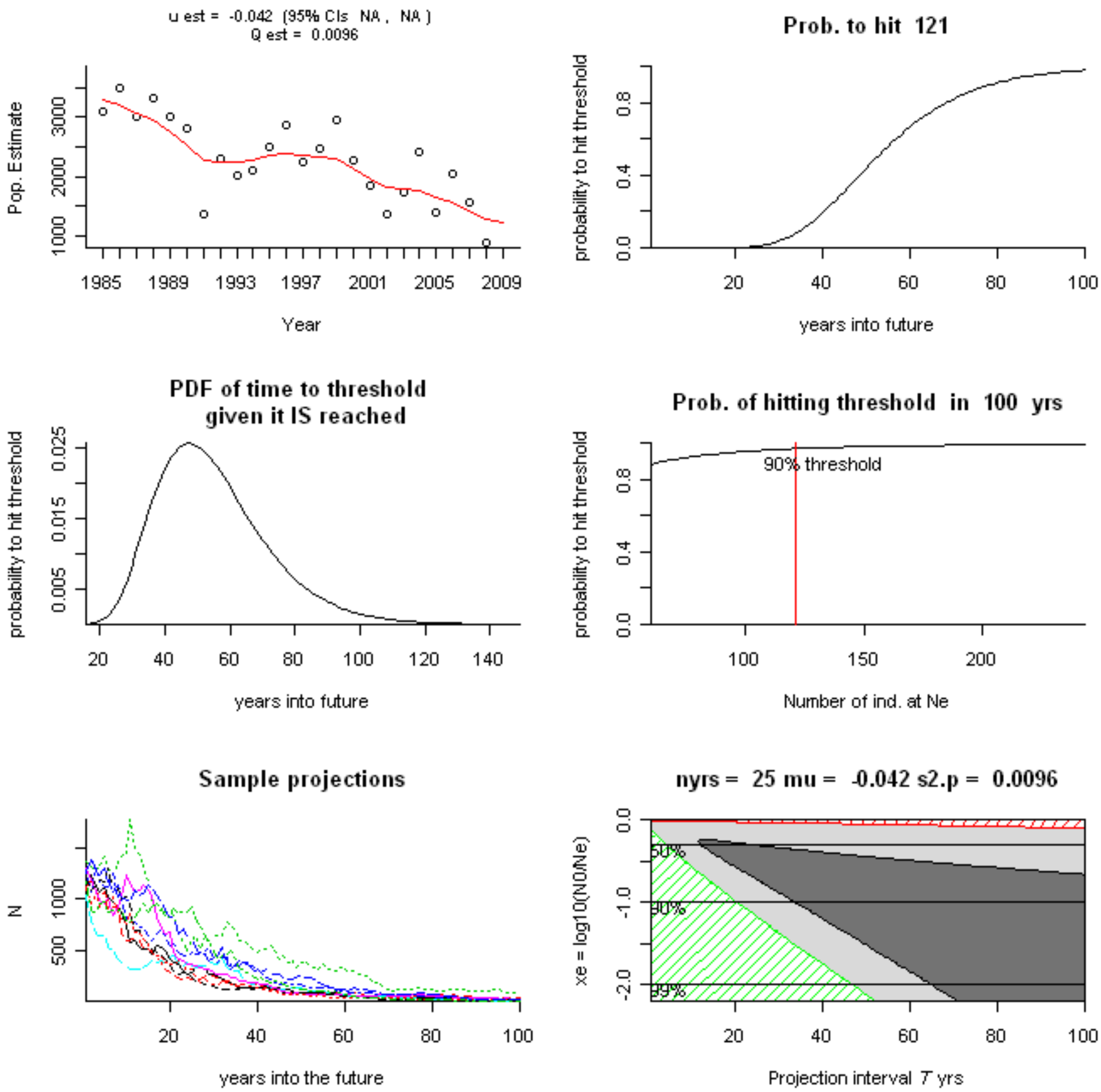


Figure 93 -- Population Viability Analysis (PVA) for Green River winter-run steelhead. See text for description.

Figure 94 depicts population trends for Puyallup River winter-run steelhead. Steelhead counts in the Puyallup River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 29 fish) is high—about 90% within 25-30 years. With an estimated mean population growth rate of -0.092 ($\lambda = 0.912$) and process variance of 0.004, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 15-20 years (but will occur within 40 years), and that a 99% decline will not occur within the next 30-40 years (but will occur within 80 years). However, for intermediate periods and other values of decline we are highly uncertain about the precise level of risk.

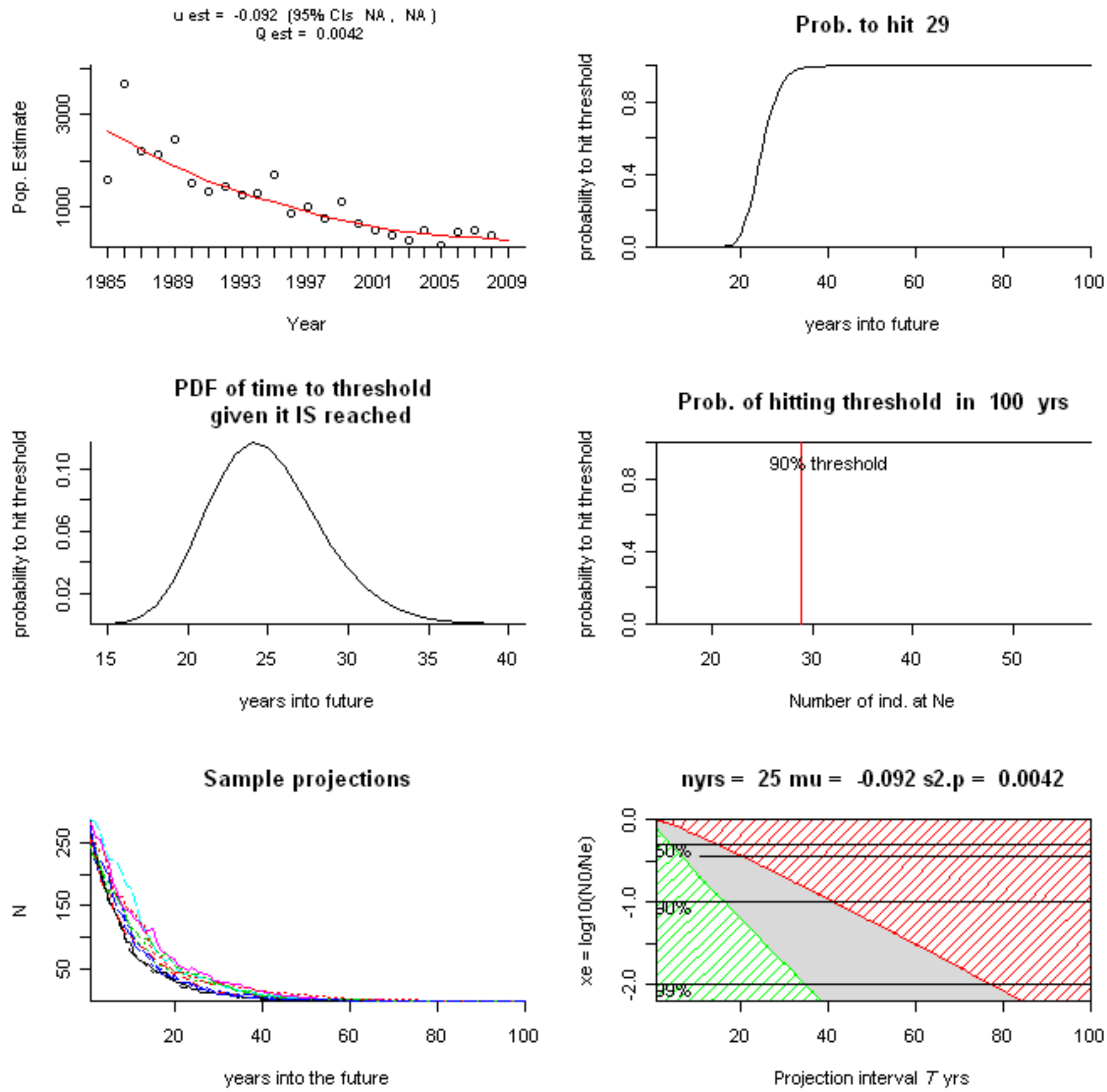


Figure 94 -- Population Viability Analysis (PVA) for Puyallup River winter-run steelhead. See text for description.

Figure 95 depicts population trends for Nisqually River winter-run steelhead. Steelhead counts in the Nisqually River declined steeply in the 1980s and 1990s and have remained low since. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 54 fish) is high—about 80% within 40 years. With an estimated mean population growth rate of -0.088 (λ = 0.916) and process variance of 0.070, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 6-8 years, and that a 99% decline will not occur within the next 15-18 years. However, beyond the next 20 years we are highly uncertain about the precise level of risk.

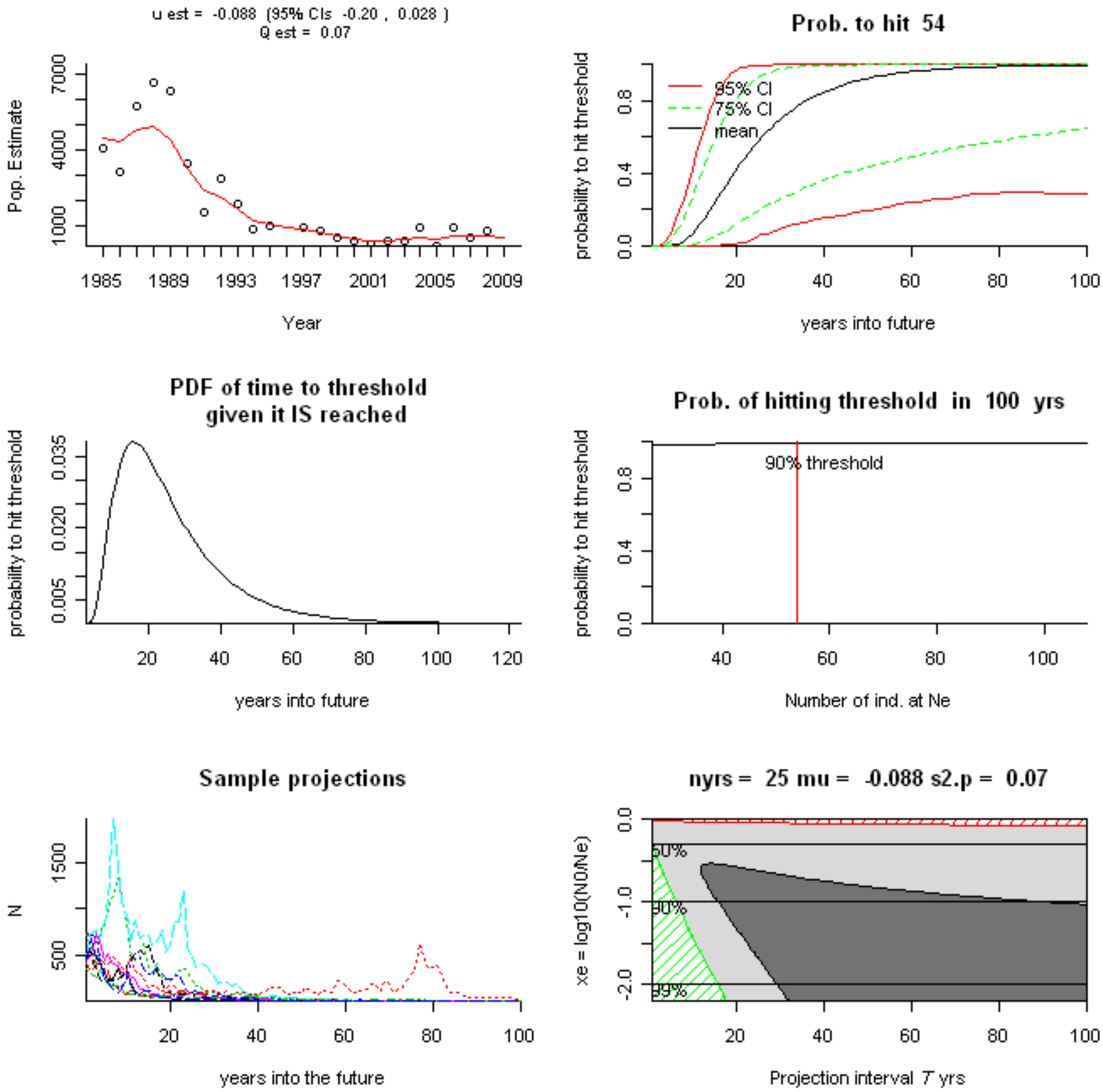


Figure 95 -- Population Viability Analysis (PVA) for Nisqually River winter-run steelhead. See text for description.

Figure 96 depicts population trends for White River winter-run steelhead. Steelhead counts in the White River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 26 fish) is high—about 90% within 50 years. With an estimated mean population growth rate of -0.062 (λ = 0.940) and process variance of 0.002, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 25 years (but will occur within 60 years), and that a 99% decline will not occur within the next 50-55 years (but will occur within 100 years). However, beyond the next 20 years we are highly uncertain about the precise level of risk.

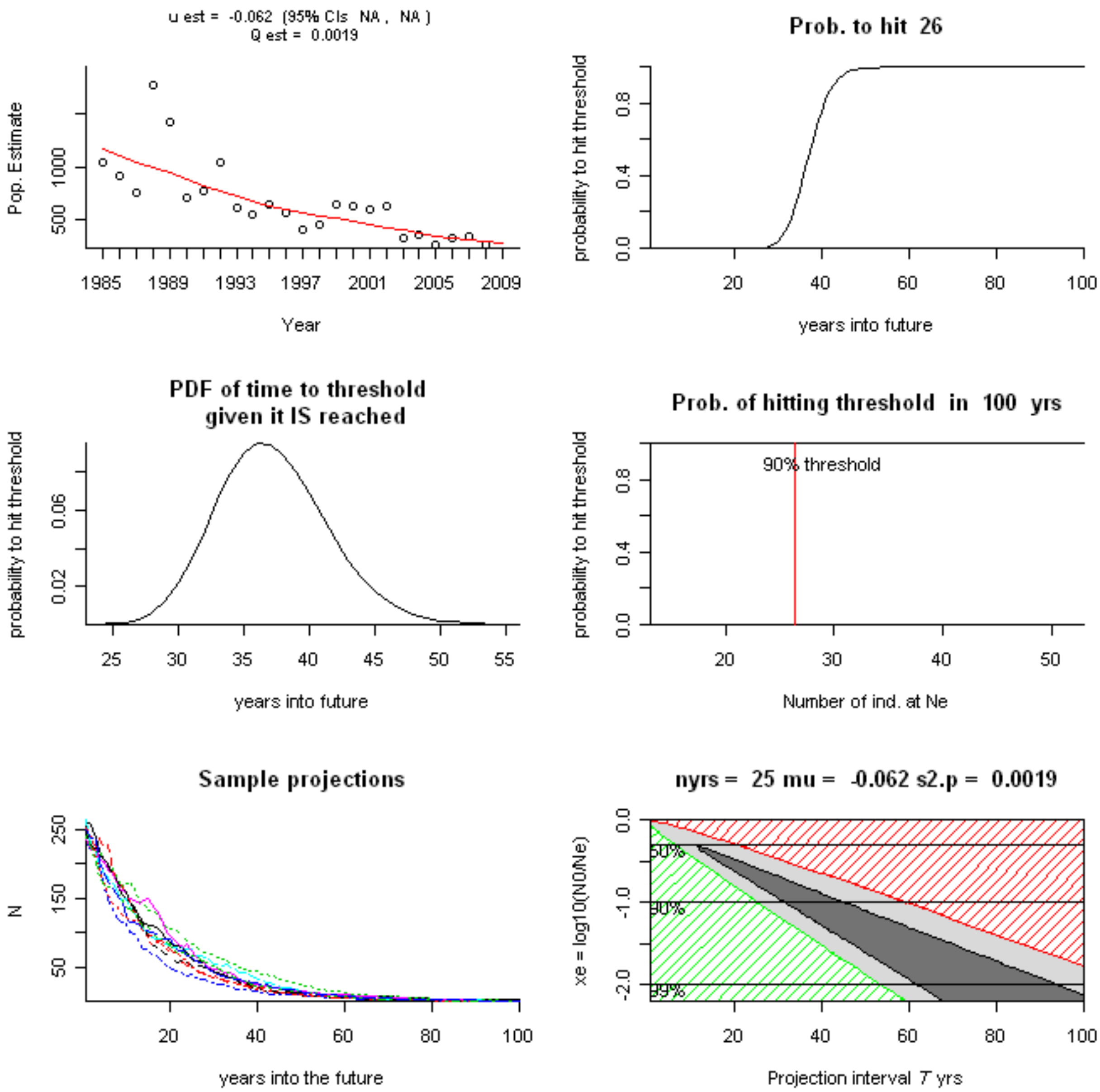


Figure 96 -- Population Viability Analysis (PVA) for White River winter-run steelhead. See text for description.

Figure 97 depicts population trends for Skokomish River winter-run steelhead. The counts have been especially low since the late 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 35 fish) is high—about 80% within 80 years. With an estimated mean population growth rate of -0.037 (λ = 0.964) and process variance of 0.019, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 20 years and that a 99% decline will not occur within the next 40 years. However, beyond the next 30-40 years we are uncertain about the precise level of risk.

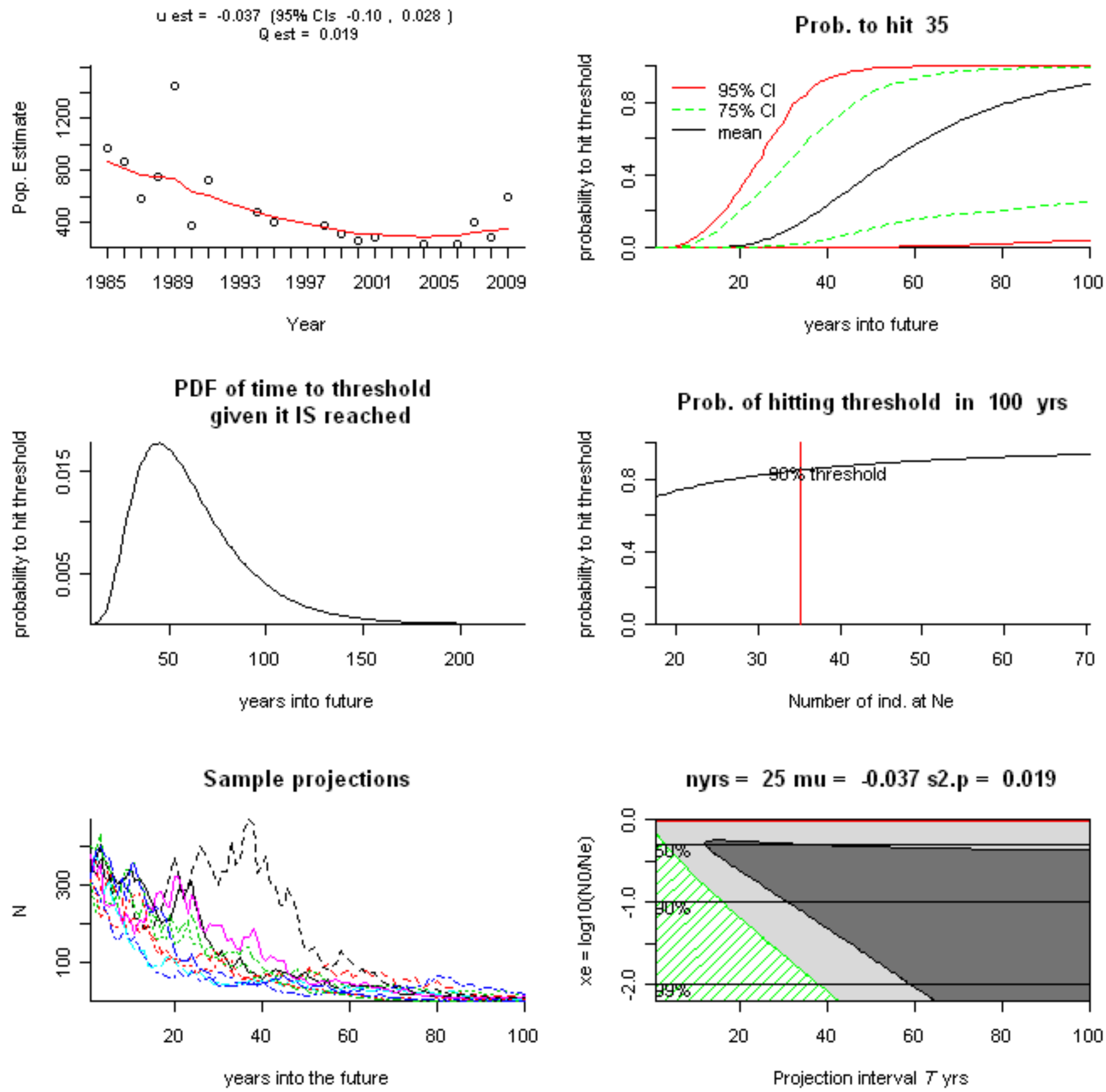


Figure 97 -- Population Viability Analysis (PVA) for Skokomish River winter-run steelhead. See text for description.

Figure 98 depicts population trends for East Hood Canal winter-run steelhead. Steelhead counts in East Hood Canal show no clear trend over the time series. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 22 fish) is relatively low—about 30% within 100 years. With an estimated mean population growth rate of -0.002 (λ = 0.998) and process variance of 0.052, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 10 years, and that a 99% decline will not occur within 30 years. However, beyond about 30 years we are highly uncertain about the precise level of risk.

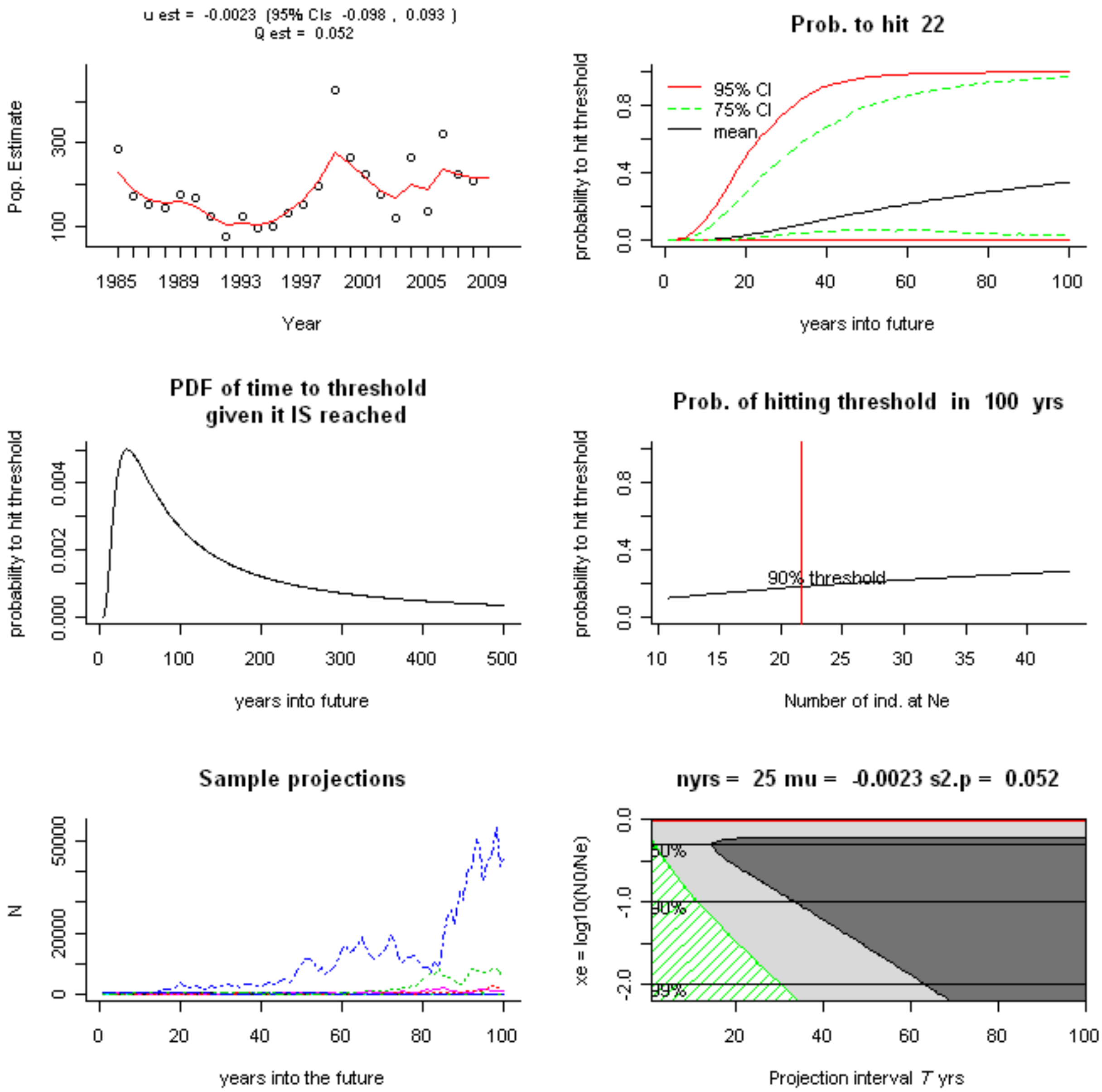


Figure 98 -- Population Viability Analysis (PVA) for East Hood Canal winter-run steelhead. See text for description.

Figure 99 depicts population trends for West Hood Canal winter-run steelhead. Steelhead counts in West Hood Canal have shown an increasing trend since the mid 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 31 fish) is low—near zero within 100 years. With an estimated mean population growth rate of 0.093 (λ = 1.097) and process variance of 0.017, we can be highly confident ($P < 0.05$) that a 50% or greater decline in this population will not occur within the next 100 years.

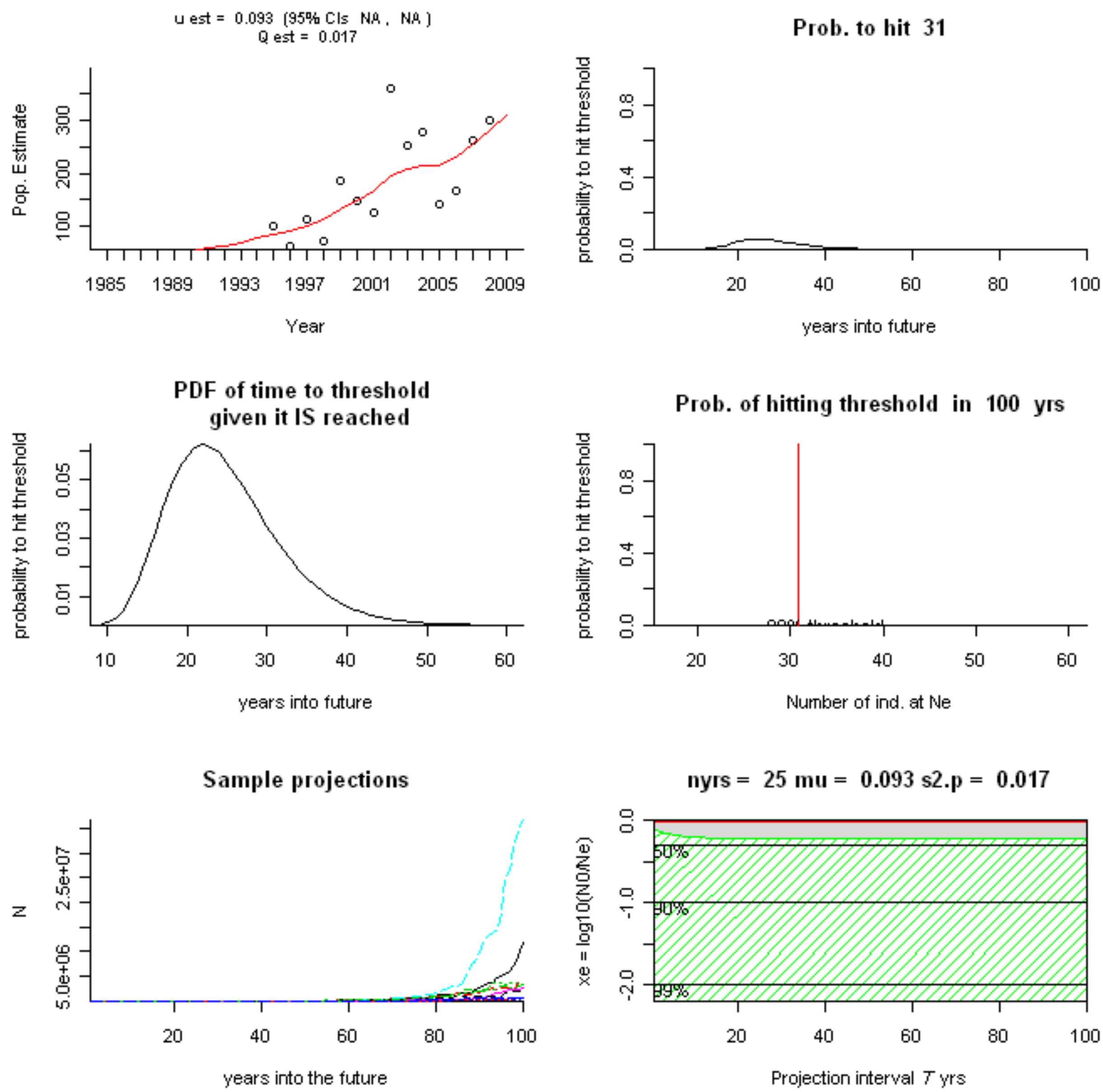


Figure 99 -- Population Viability Analysis (PVA) for West Hood Canal winter-run steelhead. See text for description.

Figure 100 depicts population trends for Port Angeles winter-run steelhead. Steelhead counts in Port Angeles have declined sharply since the late 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 11 fish) is high—nearly 80% within 100 years. With an estimated mean population growth rate of -0.033 ($\lambda = 0.968$) and process variance of 0.078, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 8-10 years, and that a 99% decline will not occur within the next 20 years. However, beyond the next 20 years we are highly uncertain about the precise level of risk.

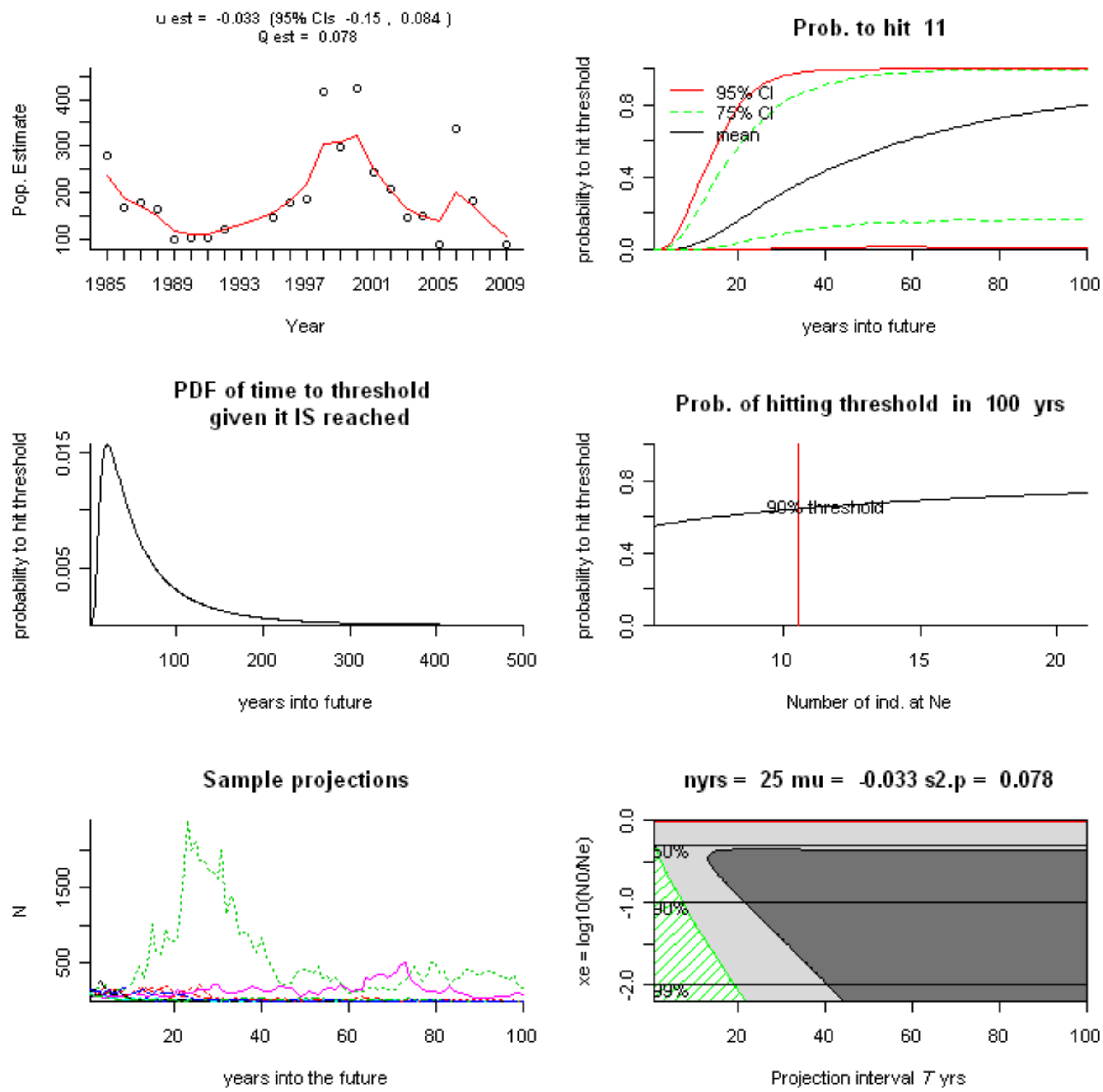


Figure 100 -- Population Viability Analysis (PVA) for Port Angeles winter-run steelhead. See text for description.

Figure 101 depicts population trends for Dungeness River winter-run steelhead. The counts have been very low and have steadily declined since the early 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 8 fish) within 100 years is high but could not be calculated. With an estimated mean population growth rate of -0.096 (λ = 0.908) and process variance of < 0.001, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 20 years (but will occur within 30 years), and that a 99% decline will not occur within the next 40 years (but will occur within 55-60 years). However, for other years and values of decline we are less certain about the precise level of risk.

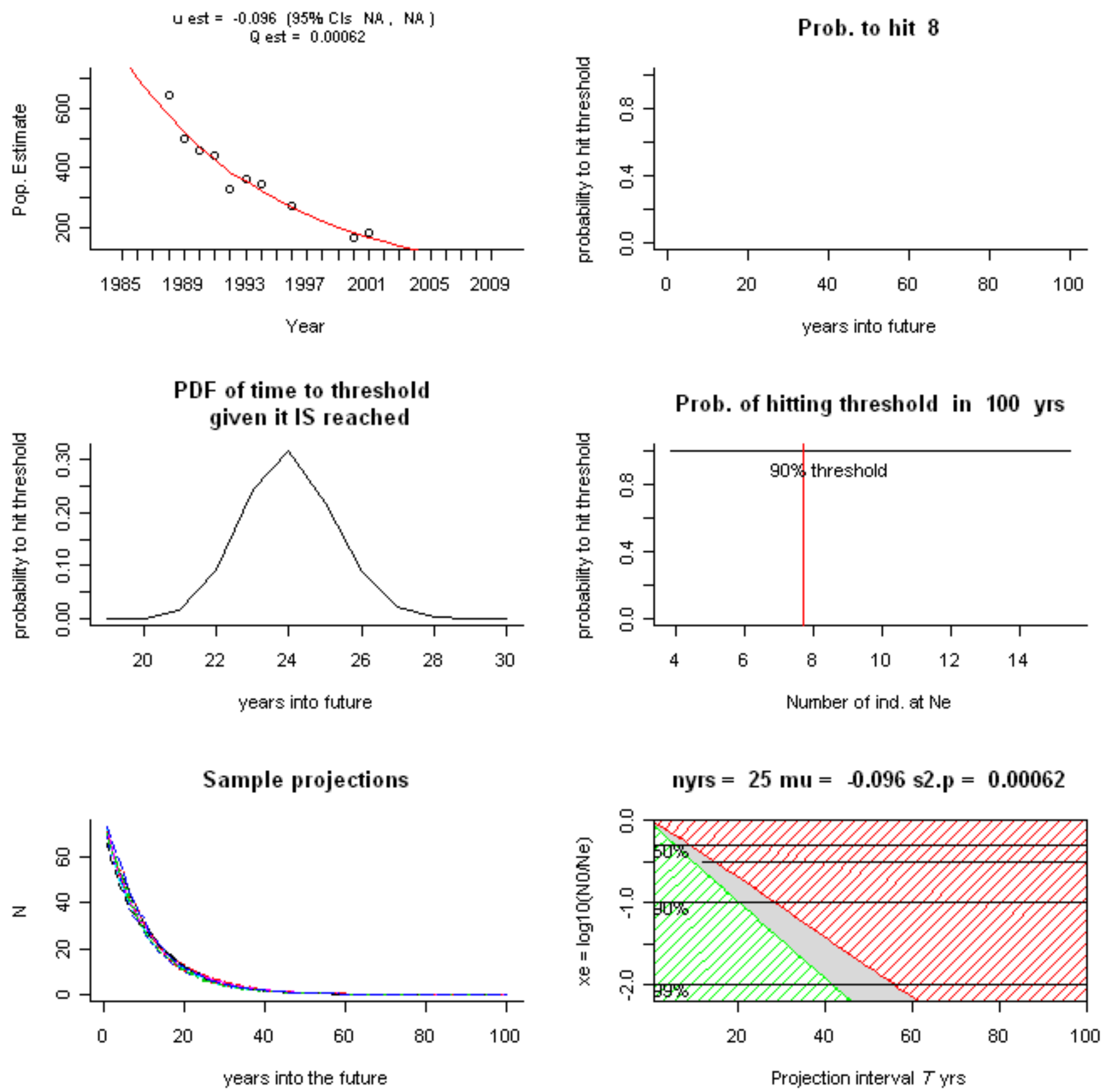


Figure 101 -- Population Viability Analysis (PVA) for Dungeness River winter-run steelhead. See text for description.

Figure 102 depicts population trends for Elwha River winter-run steelhead. The counts declined sharply in the late 1980s and early 1990s have been very low in recent years. The estimated probability that the Elwha River steelhead population would decline to 10% of its current estimated abundance (i.e., to 10 fish) is fairly high— ~ 90% within 40 years. With an estimated mean population growth rate of -0.092 (λ = 0.912) and process variance of 0.013, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 8-10 years (but will occur within 70 years), and that a 99% decline will not occur within 25-30 years (but might occur within 120-150 years). However, for intermediate years and other values of decline we are highly uncertain about the precise level of risk.

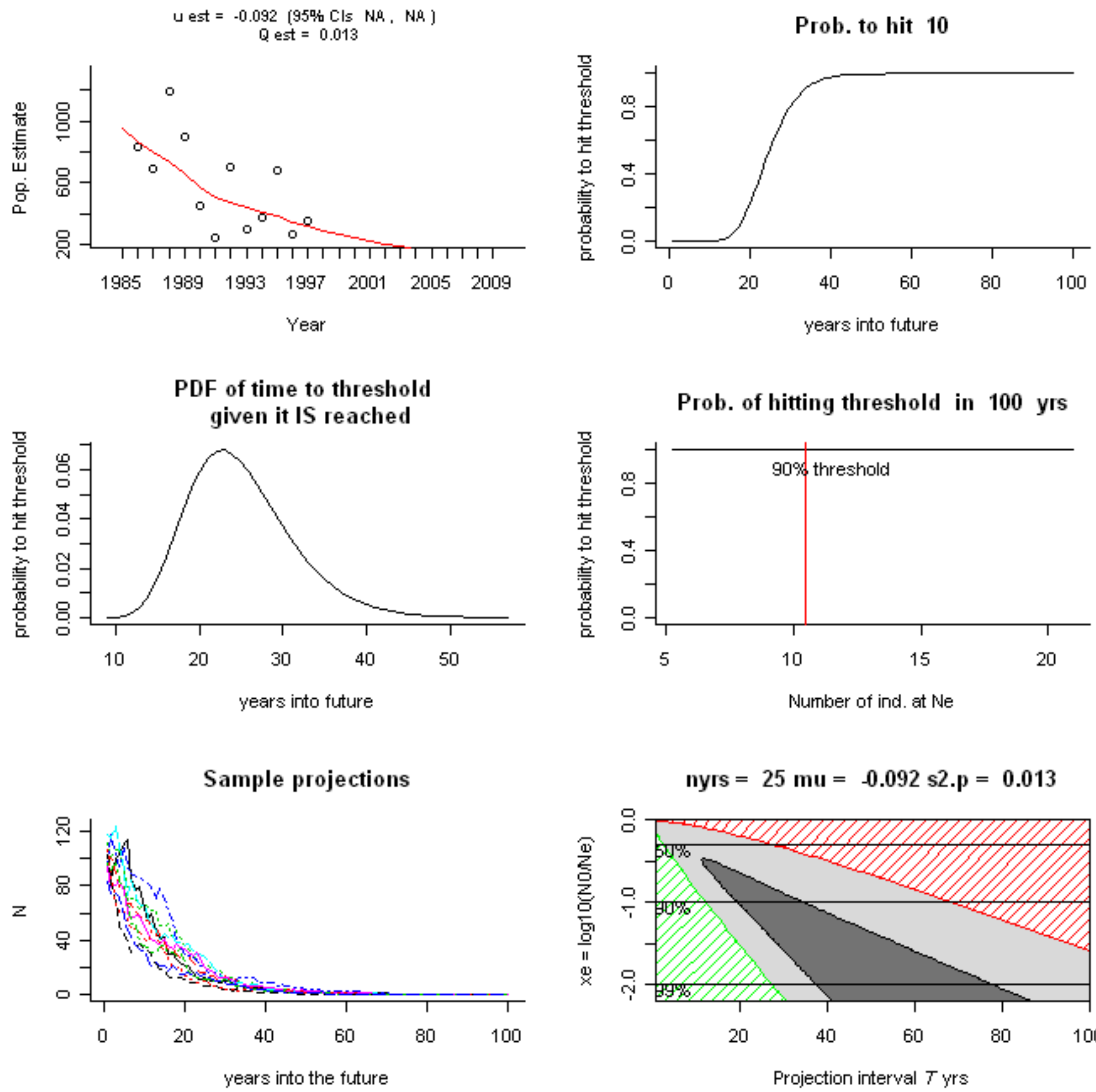


Figure 102 -- Population Viability Analysis (PVA) for Elwha River winter-run steelhead. See text for description.

Figure 103 depicts population trends for Tolt River summer-run steelhead (the only summer-run population for which redd count data are available). Steelhead counts in the Tolt River have declined since the late 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 6 fish) is high—nearly 80% within 100 years. With an estimated mean population growth rate of -0.040 (λ = 0.961) and process variance of 0.010, we can be highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 8-10, and that a 99% decline will not occur within the next 15-18 years. However, beyond the next 20 years we are highly uncertain about the precise level of risk.

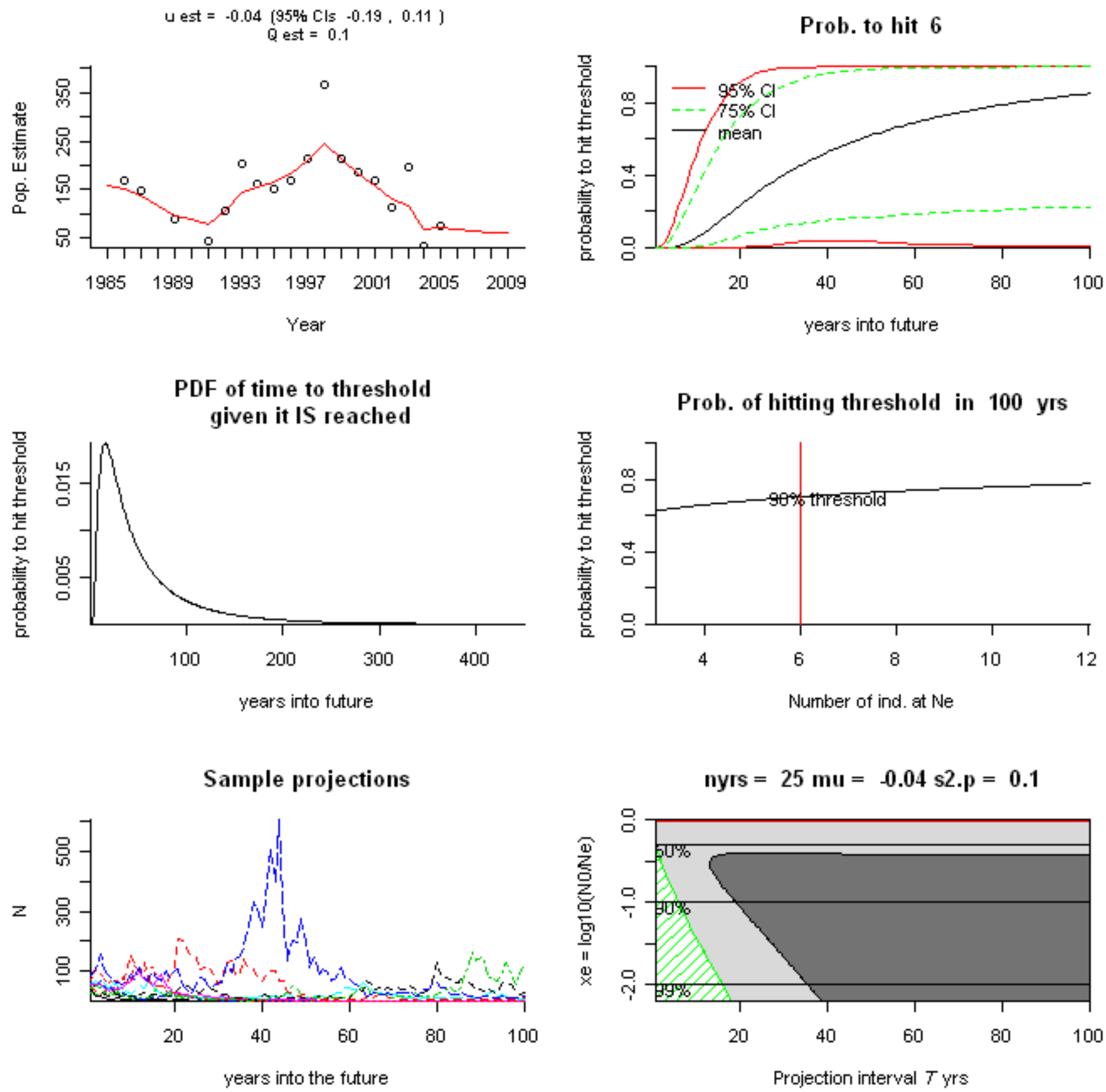


Figure 103 -- Population Viability Analysis (PVA) for Tolt River summer-run steelhead. See text for description.

Summary

For all but a few putative demographically independent populations of steelhead in Puget Sound, estimates of mean population growth rates obtained from observed spawner or redd counts are declining—typically 3 to 10% annually—and extinction risk within 100 years for most populations in the DPS is estimated to be moderate to high, especially for *draft* populations in the *putative* South Sound and Olympic MPGs. Collectively, these analyses indicate that steelhead in the Puget Sound DPS remain at risk of extinction throughout all or a significant portion of their range in the foreseeable future, but are not currently in danger of imminent extinction.

Status and Trends in the Limiting Factors and Threats Facing ESU/DPS

The Biological Review Team identified degradation and fragmentation of freshwater habitat, with consequent effects on connectivity, as a primary limiting factor and threat facing the Puget Sound steelhead DPS. In the three years since listing, the status of this threat has not changed appreciably.

Hatchery releases

Hatchery releases of steelhead in Puget Sound have remained relatively constant over the last 20 years, although releases of Chinook and coho have declined (Figure 104).

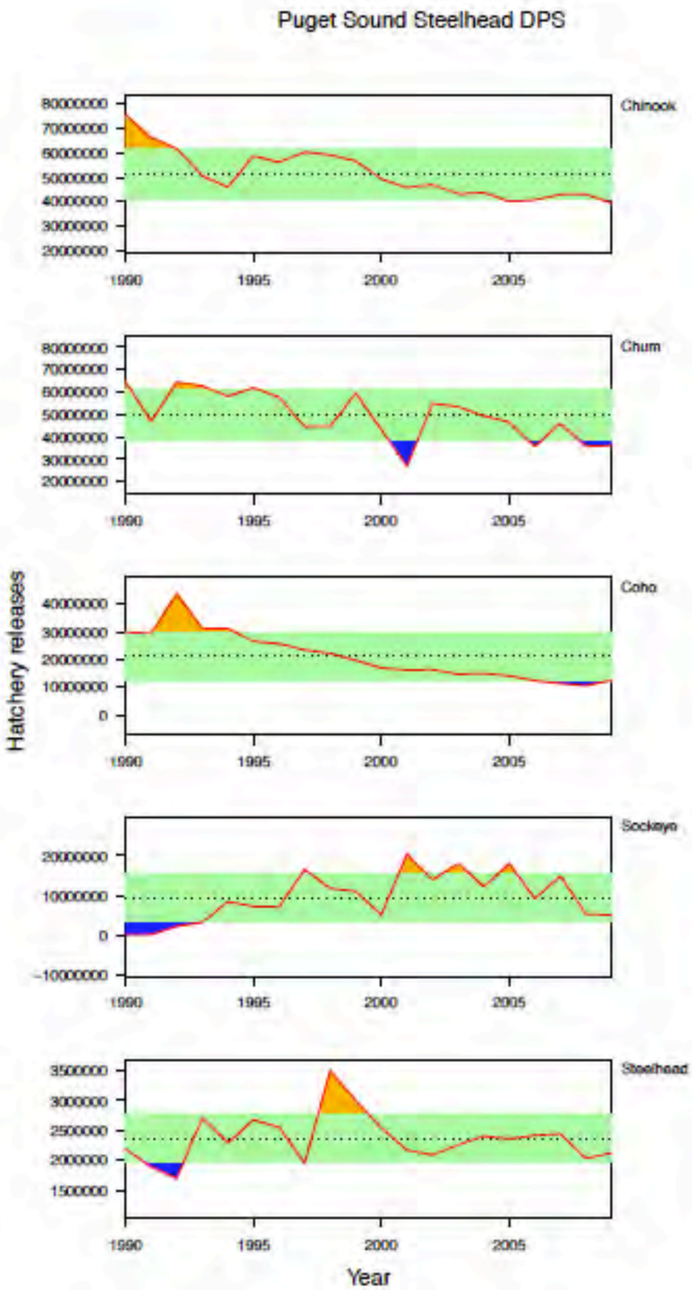


Figure 104 – Summary of annual hatchery releases within the spawning and rearing areas of the Puget Sound steelhead DPS. Data source: RMIS.

Harvest
Puget Sound steelhead are impacted in terminal tribal gillnet fisheries and in recreational fisheries. Fisheries are directed at hatchery stocks, but some harvest of natural origin steelhead occurs as incidental to hatchery directed fisheries. Winter-run hatchery steelhead production is primarily of Chambers Creek (southern Puget Sound) stock which has been selected for earlier run timing than natural stocks to minimize fishery interactions. Hatchery production of summer steelhead is primarily of Skamania River (a lower Columbia River tributary) stock which has been selected for earlier spawn timing than natural summer steelhead to minimize interactions on the spawning grounds. In recreational fisheries, retention of wild steelhead is prohibited, so all harvest impacts occur as the result of release mortality and non-compliance. In tribal net fisheries, most fishery impacts occur in fisheries directed at salmon and hatchery steelhead.

Most Puget Sound streams have insufficient sufficient catch and escapement data to calculate exploitation rates for natural steelhead. Populations with sufficient data include the Skagit, Green, Nisqually, Puyallup, and Snohomish rivers (Figure 105). Exploitation rates differ widely among the different rivers, but all have declined since the 1970s and 1980s. Exploitation rates on natural steelhead in recent years have been stable and generally less than 5%.

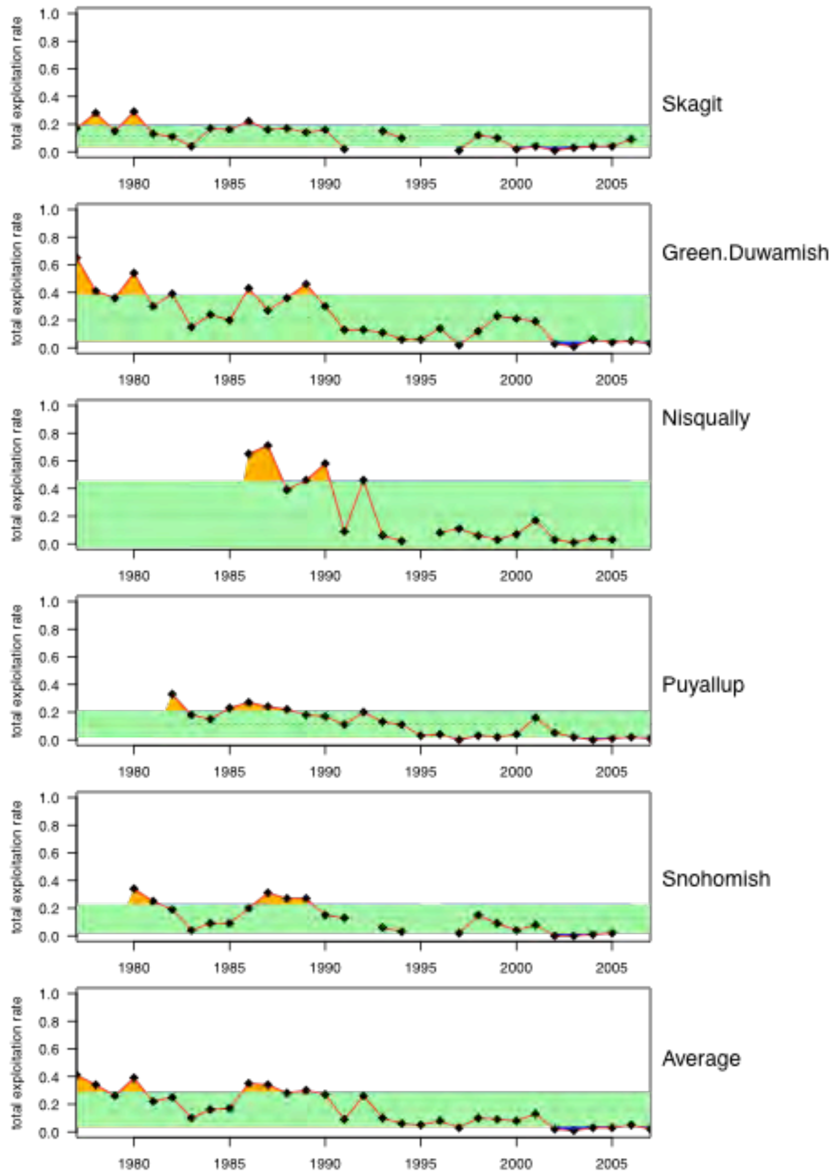


Figure 105 -- Total exploitation rates on natural steelhead from Puget Sound Rivers. Data from the Puget Sound Steelhead Harvest Management Plan, Appendix A (Bob Leland, WDFW, personal communication.

Conclusions

The status of the listed Puget Sound steelhead DPS has not changed substantially since the 2007 listing. Most populations within the DPS are showing continued downward trends in estimated abundance, a few sharply so.

References

Busby, P.J., T.C. Wainwright, G.J. Bryant, L. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-27, 261 p.

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, and R.R. Reisenbichler. 2007. Status review of Puget Sound steelhead (*Oncorhynchus mykiss*). U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-81, 117 p.

Holmes, E.E., and E.J. Ward. 2010. Analysis of multivariate time-series using the MARSS package. Technical report, Northwest Fisheries Science Center, Mathematical Biology Program, June 2010.

RDCT (R Development Core Team). 2009. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, Available at: http://www.R-project.org.

Ward, E.J., H. Chirakkal, M. González-Suárez, D. Aurioles-Gamboa, E.E. Holmes, and L. Gerber. 2010. Inferring spatial structure from time-series data: using multivariate state-space models to detect metapopulation structure of California sea lions in the Gulf of California, Mexico. J. Appl. Ecol. 47:47-56.

Lower Columbia River Chinook salmon[20]

Listed ESU/DPS

The ESU includes all naturally spawned populations of Chinook salmon from the Columbia River and its tributaries from its mouth at the Pacific Ocean upstream to a transitional point between Washington and Oregon east of the Hood River and the White Salmon River, and includes the Willamette River to Willamette Falls, Oregon.

ESU/DPS Boundary Delineation

Utilizing new information, the ESU Boundaries Review Group (see ESU Boundaries above) undertook a revaluation of the boundary between all Lower Columbia and Mid-Columbia ESUs and DPSs. The review conclusions emphasize the transitional nature the boundary between the Lower Columbia ESUs and the Mid-Columbia ESUs. After considering new DNA data, the review concludes, "Given the transitional nature of the Klickitat River Chinook salmon population it might be reasonable to assign that population to the Lower Columbia River Chinook salmon ESU." This status evaluation is based on the existing Lower Columbia ESU boundaries that do not include the Klickitat population, however.

Summary of Previous BRT Conclusions

NMFS reviewed the status of the Lower Columbia River Chinook salmon ESU initially in 1998 (Myers et al. 1998), updated it that same year (NMFS 1998a) and then conducted the most recent update in 2005 (NMFS 2005). In the 1998 update, the BRT noted several concerns for this ESU. The 1998 BRT was concerned that very few naturally self-sustaining populations of native Chinook salmon remained in the Lower Columbia River ESU. The 1998 BRT identified naturally reproducing (but not necessarily self-sustaining) populations: the Lewis and Sandy rivers bright fall runs and the tule fall runs in the Clackamas, East Fork Lewis, and Coweeman rivers. These populations were identified as the only bright spots in the ESU. The 1998 BRT did not consider the few remaining populations of spring run Chinook salmon in the ESU to be naturally self-sustaining because of either small size, extensive hatchery influence, or both. The 1998 BRT felt that the dramatic declines and losses of spring-run Chinook salmon populations in the Lower Columbia River ESU represented a serious reduction in life history diversity in the region. The team felt that the presence of hatchery Chinook salmon in this ESU posed an important threat to the persistence of the ESU and obscured trends in abundance of native fish. The team noted that habitat degradation and loss due to extensive hydropower development projects, urbanization, logging, and agriculture threatened the Chinook salmon spawning and rearing habitat in the lower Columbia River. A majority of the 1998 BRT concluded that the Lower Columbia River ESU was likely to become endangered in the foreseeable future. A minority felt that Chinook salmon in this ESU were not presently in danger of extinction, nor were they likely to become so in the foreseeable future.

In the 2005 update, a majority of the BRT votes for the Lower Columbia River Chinook salmon ESU fell in the "likely to become endangered" category, with minorities falling in the "danger of extinction" and "not likely to become endangered" categories. The BRT was still concerned about all of the risk factors identified in the 1998 review. The WLC-TRT estimated

[20] Section author: Paul McElhany

that 8 to 10 historical populations in this ESU have been extirpated, most of them spring-run populations. Near loss of that important life history type remained an important BRT concern. Although some natural production appeared to occur in 20 or so populations, only one exceeded 1,000 spawners. High hatchery production continued to pose genetic and ecological risks to natural populations and to mask their performance. Most populations in this ESU had not seen as pronounced increases in recent years as occurred in many other geographic areas.

Summary of Recent Evaluations

A report on the population structure of Lower Columbia salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The Chinook population designations in that report (Figure 106 and Figure 107) are used in this status update and were used for status evaluations in recent recovery plans by ODFW and LCFRB. LCR Chinook populations exhibit three different life history types base on return timing and other features: fall run (a.k.a. "tules), late fall run (a.k.a. "brights") and spring run.

In 2010, ODFW completed a recovery plan that included Oregon populations of Lower Columbia Chinook ESU. Also in 2010, the LCFRB completed a revision of its recovery plan that includes Washington populations of Lower Columbia Chinook. Both of these recovery plans include an assessment of current status of LCR Chinook populations. These assessments relied and built upon the viability criteria developed by the WLC-TRT (McElhany et al 2006) and an earlier evaluation of Oregon WLC populations (McElhany et al. 2007). These evaluations assessed the status of populations with regard to the VSP parameters of abundance and productivity, spatial structure and diversity (McElhany et al. 2000). The results of these analyses are shown in Figure 108 - Figure 110.

These analyses indicate that for all but one of the 21 fall Chinook populations are most likely in the "very high risk" category (also described as "extirpated or nearly so"). "Very high risk" is broad category ranging from 100% extinction probability (already extirpated) to 60% probability of extinction in 100 years (Table 66). The Clatskanie fall Chinook population was designated most likely in the "high risk" category, but with substantial possibility of falling in the "very high risk" category. Of the nine spring Chinook populations, eight are most likely at "very high risk". The Sandy spring Chinook was considered most likely in the "moderate" to "high" risk range. The late fall life history (two populations) was considered the strongest in the ESU with the Lewis late fall population most likely in the "very low risk" category and the Sandy late fall population most likely in the "low risk" category.

Table 66 -- Population persistence categories (from McElhany et al 2006).

Population Persistence Category	Probability of population persistence in 100 years	Probability of population extinction in 100 years	Description
0	0–40%	60-100%	Either extinct or very high risk of extinction.
1	40–75%	25-60%	Relatively high risk of extinction in 100 years.
2	75–95%	5-25%	Moderate risk of extinction in 100 years.
3	95–99%	1-5%	Low ("negligible") risk of extinction in 100 years (viable salmonid population).
4	>99%	<1%	Very low risk of extinction in 100 years.

In addition to the recovery plans, two analyses of Lower Columbia fall Chinook have been conducted to inform Biological Opinions related to harvest (Ford et al. 2007, NWFSC 2010). The NWFSC 2010 analysis used a life-cycle modeling approach to estimate how six of the populations targeted by recovery planners for high viability might respond with various recovery scenarios involving harvest, hatchery and habitat changes. The analysis results can be summarized by the first paragraph of the report's discussion section describing current viability:

> *One of the clearest results of this modeling effort is the striking difference in apparent viability among the six populations we modeled. Three populations – Lewis, Coweeman, and Washougal – are relatively large and have low estimated risks of quasi-extinction under a variety of the scenarios we explored, at least at harvest rates below ~30%. Three other populations – Clatskanie, Elochoman and Scappoose – appear to be sustained mostly through hatchery straying under current conditions, and are predicted to be self-sustaining under the 'recovery' actions modeled only at very low harvest rates. The Hood and MAG populations were intermediate between these two cases and could sustain themselves without hatchery input at low harvest rates under current conditions and under some modeled assumptions but not others. This basic result – that the populations differ markedly in their current status and ability to sustain harvest – is consistent with previous modeling efforts.*

These results provide a more nuanced view of tule status than is implied by the near uniform "very high risk" designation of the recovery plans.

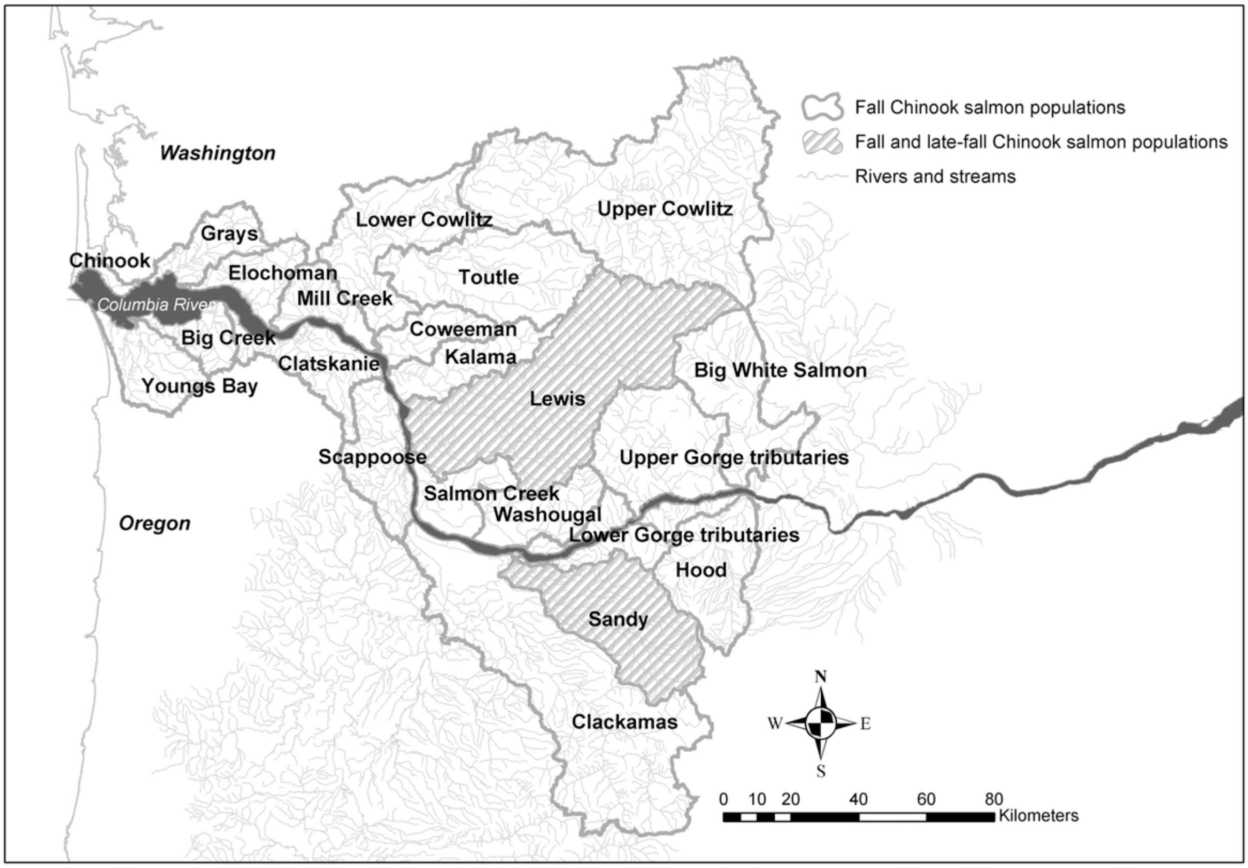


Figure 106 -- Historical LCR fall and late fall Chinook populations (From Myers et al. 2006).

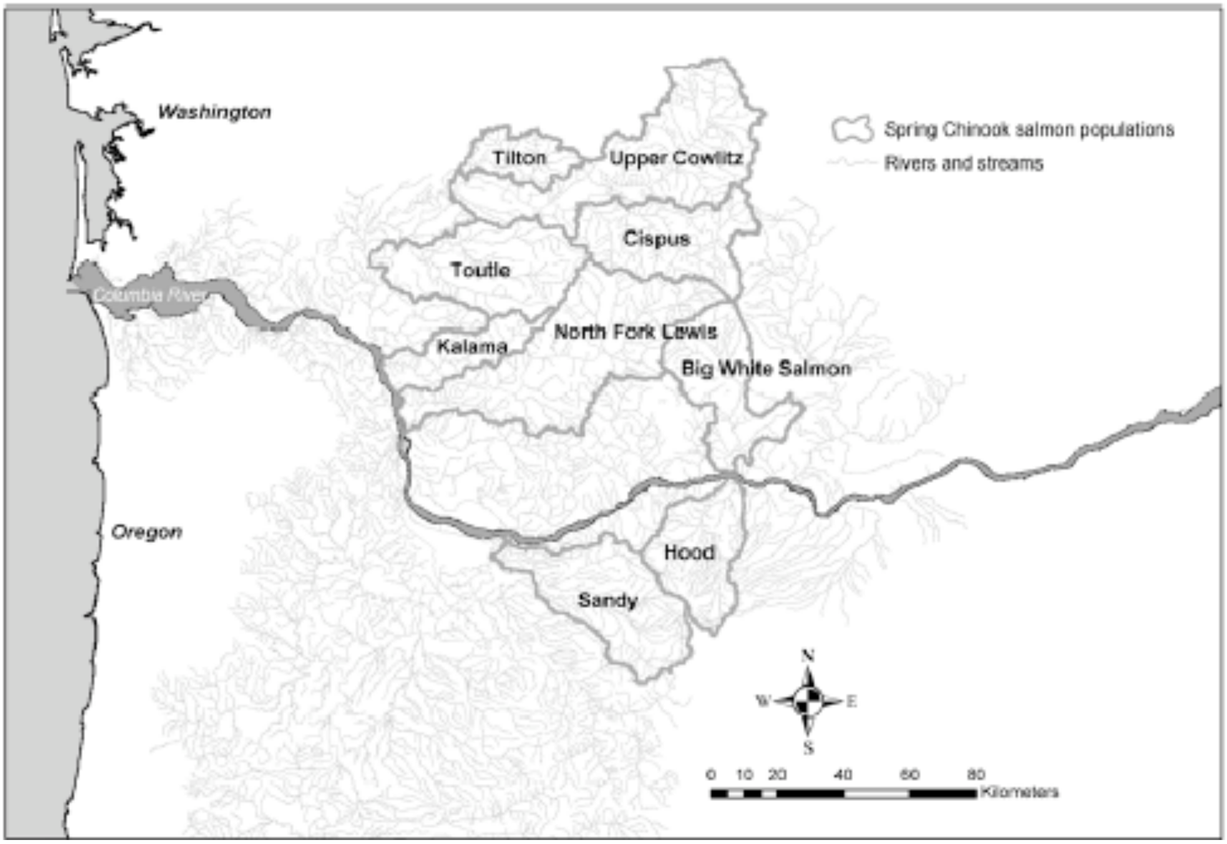


Figure 107 -- Historical LCR spring Chinook populations (From Myers et al. 2006).

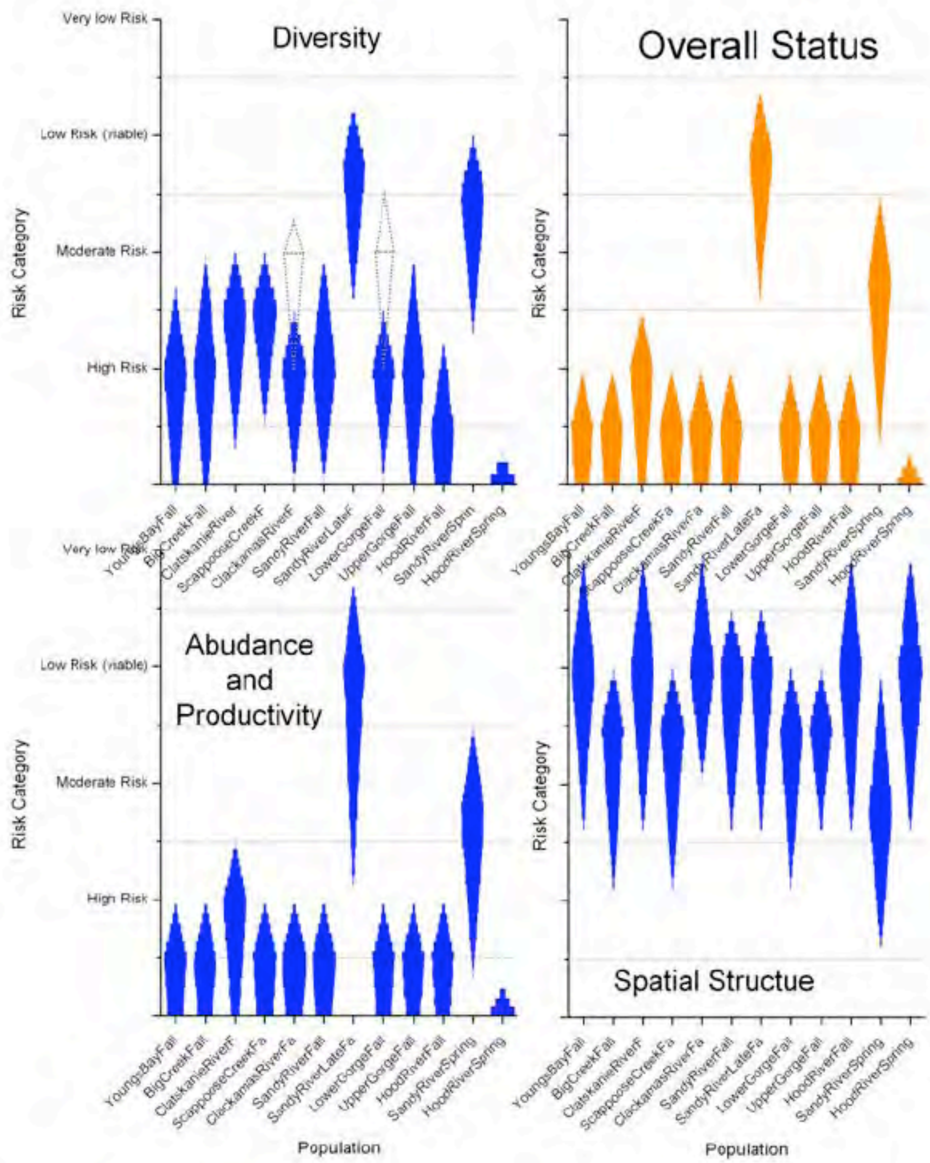


Figure 108 -- Extinction risk ratings for LCR Chinook populations in Oregon for the assessment attributes abundance/productivity, diversity, and spatial structure as well as an overall rating for populations that combines the three attribute ratings. Where updated ratings differ from those presented by McElhany et al. (2007), the older rating is shown as an open diamond with a dashed outline. Reproduced from ODFW (2010).

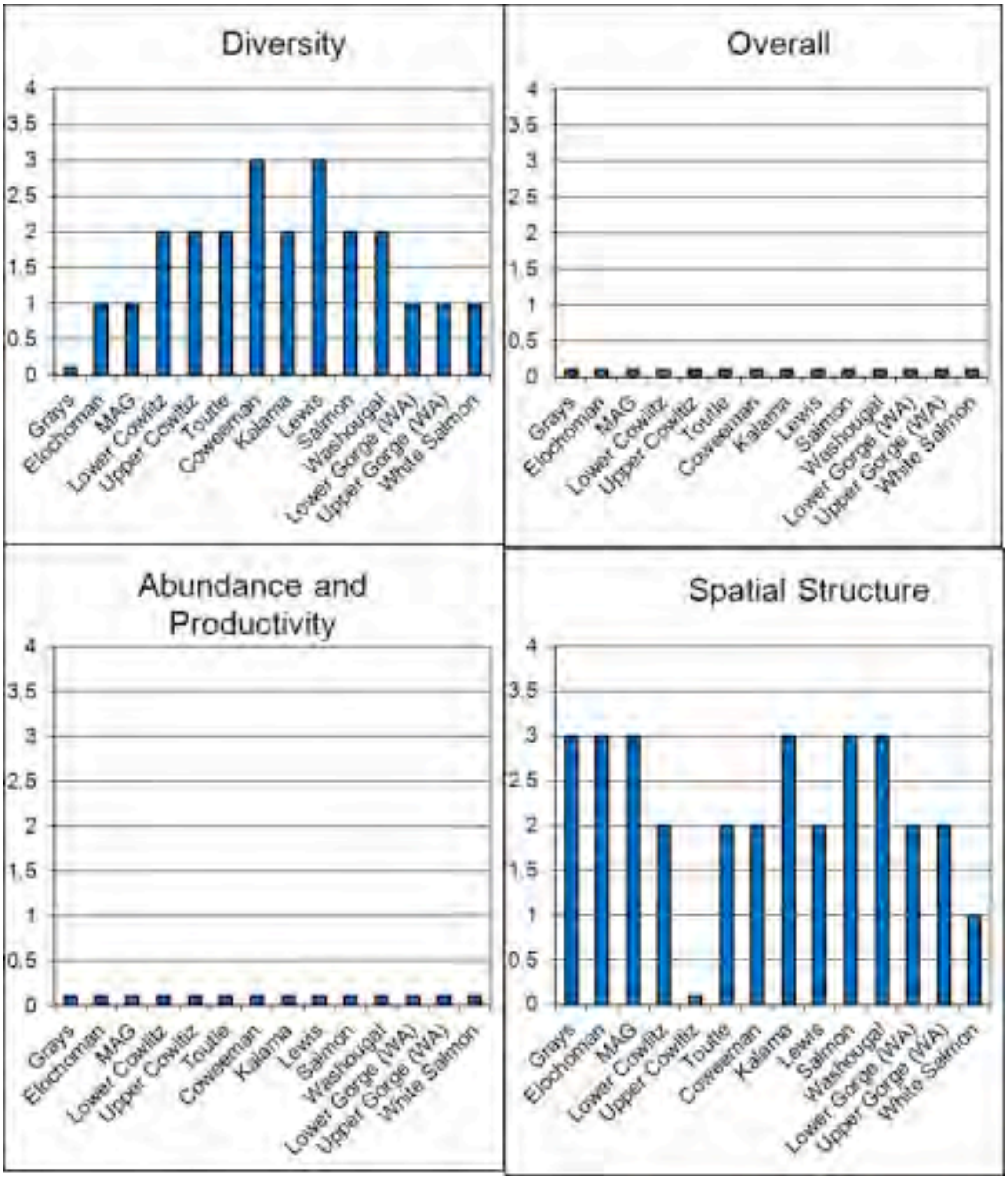


Figure 109 -- Current status of Washington LCR fall ("tule") Chinook populations for the VSP parameters and overall population risk. (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk ("viable") and 4 is very low risk.

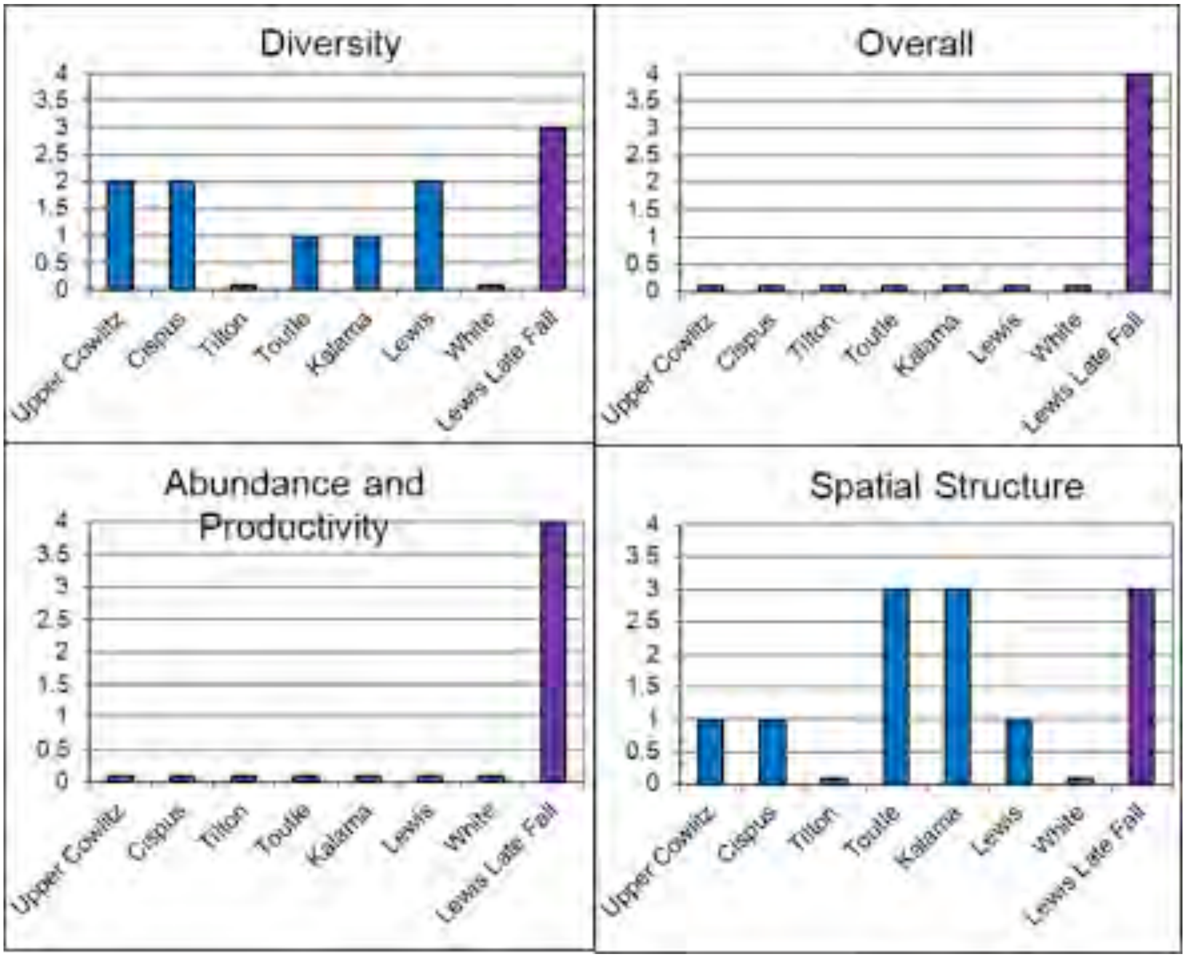


Figure 110 -- Current status of Washington LCR spring Chinook and late fall ("bright") Chinook populations for the VSP parameters and overall population risk. (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk ("viable") and 4 is very low risk.

New Data and Analyses

The 2005 BRT status evaluation included abundance data for most LCR Chinook populations up to the year 2001. For the current evaluation, we have compiled data through 2008 or 2009 for most populations, though data are available for two populations (Clatskanie fall and Sandy late fall) only through 2006. Trend data are presented in Figure 111 - Figure 114, with statistical summary in the Appendix. Since the last status evaluations, all of the populations increased in abundance during the early 2000's but have since declined back to about the levels seen in 2000. An exception is the Sandy spring Chinook, which declined from the early 2000 levels, but are still higher than 2000. In general, the populations do not show any dramatic changes in abundance or fraction of hatchery origin spawners since the 2005 BRT evaluation.

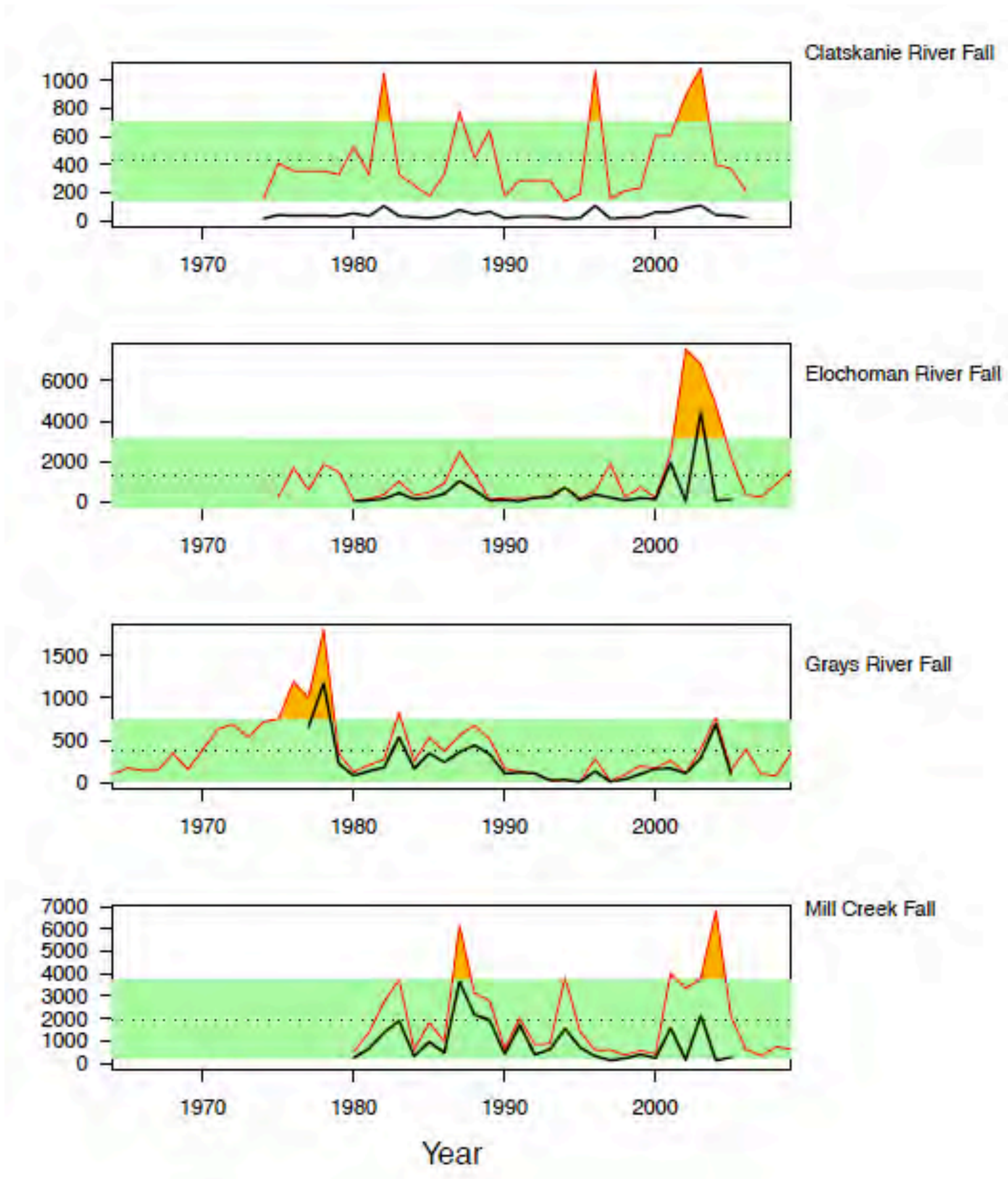


Figure 111 – Estimated spawning abundance for the Coastal major population group (stratum). The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

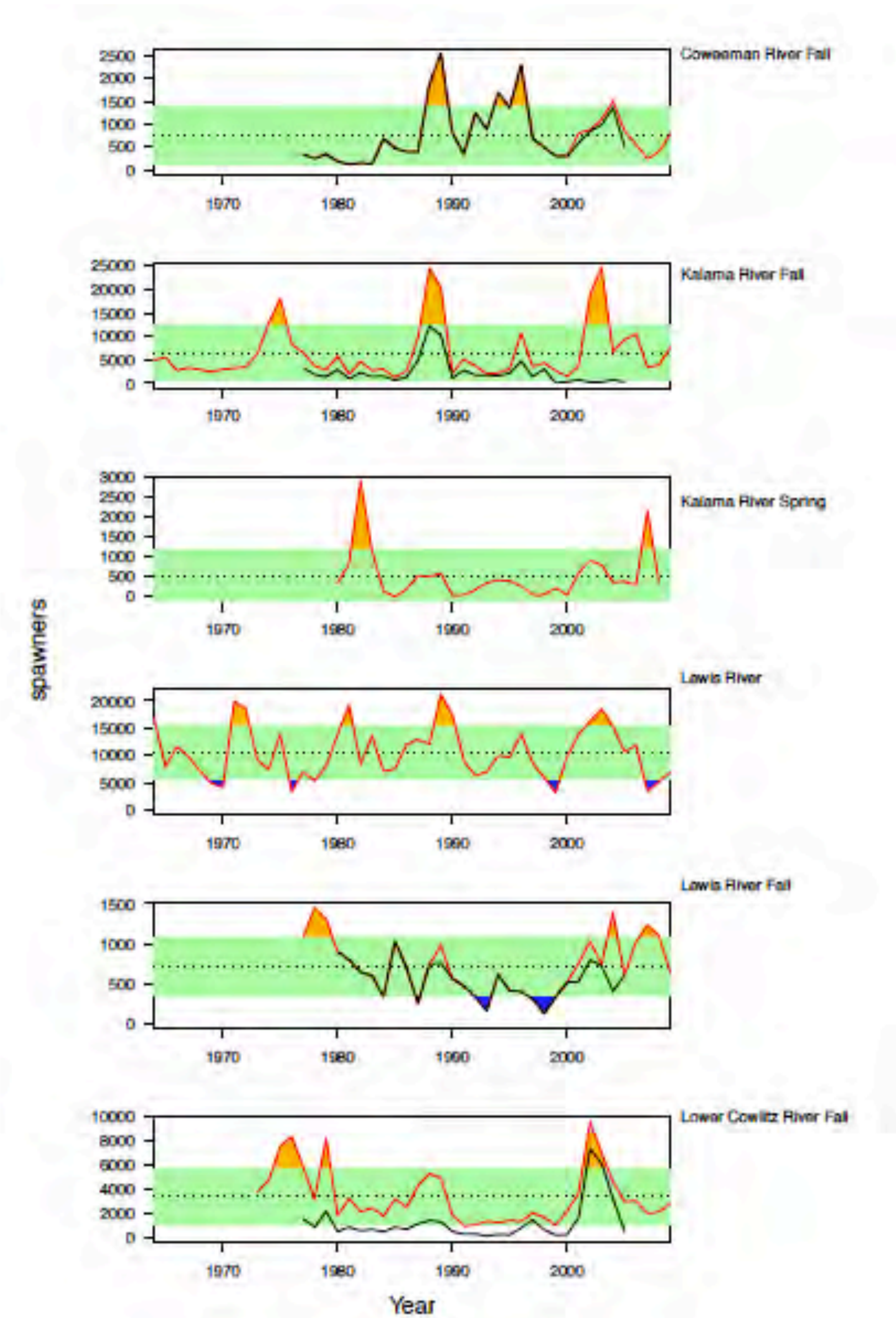


Figure 112 -- Estimated spawning abundance for the Cascade fall and spring major population group (strata). The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

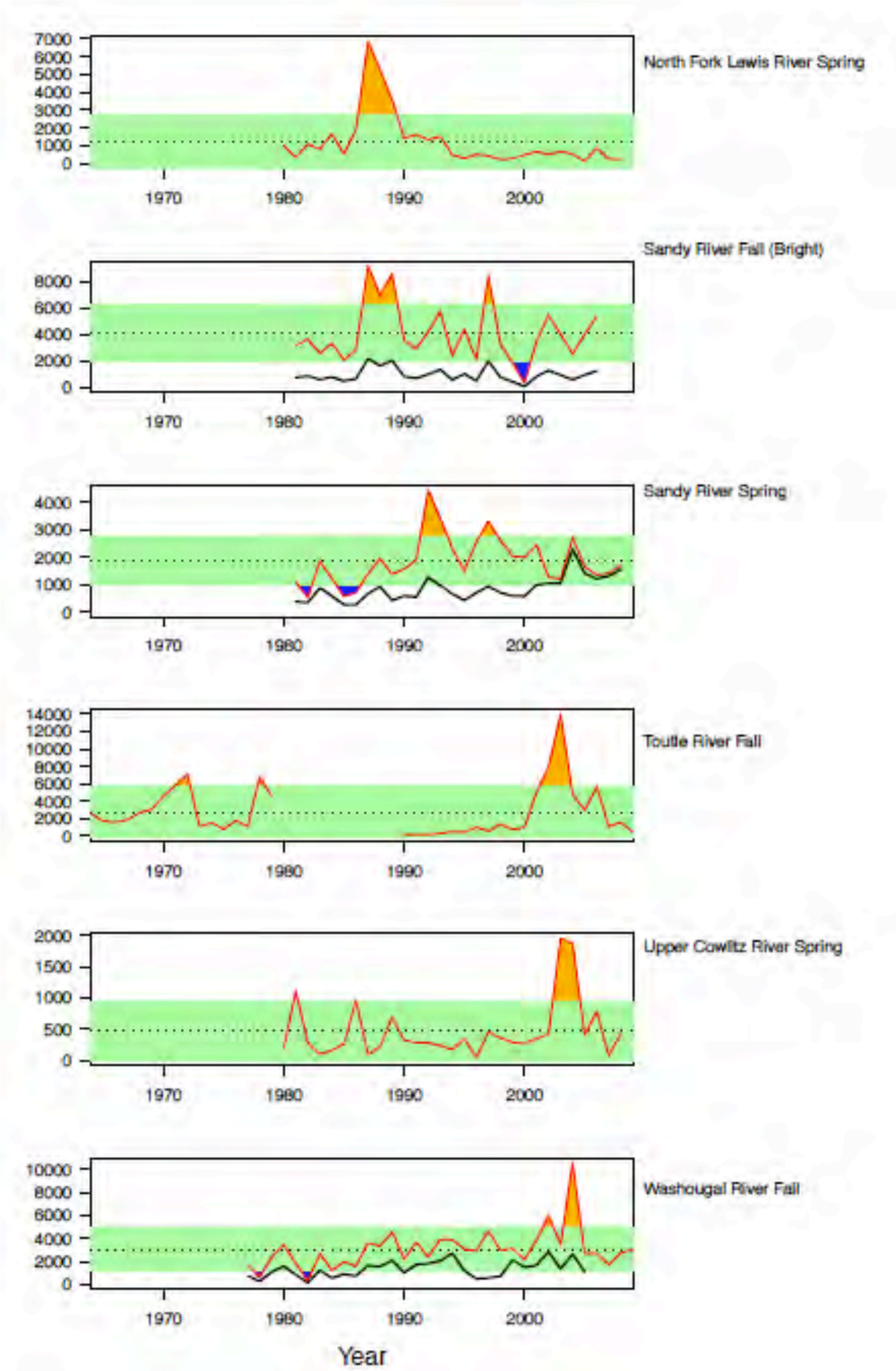


Figure 113 -- Estimated spawning abundance for the Cascade fall and spring major population group (strata) (cont). The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

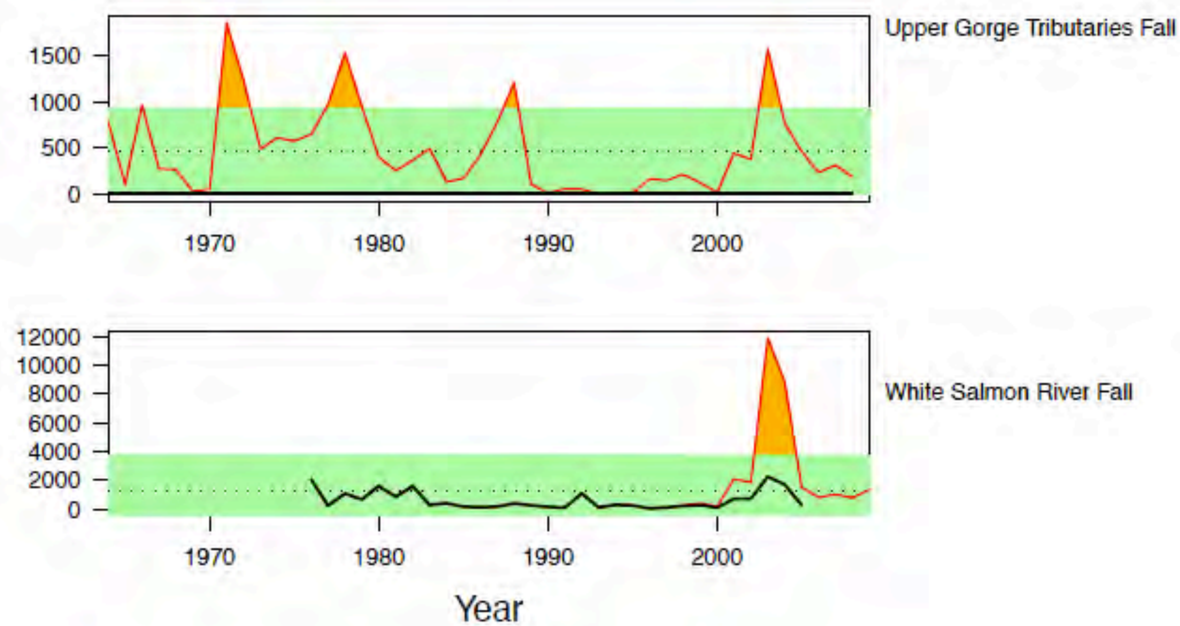


Figure 114 -- Estimated spawning abundance for the Gorge fall run major population group (stratum). The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

Harvest

Lower Columbia River Chinook salmon include three distinct components: spring-run Chinook, tule fall Chinook, and bright fall Chinook. These different components are subject to different in-river fisheries because of differences in river entry timing, but share similar ocean distributions. Because of this they have similar patterns of exploitation. All saw a drop in exploitation rates in the early 1990s with a modest increase since then (Figure 115). Fishery impact rates have been relatively stable in the past few years, with the exception of the bright fall component of the ESU. The tule portion of the ESU have been subject to several detailed modeling efforts aimed at evaluating the viability impacts of alternative exploitation rates (Ford et al. 2007, NWFSC 2010).

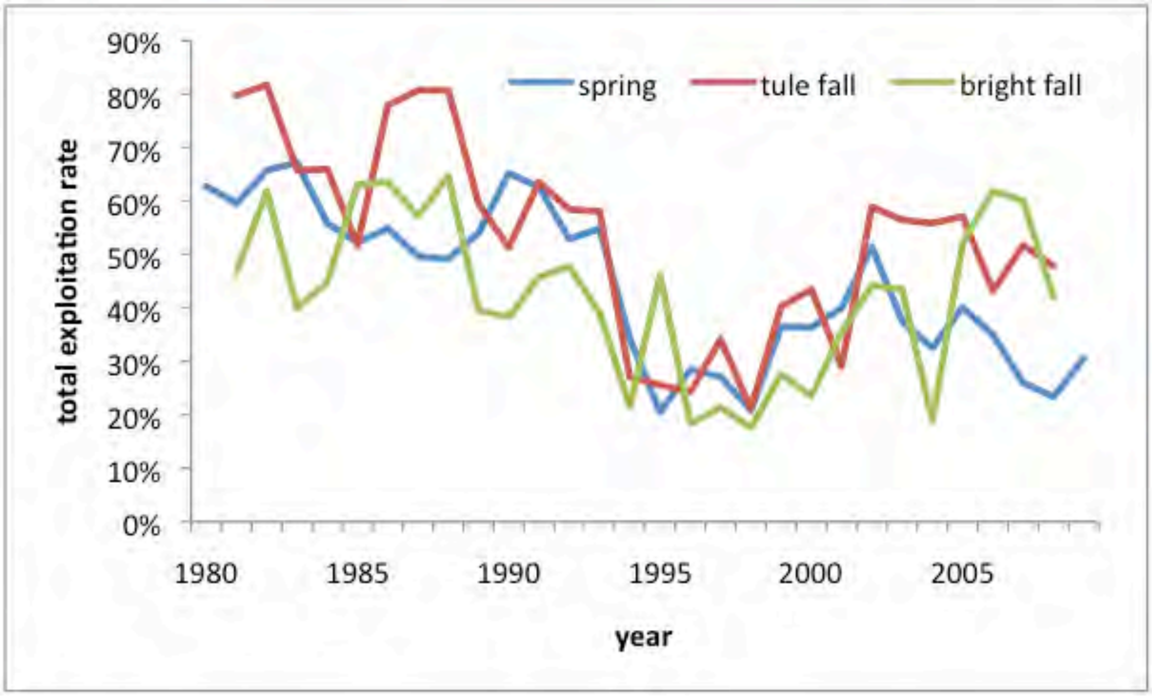


Figure 115 -- Total exploitation rates on the three components of the Lower Columbia River Chinook ESU. Data for tule fall Chinook from exploitation rate analysis of aggregate tule stock made up of tag codes from the Big Creek, Cowlitz, Kalama, and Washougal hatcheries. Data for bright fall Chinook from the CTC exploitation rate analysis (CTC in prep). Data for spring Chinook from CTC model calibration for Cowlitz spring Chinook (CTC in prep.) for ocean impacts and TAC run reconstruction data for in-river impacts (Cindly LeFleur, WDFW, personal communication).

Hatcheries

Total hatchery releases of all Chinook life-histories in the LCR ESU have been relatively stable since the last status review update (Figure 116). Although recovery plans call for multiple actions to the reduce the impact of hatchery fish on the LCR Chinook ESU, provisions in the plans have yet to be implimented for all populations and hatchery fish still remain a significant risk factor in this ESU.

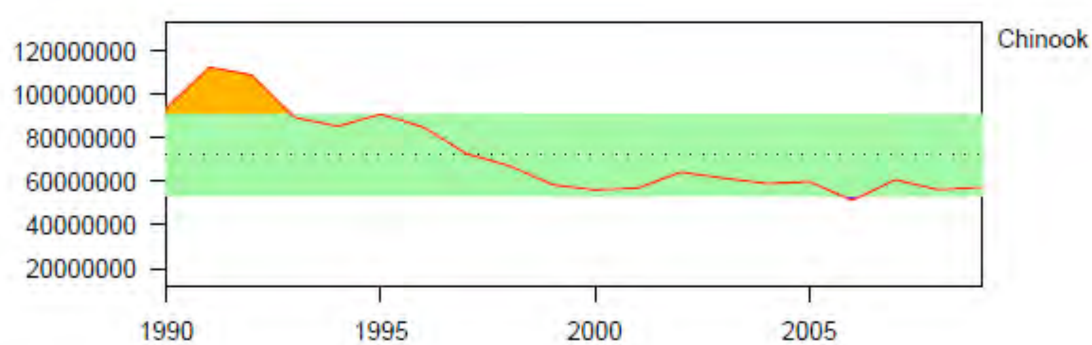


Figure 116 -- Total Chinook hatchery releases in the LCR ESU. Dotted line indicates the mean, and the shaded area the standard deviations. Source: RMIS.

Lower Columbia River Chinook salmon: Updated Risk Summary

Three status evaluations of LCR Chinook status, all based on WLC-TRT criteria, have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, ODFW 2010, LCFRB 2010). All three evaluations concluded that the ESU is currently at very high risk of extinction. Of the 32 historical populations in the ESU, 28 are considered extirpated or at very high risk. Based on the recovery plan analyses, all of the tule populations are considered very high risk except one that is considered at high risk. The modeling conducted in association with tule harvest management suggests that three of the populations (Coweeman, Lewis and Washougal) are at a somewhat lower risk. However, even these more optimistic evaluations suggest that the remaining 18 populations are at substantial risk because of very low natural origin spawner abundance (<100/population), high hatchery fraction, habitat degradation and harvest impacts.

Spring Chinook populations remain cut-off from access to essential spawning habitat by hydroelectric dams. Projects to allow access have been initiated in the Cowlitz and Lewis systems but these are not close to producing self-sustaining populations. The Sandy spring Chinook population, without a mainstem dam, is considered at moderate risk and is the only spring Chinook population not considered extirpated or nearly so. The Hood River currently contains an out-of-ESU hatchery stock. The two late fall populations, Lewis and Sandy, are the only populations considered at low or very low risk. They contain relatively few hatchery fish and have maintained high spawner abundances (especially Lewis) since the last BRT evaluation. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Ford, M. J., N. J. Sands, P. McElhany, K. R.G., D. Simmons, and P. Dygert. 2007. Analyses to Support a Review of an ESA Jeopardy Consultation on Fisheries Impacting Lower Columbia Tule Chinook Salmon. *.in* N. F. S. C. National Marine Fisheries Service, Conservation Biology Division; National Marine Fisheries Service, Northwest Regional Office, Sustainable Fisheries Division, editor.

Good, T. P., R. S. Waples, and P. Adams, editors. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, Seattle.

Lower Columbia Fish Recovery Board. 2010. Washington lower Columbia salmon recovery and Fish and Wildlife subbasin plan. Lower Columbia Fish Recovery Board, Olympia, WA.

McElhany, P., C. Busack, M. Chilcote, S. Kolmes, B. McIntosh, J. M. Myers, D. Rawding, A. Steel, C. Steward, D. Ward, T. Whitesel, and C. Willis. 2006. Revised viability criteria for salmon and steelhead in the Willamette and Lower Columbia Basins. Report, NOAA Northwest Fisheries Science Center, Seattle.

McElhany, P., M. Chilcote, J. M. Myers, and R. Beamesderfer. 2007. Viability status of Oregon salmon and steelhead populations in the Willamette and Lower Columbia Basins. NOAA-Northwest Fisheries Science Center, Seattle, WA.

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. Technical Memorandum NMFS-NWFSC-42, NOAA, Seattle.

Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. Van Doornik, and M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. NMFS-NWFSC-73, NOAA NWFSC, Seattle, WA.

Myers, J. M., R. G. Kope, G. J. Bryant, D. J. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. Tech. Memo. NMFS-NWFSC-35, U.S. Dept. Commer, NOAA.

NMFS. 1998. Endangered and threatened species: Threatened status for two ESUs of steelhead in Washington, Oregon, and California. [Docket No. 980225046-8060-02, 19 March 1998]. Page 13347. Federal Register.

NWFSC. 2010. Lower Columbia River tule Chinook salmon life-cycle modeling. Northwest Fisheries Science Center.

Oregon Department of Fish and Wildlife, R. Beamesderfer, L. Berg, M. Chilcote, J. Firman, E. Gilbert, K. Goodson, D. Jepsen, T. Jones, S. Knapp, C. Knutsen, K. Kostow, B. McIntosh, J. Nicholas, J. Rodgers, T. Stahl, and B. Taylor. 2010. Lower Columbia river conservation and recovery plan for Oregon populations of salmon and steelhead. Oregon Department of Fish and Wildlife, Salem, OR.

Upper Willamette River Chinook salmon[21]

Listed ESU/DPS

The ESU includes all naturally spawned populations of spring-run Chinook salmon in the Clackamas River and in the Willamette River, and its tributaries, above Willamette Falls, Oregon, as well as seven artificial propagation programs: the McKenzie River Hatchery (Oregon Department of Fish and Wildlife (ODFW) stock #24), Marion Forks/North Fork Santiam River (ODFW stock #21), South Santiam Hatchery (ODFW stock #23) in the South Fork Santiam River, South Santiam Hatchery in the Calapooia River, South Santiam Hatchery in the Mollala River, Willamette Hatchery (ODFW stock #22), and Clackamas hatchery (ODFW stock #19) spring-run Chinook hatchery programs.

ESU/DPS Boundary Delineation

The ESU Boundaries Review Group (see ESU Boundaries above) did not identify any new information suggesting a revaluation of the UW spring Chinook ESU. This status evaluation was conducted based on existing ESU boundaries.

Summary of Previous BRT Conclusions

NMFS reviewed the status of the Upper Willamette River Chinook salmon ESU initially in 1998 (Myers et al. 1998) and updated it that same year (NMFS 1998). The most recent status review update was in 2005 (Good et al. 2005). In the 1998 update, the BRT noted several concerns for this ESU. The 1998 BRT was concerned about the few remaining populations of spring-run Chinook salmon in the Upper Willamette River ESU, and the high proportion of hatchery fish in the remaining runs. The 1998 BRT noted with concern that the Oregon Department of Fish and Wildlife (ODFW) was able to identify only one remaining naturally reproducing population in this ESU, the spring-run Chinook salmon in the McKenzie River. The 1998 BRT was concerned about severe declines in short-term abundance that occurred throughout the ESU, and that the McKenzie River population had declined precipitously, indicating that it may not be self-sustaining. The 1998 BRT also noted that the potential for interactions between native spring-run and introduced fall-run Chinook salmon had increased relative to historical times due to fall-run Chinook salmon hatchery programs and the laddering of Willamette Falls. The 1998 BRT partially attributed the declines in spring-run Chinook salmon in the Upper Willamette River ESU to the extensive habitat blockages caused by dam construction. A majority of the 1998 BRT concluded that the Upper Willamette River Chinook salmon ESU was likely to become endangered in the foreseeable future. A minority of 1998 BRT members felt that Chinook salmon in this ESU were not presently in danger of extinction, nor were they likely to become so in the foreseeable future.

The 2005 BRT considered updated abundance information, habitat accessibility analyses and the results of preliminary WLC-TRT analyses. These analyses supported previous BRT conclusions that the majority of populations in the ESU are likely extirpated or nearly so and that excessive numbers of hatchery and loss of access to historical habitat are important risk factors. The McKenzie River population was the only population identified as potentially self-sustaining and increases in abundance were noted for this population in the most recent returns available at the time (2000 and 2001). However, BRT was concern about the long-term potential for this

[21] Section author: Paul McElhany

population. The majority (70%) of the 2005 BRT votes fell in the "likely to become endangered" category, with a minority in the "in danger of extinction" and the "not likely to become endangered categories".

Summary of Recent Evaluations

A report on the population structure of Lower Columbia and Willamette salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The UW Spring Chinook population designations in that report (Figure 117) are used in this status update and were used for status evaluations in a recent recovery plan by ODFW (2010).

A draft recovery plan for UW Chinook and Steelhead was released for comment by ODFW in 2010. The status evaluation in the ODFW recovery plan provided an update of the status evaluation of McElhany et al. (2007), which relied on methods and viability criteria developed by the WLC-TRT (McElhany et al. 2006). The results of the McElhany et al. (2007) evaluation are summarized in Figure 118. These results indicate that the overall status of all populations except the Clackamas and McKenzie fall in the "very high risk" category (also called "extirpated or nearly so). The McElhany et al (2007) analysis found that the Clackamas population is most likely in the "low risk" category (though with substantial uncertainty) and the McKenzie population most likely in the moderate risk category. The ODFW recovery plan update analysis (2010) found the Clackamas population most likely in the moderate risk category and the McKenzie most likely in the low risk category. The McElhany et al. analysis and the ODFW analyses both used abundance data on the McKenzie for years 1970-2005. For the Clackamas analyses, McEhany et al. used abundance data for years 1958-2005, whereas ODFW used data for years 1980-2008.

Based on the status of the component populations in either the McElhany et al or ODFW analyses, the overall status of the entire ESU was determined to be substantially below the viability criteria established by the WLC-TRT. Using a 0-4 population viability scale (Table 67), the WLC-TRT criteria require a viable ESU to have average population score greater than 2.25. The average for the UW spring Chinook ESU was estimated at 0.71. The main factors contributing to the high risk determination for this ESU were the low abundance of natural origin spawners, high fraction of hatchery origin spawners (>90% in most populations) and lack of access to the primary spawning habitat. Additional factors cited include a high incidence of pre-spawning mortality and increased human development in the entire Willamette Basin.

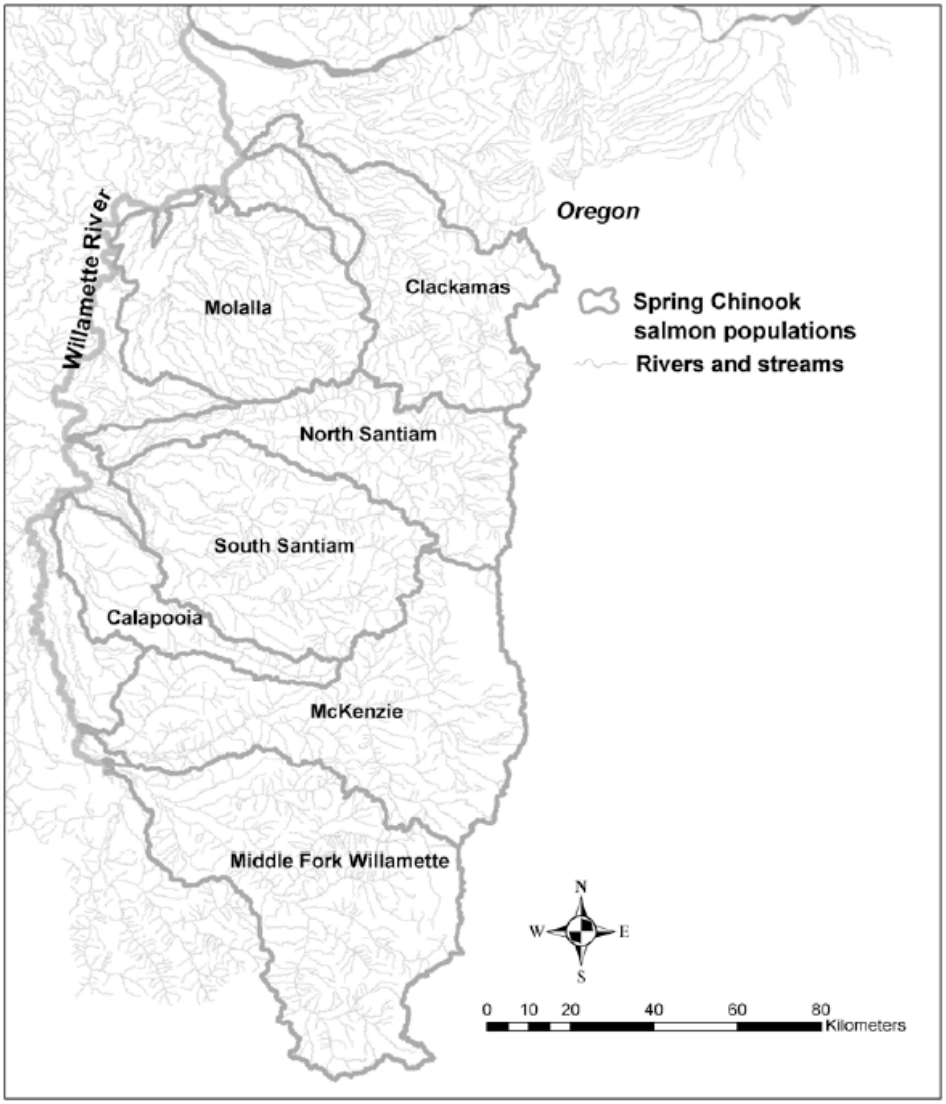


Figure 117 -- Upper Willamette spring Chinook populations (from Myers et al 2006).

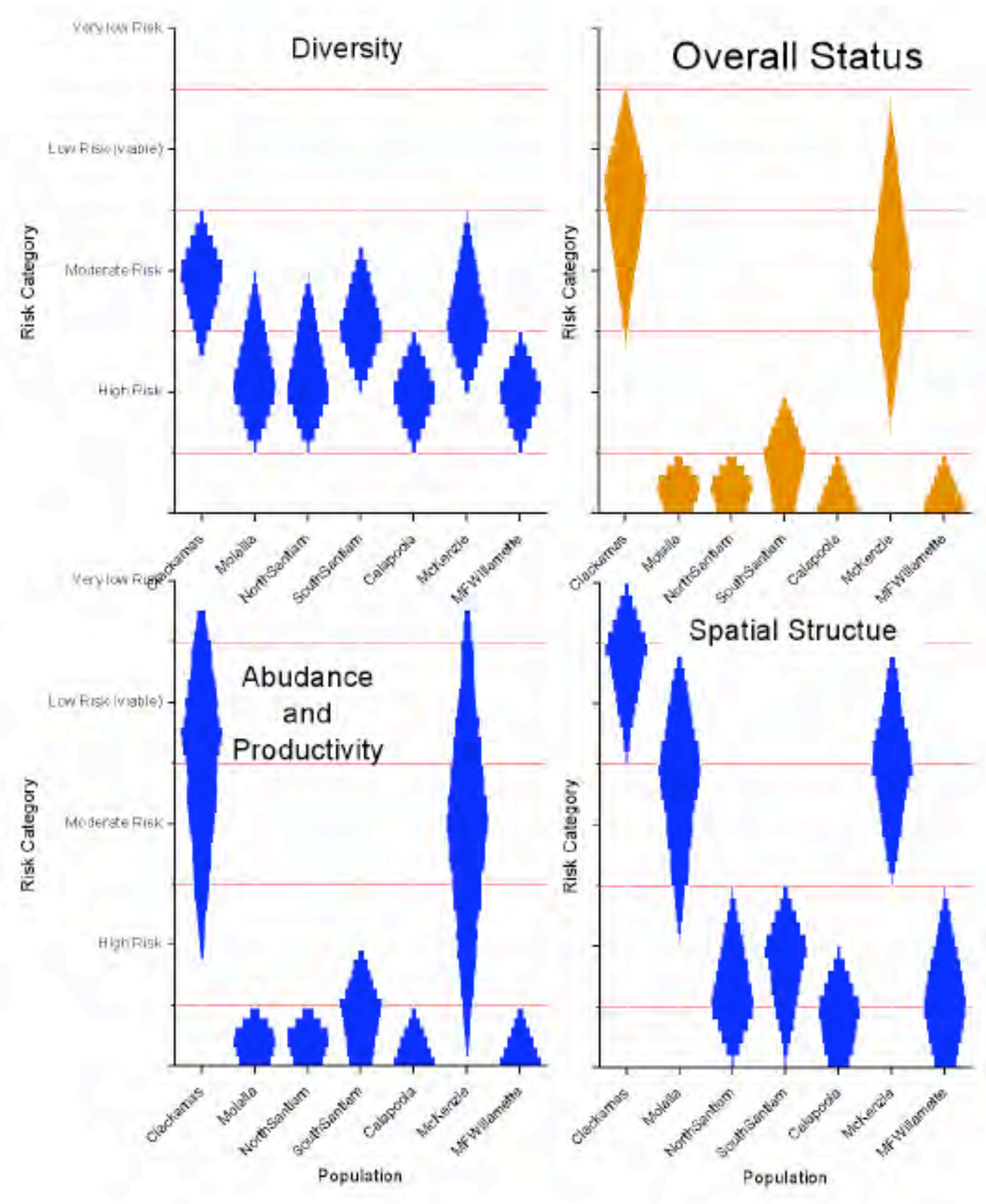


Figure 118 -- Status evaluation for UW spring Chinook populations (McElhany et al 2007).

Table 67 -- Population persistence categories (from McElhany et al 2006).

Population Persistence Category	Probability of population persistence in 100 years	Probability of population extinction in 100 years	Description
0	0–40%	60-100%	Either extinct or very high risk of extinction.
1	40–75%	25-60%	Relatively high risk of extinction in 100 years.
2	75–95%	5-25%	Moderate risk of extinction in 100 years.
3	95–99%	1-5%	Low ("negligible") risk of extinction in 100 years (viable salmonid population).
4	>99%	<1%	Very low risk of extinction in 100 years.

New Data and Analysis

Clackamas

The Clackamas River contains one of two population in the ESU (along with the McKenzie) considered to have some natural production. The majority of natural production in the Clackamas occurs upstream of the North Fork Dam, though there is some spawning, primarily by hatchery origin fish, downstream of the dam. Since 2001, only fish without a hatchery mark have been passed above North Fork dam, though, due to incomplete marking or identification, some fish classified as unmarked and passed over the dam are actually of hatchery origin. The 2005 BRT status evaluation included abundance data for the Clackamas spring Chinook population for the years 1958-2002. The most recent abundance time series for the Clackamas River population combines the data in the ODFW 2010 FMEP report with data from Portland General Electric (2010) (Figure 119). Summary statistics for this population are included in the Appendix. When the BRT considered this population in 2005, the population was at the beginning of what turned out to be a very short-term increase in abundance. After a peak of over 12,000 returns to the North Fork Dam in 2004, the return at the dam has dropped to about 2,000. The geometric mean number of natural origin spawners for the last five years is 850 fish.

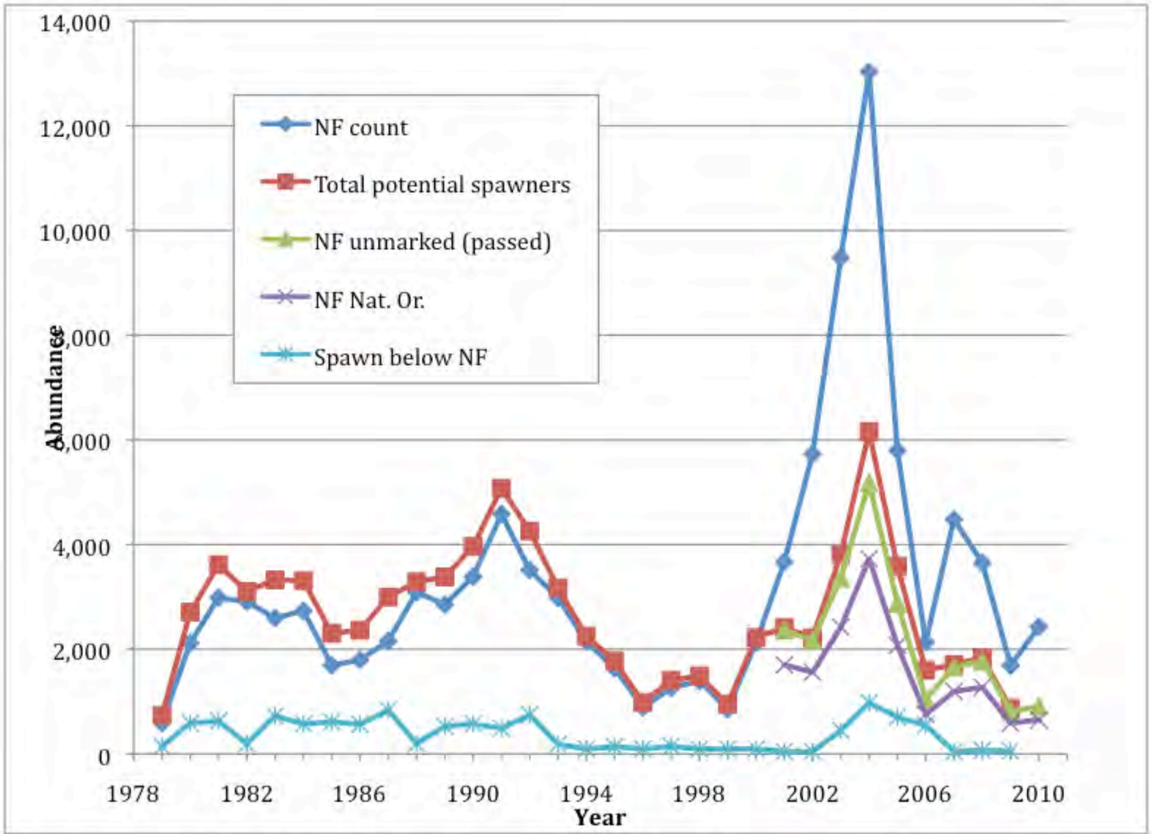


Figure 119 -- Clackamas River Spring Chinook abundance estimates. The "NF count" is the total number of Chinook counted at the North Fork Dam. Since 2001, all hatchery fish returns have been marked with an adipose fin clip. Only unmarked fish have been passed above North Fork Dam. The count of unmarked fish passed over the dam are shown in the series labeled "NF unmarked (passed)". Studies have shown that because of incomplete marking, only about 72% of the unmarked fish passed over North Fork dam are actually of natural origin (labeled "NF Nat. Or." in the figure). The majority of spring Chinook spawning occurs above North Fork Dam, but some spawning is estimated below the dam (labeled "Spawn below NF"). The majority of these below North Forks spawners are likely of hatchery origin. The "Total potential spawners" are the fish passed above North Fork Dam plus the estimated number of fish spawning below the dam. Data for 1979-2009 are from ODFW 2010 FMEP report. Data for 2010 are from the PGE fish count database (http://portlandgeneralelectric.net/community_environment/initiatives/protecting_fish/clackamas_river/default.aspx). Note that the PGE data only include the count up to September 9, 2010. Peak return at North Fork Dam occurs May-July but the tail of the return extends into October, so the final count for 2010 may be slightly higher than shown here.

Willamette Falls

Except those returning to the Clackamas River, all of the fish in this ESU are counted at Willamette Falls (Figure 120). The count does not identify whether returning Chinook are of hatchery or natural origin, but spawning ground surveys in Willamette tributaries indicate that the vast majority of fish are of hatchery origin. The primary source of naturally produce spring Chinook above Willamette Falls is the McKenzie River population upstream of Leaburg Dam. Figure 120 shows both the Willamette Falls count (averaging about 40,000 fish) and the estimated number of unmarked (mostly natural origin) spawners above Leaburg Dam (averaging about 2,000 fish).

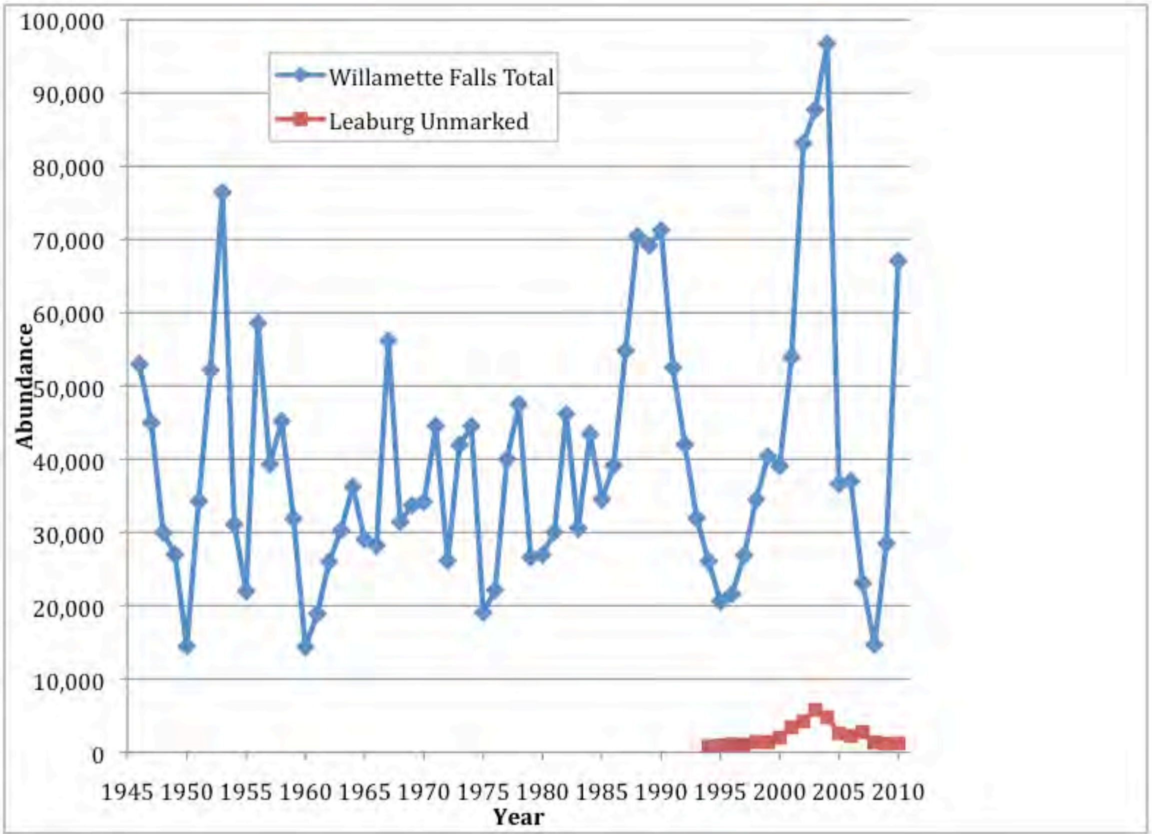


Figure 120 -- Willamette Falls total spring Chinook count (blue line - includes natural and hatchery origin) and the count of unmarked fish at Leaburg dam on the McKenzie (red line – unmarked fish are about 70% natural origin). Willamette Falls data from ODFW online database (http://www.dfw.state.or.us/fish/fish_counts/willamette%20falls.asp). McKenzie data from ODFW FMEP report (2010).

McKenzie River

The McKenzie River contains one of two populations (along with the Clackamas) with some level of natural production. The majority of natural origin spawning occurs above Leaburg Dam and in recent years, managers have limited the passage of hatchery marked fish above the dam. The 2005 BRT status evaluation included abundance data for the McKenzie spring Chinook population for the years 1970-2001. The most recent abundance time series for the Clackamas River population combines the data in the ODFW 2010 FMEP report with data from the ODFW online database (Figure 121 and Figure 122). Data acquired since the 2005 BRT report show in increase in abundance peaking in 2004 that as since dropped and has currently returned to previous levels of a little more than 1,000 unmarked fish at Leaburg.

It is interesting to note that the increase in returns at Willamette Falls observed in 2010 is not reflected by an increase in abundance of natural origin spawners in the McKenzie. The McKenzie abundance remains flat in 2010, though it did follow the increase that peaked in 2004. This may signal a failure of the natural population to respond to increased ocean survivals, but it is only a single data point and there multiple factors at play that have not yet been completely evaluated.

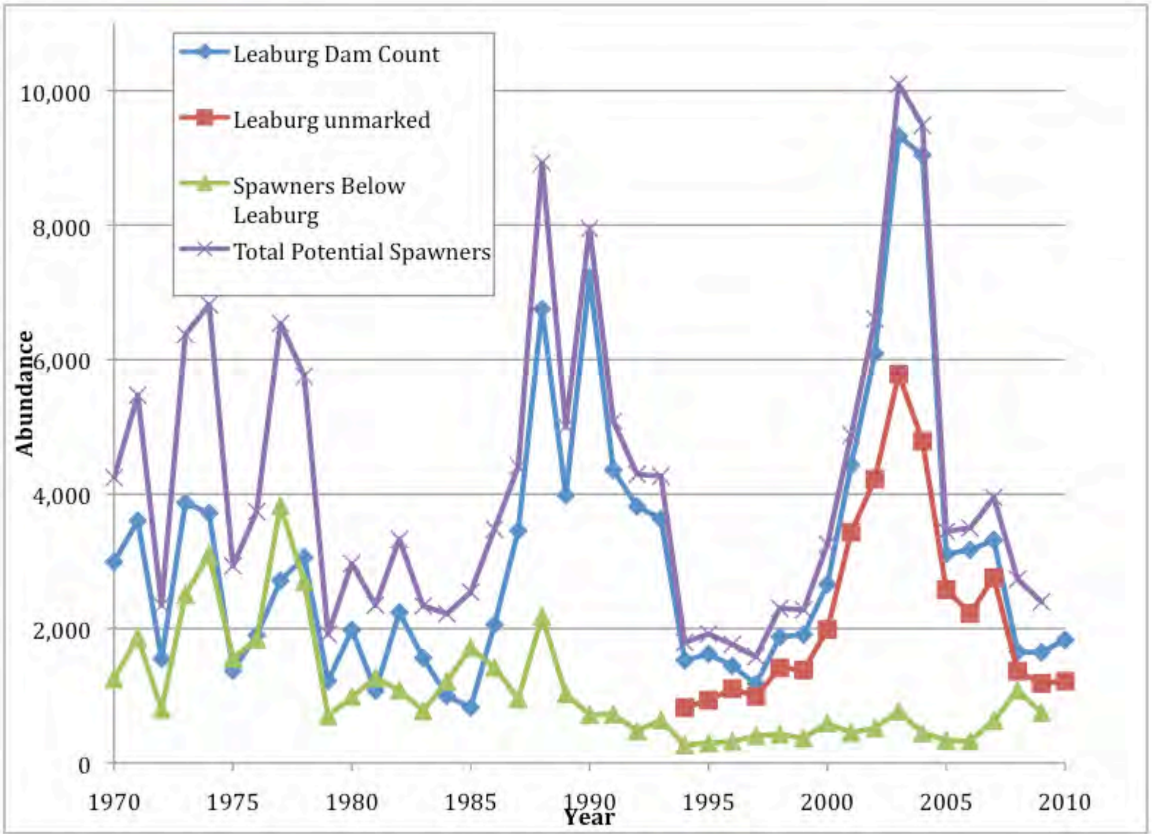


Figure 121 -- McKenzie River spring Chinook abundance estimates. The "Leaburg Dam Count" is the total number of Chinook counted at Leaburg Dam. The count with out a hatchery mark (fin clip) are shown in the series labeled "Leaburg unmarked". Studies have shown that because of incomplete marking, only a fraction of the unmarked fish are actually of natural origin (e.g.. only 72% of unmarked fish in the Clackamas are of natural origin). The majority of spring Chinook spawning occurs above Leaburg Dam, but some spawning is estimated below the dam (labeled "Spawners below Leaburg"). The majority of these below Leaburg spawners are likely of hatchery origin. The "Total potential spawners" are the fish counted at Leaburg plus the estimated number of fish spawning below the dam. Data for 1970-2009 are from ODFW 2010 FMEP report. The 2010 Leaburg counts are from the ODFW fish count online database ((http://www.dfw.state.or.us/fish/fish_counts/leaburg_dam/index.asp).

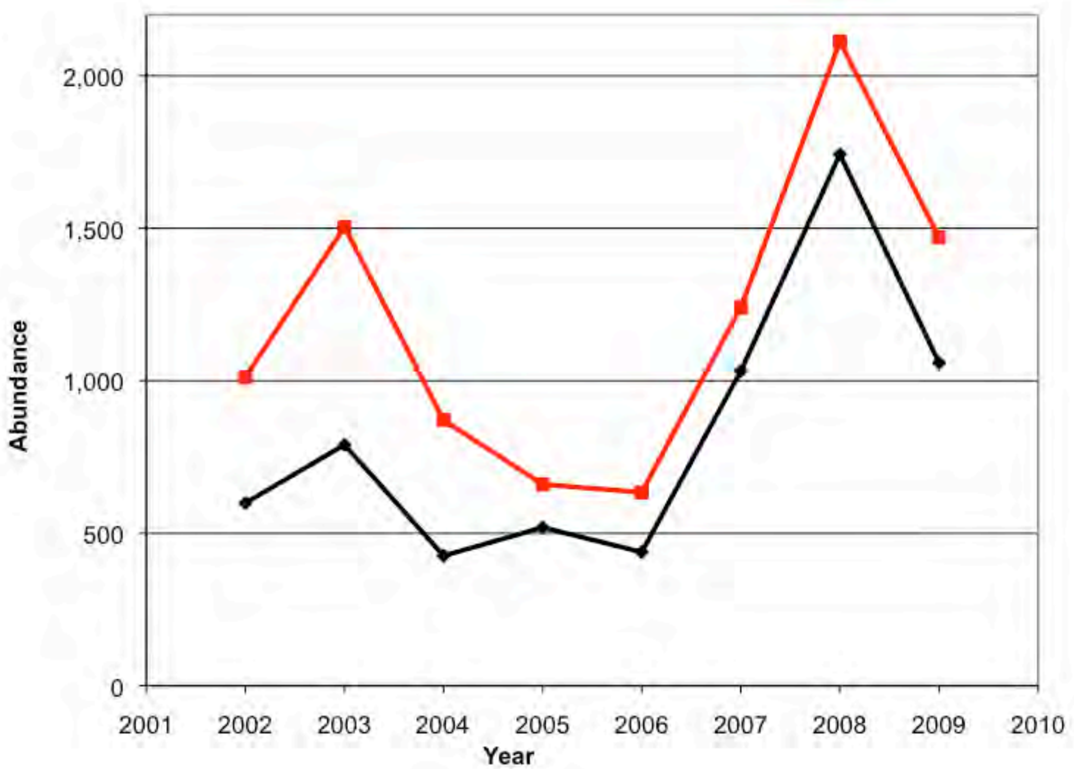


Figure 122 -- Natural origin (lower black line) and total spawner (upper red line) estimates for the McKenzie river based on the run reconstruction in ODFW 2010 FMEP report. Estimates differ from those shown in Figure 121 because of different extrapolation assumptions.

Other populations (Mollala, North Santiam, South Santiam, Calapooia, Middle Fork)

The 2005 BRT analysis reported that nearly all the fish returning and spawning in these populations are of hatchery origin. The analysis of hatchery fraction data collected since the 2005 BRT report support the view that these populations are hatchery dominated and likely not self-sustaining (Schroeder et al. 2005, McElhany et al. 2007, Schroeder et al. 2007, ODFW 2010b). In addition, these populations appear to be experiencing significant risks from pre-spawning mortality (Schroeder et al. 2005, McElhany et al. 2007, Schroeder et al. 2007).

Harvest

Upper Willamette River spring Chinook are taken in ocean fisheries primarily in Canada and Alaska. They are also taken in lower mainstem Columbia River commercial gillnet fisheries, and in recreational fisheries in the mainstem Columbia River and the Willamette River. These fisheries are directed at hatchery production, but historically could not discriminate between natural and hatchery fish. In the late 1990s ODFW began mass-marking the hatchery production, and recreational fisheries within the Willamette River switched over to retention of only hatchery fish, with mandatory release of unmarked fish. Overall exploitation rates reflect this change in fisheries dropping from the 50%-60% range in the 1980s and early 1990s to around 30% since 2000 (Figure 123).

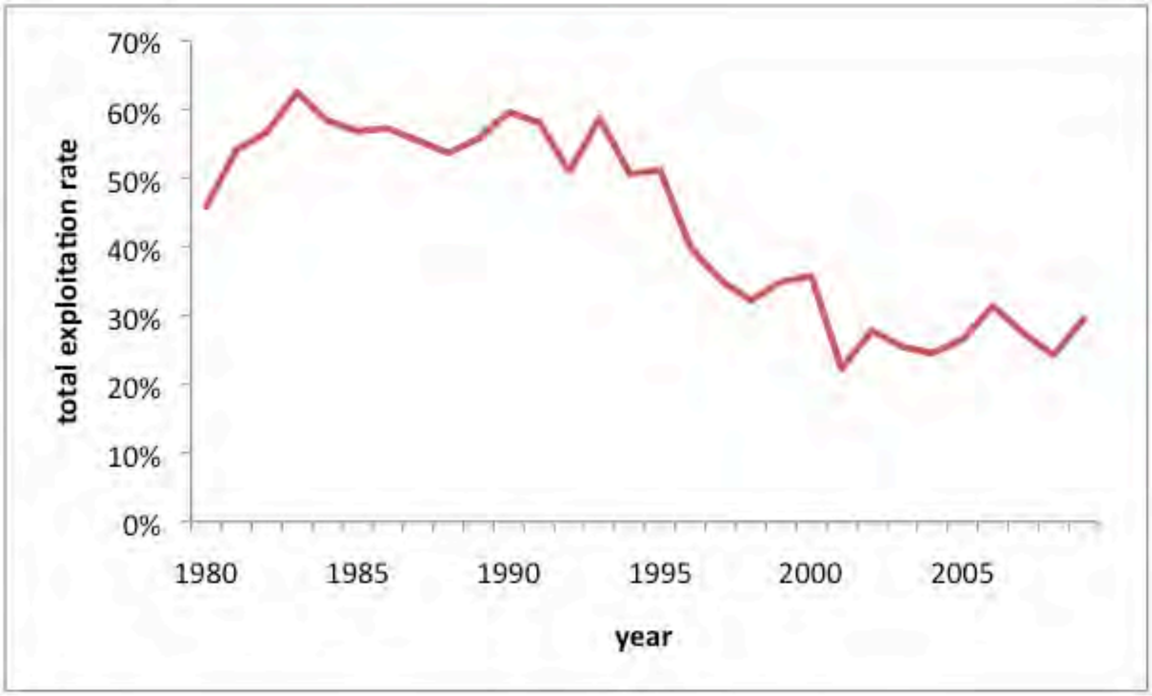


Figure 123 -- Total exploitation rates on Willamette River Spring Chinook. Data from CTC (in prep) exploitation rate analysis for ocean impacts, from TAC (2010) for inriver impacts from 1980-1997, and Chris Kern, ODFW, personal communication for 1998-2008.

Hatcheries

Since 1995, total spring Chinook hatchery production has remained relatively constant in the Upper Willamette at about 5 million smolts (Figure 124). As noted above the majoritiy of populations are dominated hatchery origin spawners. No major hacthery production changes have been noted since the last (2005) BRT report.

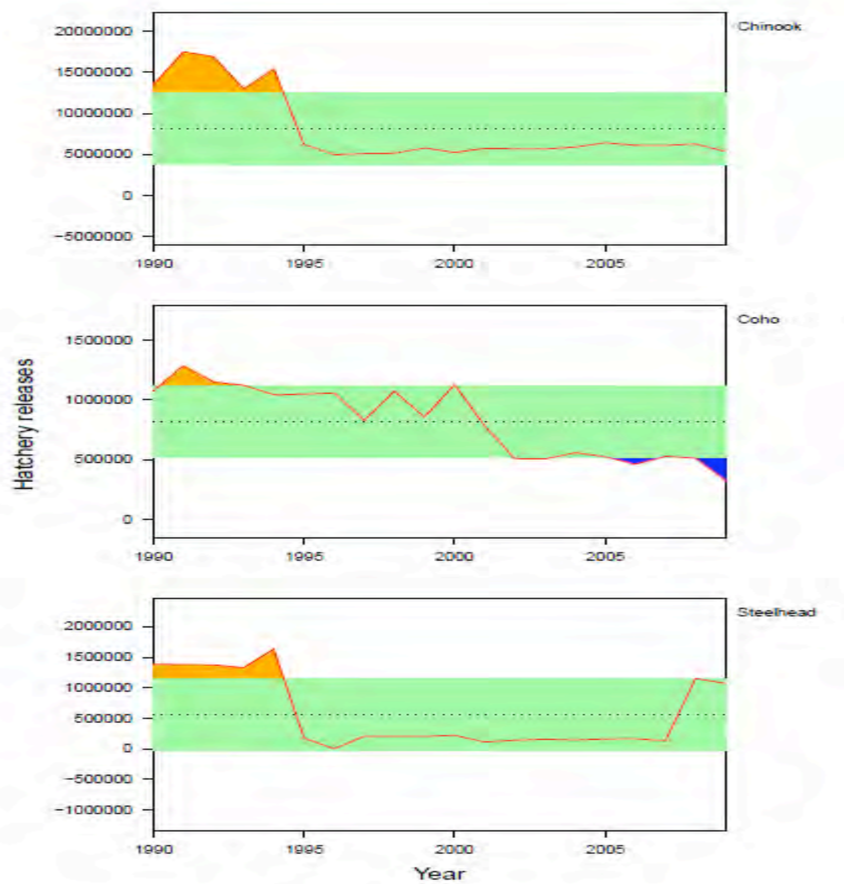


Figure 124 -- Hatchery releases of Chinook, coho and Steelhead in the area of the Upper Willamette Chinook ESU. Dotted lines indicate the means, shaded areas the standard deviations. Data source: RMIS.

Upper Willamette Chinook salmon: Updated Risk Summary

Two related status evaluations of UW Chinook have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, ODFW 2010). Both evaluations were based on the WLC-TRT viability criteria and both concluded that the ESU is currently at very high risk of extinction. Of the seven historical populations in the ESU, five are considered at very high risk. The remaining two (Clackamas and McKenzie) are considered at moderate to low risk. New data collected since the last BRT report have verified the high fraction of hatchery origin fish in all of the populations all in the ESU (even the Clackamas and McKenzie have hatchery fractions above WLC-TRT viability thresholds). The new data have also highlighted the substantial risks associated with pre-spawning mortality. Although recovery plans are targeting key limiting factors for future actions, there have been no significant on-the-ground-actions since the last BRT report to resolve the lack of access to historical habitat above dams nor have there been substantial actions removing hatchery fish from the spawning grounds. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good, T. P., R. S. Waples, and P. Adams, editors. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, Seattle.
McElhany, P., C. Busack, M. Chilcote, S. Kolmes, B. McIntosh, J. M. Myers, D. Rawding, A. Steel, C. Steward, D. Ward, T. Whitesel, and C. Willis. 2006. Revised viability criteria for salmon and steelhead in the Willamette and Lower Columbia Basins. Report, NOAA Northwest Fisheries Science Center, Seattle.
McElhany, P., M. Chilcote, J. M. Myers, and R. Beamesderfer. 2007. Viability status of Oregon salmon and steelhead populations in the Willamette and Lower Columbia Basins. NOAA-Northwest Fisheries Science Center, Seattle, WA.
Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. Van Doornik, and M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. NMFS-NWFSC-73, NOAA NWFSC, Seattle, WA.
Myers, J. M., R. G. Kope, G. J. Bryant, D. J. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. Tech. Memo. NMFS-NWFSC-35, U.S. Dept. Commer, NOAA.
NMFS. 1998. Endangered and threatened species: Threatened status for two ESUs of steelhead in Washington, Oregon, and California. [Docket No. 980225046-8060-02, 19 March 1998]. Page 13347. Federal Register.
ODFW. 2010a. Fisheries management and evaluation for 2009 Willamette River spring Chinook.in O. D. o. F. a. Wildlife, editor.
ODFW. 2010b. Upper Willamette conservation and recovery plan for Chinook and steelhead (Draft February 23, 2010) Oregon Department of Fish and Wildlife.
Schroeder, R. K., K. R. Kenaston, and L. K. Krentz. 2005. Spring Chinook salmon in the Willamette and Sandy Rivers. Oregon Department of Fish and Wildlife, Corvalis, OR.
Schroeder, R. K., K. R. Kenaston, and L. K. McLaughlin. 2007. Spring Chinook salmon in the Willamette and Sandy Rivers (Annual Progress Report).in O. D. o. F. a. Wildlife, editor.

Columbia River chum salmon[22]

Listed ESU/DPS

The ESU includes all naturally spawned populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon, as well as three artificial propagation programs: the Chinook River (Sea Resources Hatchery), Grays River, and Washougal River/Duncan Creek chum hatchery programs.

Summary of Previous BRT Conclusions

NMFS provided an updated status report on the Columbia River chum salmon ESU in 1999 (NMFS 1999). As documented in the 1999 report, the previous BRT's were concerned about the dramatic declines in abundance and contraction in distribution from historical levels. Previous BRTs were also concerned about the low productivity of the extant populations, as evidenced by flat trend lines at low population sizes. A majority of the 1999 BRT concluded that the Columbia River chum salmon ESU was likely to become endangered in the foreseeable future, and a minority concluded that the ESU was currently in danger of extinction.

The most recent status update for CR chum was in 2005(Good et al. 2005). In the 2005 BRT, nearly all votes for the Columbia River chum salmon ESU fell in the "likely to become endangered" (63%) or "danger of extinction" (34%) categories. The BRT had substantial concerns about every VSP element. Most or all risk factors the BRT previously identified remain important concerns. The WLC-TRT estimated that close to 90% of this ESU's historical populations are extinct or nearly so, resulting in loss of much diversity and connectivity between populations. The 2005 BRT was concerned that populations that remained are small, and overall abundance for the ESU was low. The ESU had shown low productivity for many decades, even though the remaining populations were at low abundance and density-dependent compensation might be expected. The BRT was encouraged that unofficial reports for 2002 suggested a large increase in abundance in some (perhaps many) locations, but was unclear on the cause of the increase and whether it would be sustaining for multiple years.

Summary of Recent Evaluations

A report on the population structure of Lower Columbia salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The chum population designations in that report (Figure 125) are used in this status update and were used for status evaluations in recent recovery plans by ODFW and LCFRB.

In 2010, ODFW completed a recovery plan that included Oregon populations of the Columbia River chum ESU. Consistent with previous BRT and other analyses (e.g. McElhany et al. 2007), the ODFW recovery plan concluded that chum are extirpated or nearly so in all Oregon Columbia river populations. A few chum are occasionally encountered during surveys or return to hatchery collection facilities, but this are likely either strays from one of the Washington population or part of a few extremely small and erratic remnant populations.

The LCFRB completed a revision recovery plan in 2010 that includes Washington populations of Columbia River chum. This plan includes an assessment of the current status

---

[22] Section author: Paul McElhany

of CR chum populations. This assessment relied and built upon the viability criteria developed by the WLC-TRT (McElhany et al 2006) and an earlier evaluation of Oregon WLC populations (McElhany et al. 2007). This evaluation assessed the status of populations with regard to the VSP parameters of abundance and productivity, spatial structure and diversity (McElhany et al. 2000). The result of this analysis is shown in Figure 126. This analysis indicates that all of the Washington populations with two exceptions are in the overall “very high risk” category (also described as “extirpated or nearly so”). The Grays river population was considered to be at moderate risk and the Lower Gorge population be at low risk. The very high risk status assigned to the the majority of Washington populations (and all the Oregon populations) reflects the very low abundance observed in these populations (e.g. <10 fish/year).

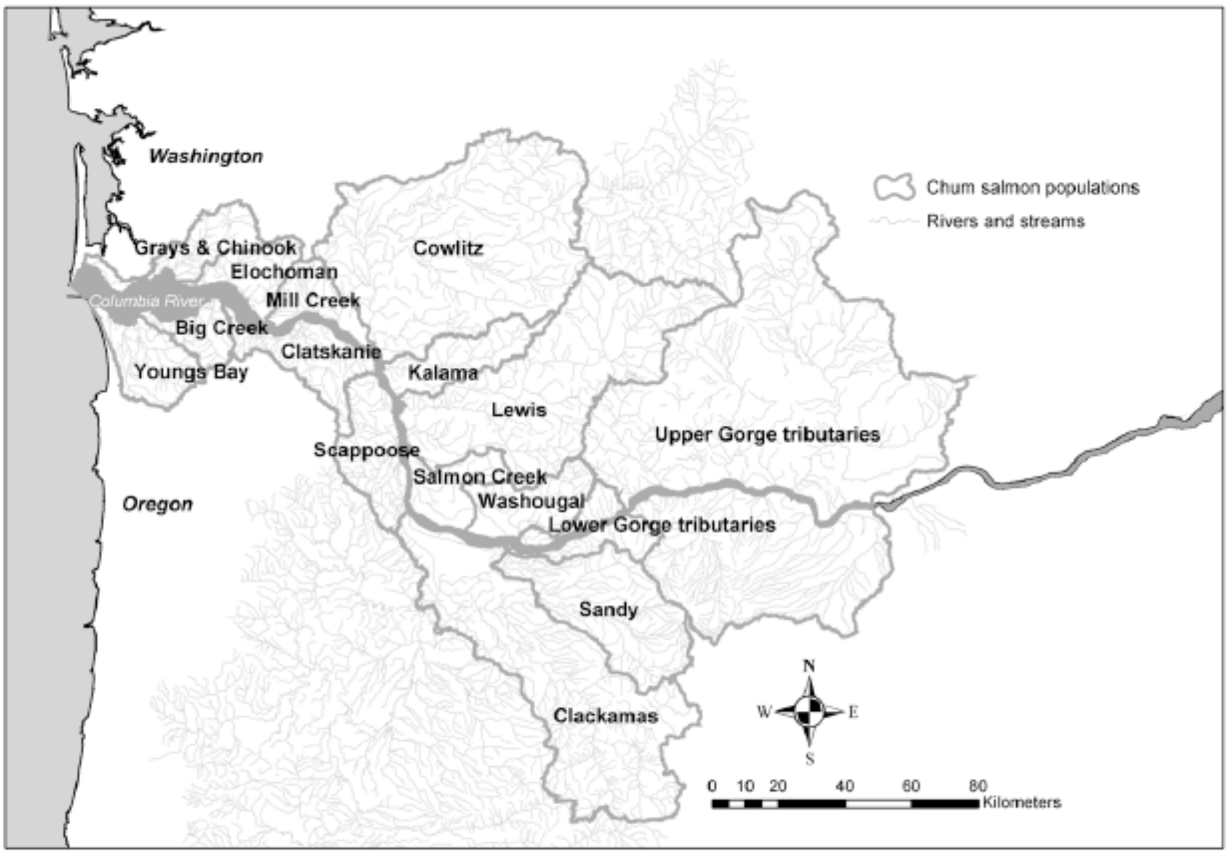


Figure 125 -- Historical Columbia River chum populations (from Myers et al. 2006).

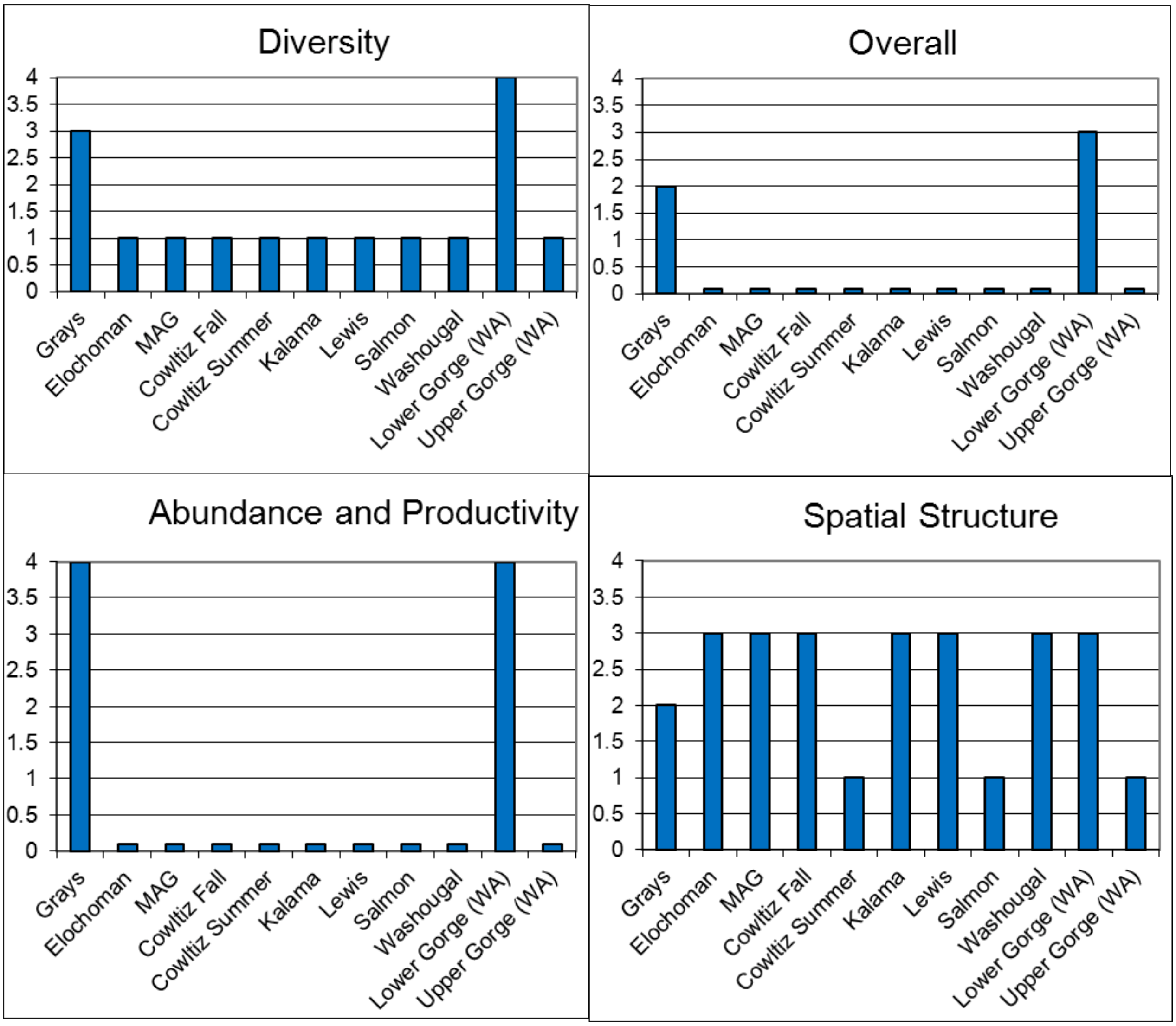


Figure 126 -- Current status of Washington CR chum populations for the VSP parameters and overall population risk. (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk ("viable") and 4 is very low risk.

New Data and Analyses

Population Designations

Genetic studies since the last BRT analysis indicate that there historically existed a summer run chum population in the Cowlitz River (Small et al. 2006). This population appears to have occupied the upper reaches of the chum distribution in the Cowlitz. A few fish displaying this summer run life-history are occasionally observed in the Cowlitz. The new analysis suggests adding a new population to the Cascade strata of the WLC-TRT criteria. This summer run population exhibits a unique life history in the chum ESU and represents an important component of chum diversity.

Grays and Lower Gorge

Grays River and the Lower Gorge area are the only locations that have consistently maintained natural spawning. Surveys for chum are regularly conducted in these areas, but a consistent methodology for obtaining population level abundance estimates are still in development. Figure 127 and Figure 128 show long-term abundance index series and a few recent years with absolute abundance estimates. These data indicate a significant increase in abundance in 2002-2004 in Grays River and Lower Gorge population. The 2002 increase was noted by the 2005 BRT as an encouraging sign. However, recent data indicate that abundances have returned to previous relatively low levels of perhaps a few thousand in the Grays and less than a thousand in the Lower Gorge. The Grays data are confounded by the initiation of a hatchery program in the early 1999, so the Grays time series contains and unknown number of hatchery origin spawners starting in 2002 (coinciding with the large increase in abundance for that population). The Lower Gorge population does not have a hatchery program.

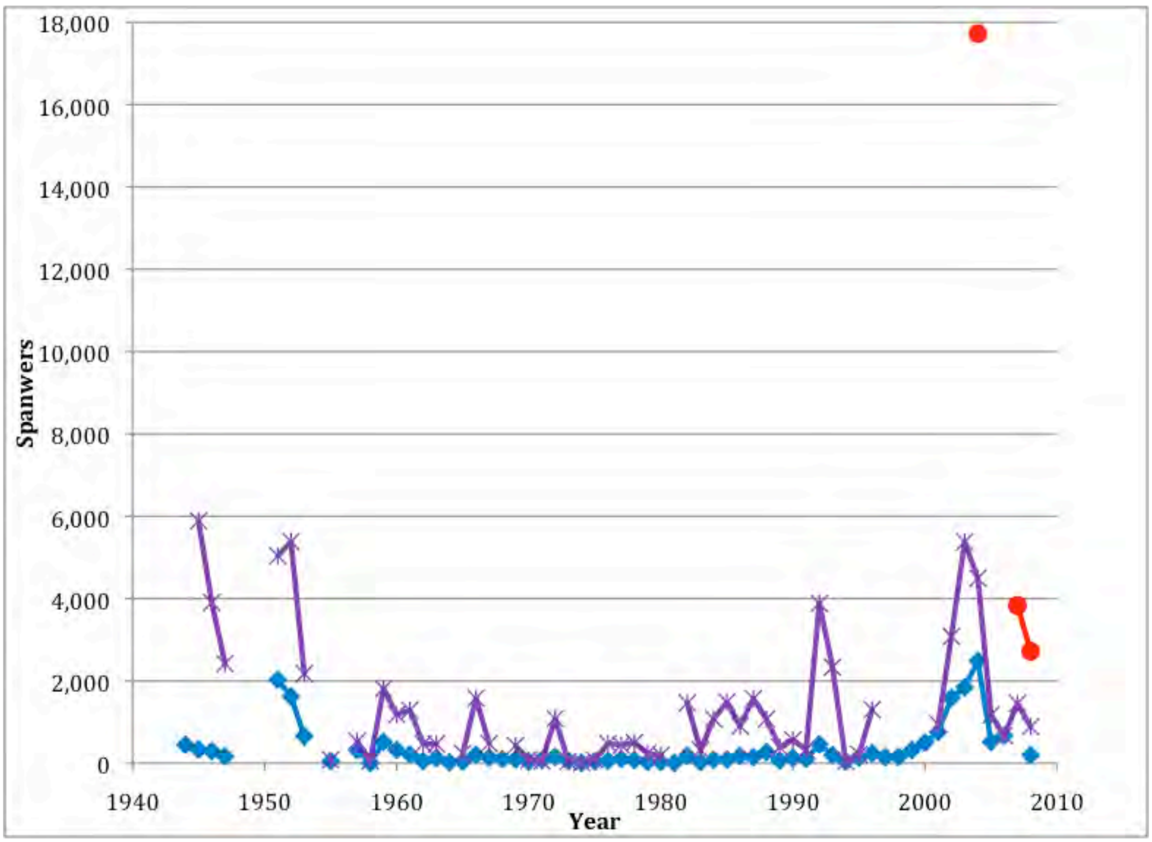


Figure 127 -- Grays River chum spawner time series. The blue line and diamonds are "spawners per mile" from the WDFW SaSi database. The purple lines and stars are the "Total live" count from the Streamnet database. The red dots and line are the estimate of "Total Spawners" from the WDFW SaSi database.

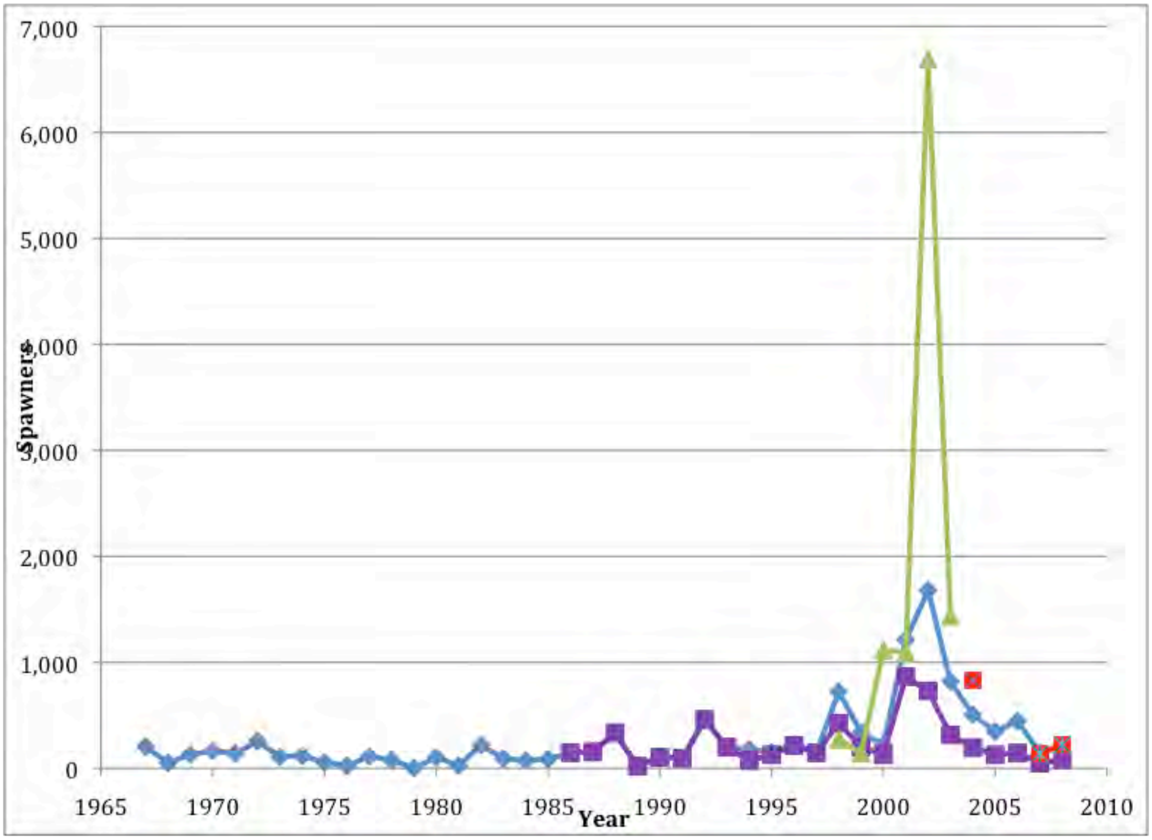


Figure 128 -- Lower Gorge chum spawner time series. The blue diamonds are the "Spawner Index" from the WDFW SaSi database. The purple squares are "Spawners per mile" from the WDFW SaSi database. The green triangles are the "Total Live" count from the Streamnet database. The red squares are "Total Spawners" from the WDFW SaSi database.

Washougal

The 2005 BRT report noted the discovery of a chum spawning group in the mainstem Columbia beneath the I-205 bridge within the area of the Washougal River population. Approximately 350 spawners were observed in 2000. Although surveys of this population have been conducted, updated abundance information is not available at this time.

Above Bonneville

In most years, a small number of chum migrate past Bonneville Dam to the Upper Gorge population area (Figure 129). Spawning above Bonneville is thought to be limited, however, for the first time, chum fry were observed outmigrating past Bonneville in 2010 (Krasnow pers. com.)

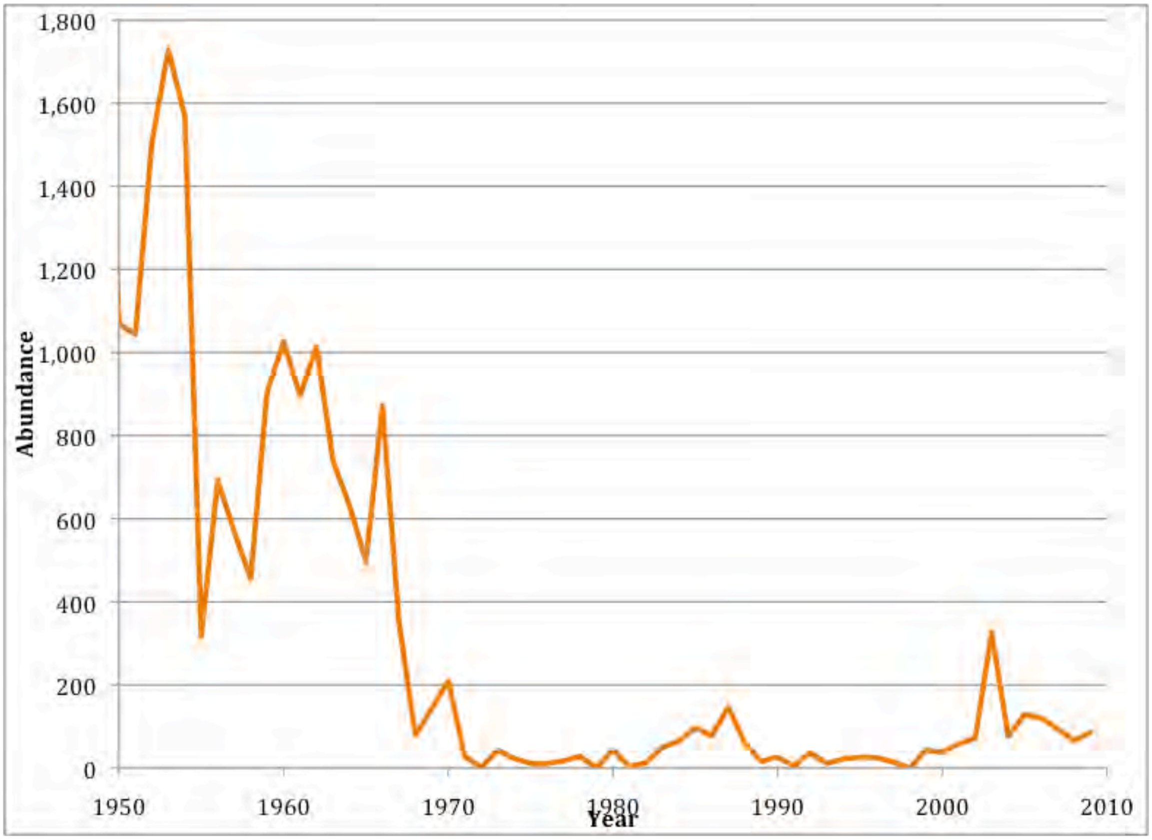


Figure 129 -- Chum count at Bonneville Dam. Some chum fall back over the dam after being counted. (data from Fish Passage Center online database).

Other Washington Population

New data since the last BRT report –still occasional reports of a few chum.

Oregon populations

New data since the last BRT report – still occasional reports of a few chum.

Harvest

Columbia River chum salmon were historically abundant and subject to substantial harvest. In recent years there has been no directed harvest of Columbia River chum salmon. Data on the incidental harvest of chum salmon in lower Columbia River gillnet fisheries exist, but escapement data are inadequate to calculate exploitation rates. Commercial harvest has been less than 100 fish per year since 1993, and all recreational fisheries have been closed since 1995.

Hatcheries

A chum hatchery was initiated in Grays River in 1999 that currently releases approximately 200,000 fry as part of an integrated conservation hatchery program (HSRG 2009) (Figure 130). The hatchery fish are not externally marked. The HSRG has recommended that the hatchery "sunset" in three generations.

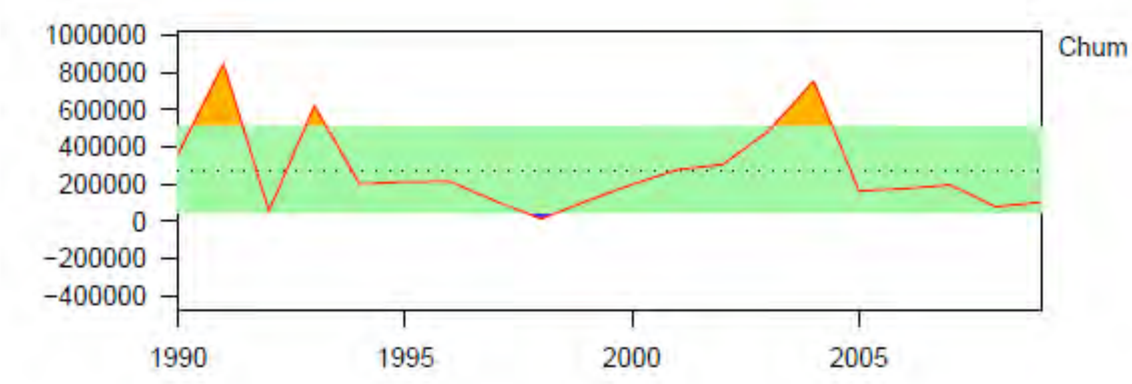


Figure 130 -- Columbia River chum hatchery releases. The dotted line indicates the mean, and the shaded area the stardard deviation. Source: RMIS.

Columbia River chum salmon: Updated Risk Summary

The vast majority (14 out of 17) chum populations remain extirpated or nearly so. The Grays River and Lower Gorge populations showed a sharp increase in 2002, but have since declined back to relatively low abundance levels in the range of variation observed over the last several decades. Chinook and coho populations in the Lower Columbia and Willamette show similar increases in the early 2000's followed by declines to typical recent levels, suggesting the increase in chum may be related to ocean conditions. Recent data on the Washougal/mainstem Columbia population are not available, but we suspect they follow a pattern similar to the Grays and Lower Gorge populations. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good, T. P., R. S. Waples, and P. Adams, editors. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, Seattle.

HSRG. 2009. Hatchery Scientific Review Group review and recommendations: Grays River chum population and related hatchery programs.

Lower Columbia Fish Recovery Board. 2010. Washington lower Columbia salmon recovery and Fish and Wildlife subbasin plan. Lower Columbia Fish Recovery Board, Olympia, WA.

McElhany, P., C. Busack, M. Chilcote, S. Kolmes, B. McIntosh, J. M. Myers, D. Rawding, A. Steel, C. Steward, D. Ward, T. Whitesel, and C. Willis. 2006. Revised viability criteria for salmon and steelhead in the Willamette and Lower Columbia Basins. Report, NOAA Northwest Fisheries Science Center, Seattle.

McElhany, P., M. Chilcote, J. M. Myers, and R. Beamesderfer. 2007. Viability status of Oregon salmon and steelhead populations in the Willamette and Lower Columbia Basins. NOAA-Northwest Fisheries Science Center, Seattle, WA.

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. Technical Memorandum NMFS-NWFSC-42, NOAA, Seattle.

Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. Van Doornik, and M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. NMFS-NWFSC-73, NOAA NWFSC, Seattle, WA.

NMFS. 1999. Conclusions regarding the updated status of the Columbia River chum salmon ESU and Hood Canal summer-run chum salmon ESU. Memo 12 February 1999 to W. Stelle, Northwest Fisheries Science Center, and W. Hogarth, Southwest Fisheries Science Center, from M. H. Schiewe, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.

Oregon Department of Fish and Wildlife, R. Beamesderfer, L. Berg, M. Chilcote, J. Firman, E. Gilbert, K. Goodson, D. Jepsen, T. Jones, S. Knapp, C. Knutsen, K. Kostow, B. McIntosh, J. Nicholas, J. Rodgers, T. Stahl, and B. Taylor. 2010. Lower Columbia river conservation and recovery plan for Oregon populations of salmon and steelhead. Oregon Department of Fish and Wildlife, Salem, OR.

Small, M. P., A. E. Frye, J. F. Von Bargen, and S. F. Young. 2006. Genetic structure of chum salmon (Oncorhynchus keta) populations in the lower Columbia River: are chum salmon in Cascade tributaries remnant populations? Consevation Genetics 7:65-78.

Lower Columbia River coho salmon[23]

Listed ESU/DPS

This report covers the Evolutionarily Significant Unit (ESU) of Lower Columbia River Coho Salmon (*Oncorhynchus kisutch*). Originally part of a larger Lower Columbia River/Southwest Washington ESU, Lower Columbia coho were identified as a separate ESU and listed as threatened on June 28, 2005. The ESU includes all naturally spawned populations of coho salmon in the Columbia River and its tributaries in Washington and Oregon, from the mouth of the Columbia River up to and including the Big White Salmon and Hood Rivers, and includes the Willamette River to Willamette Falls, Oregon, as well as twenty-five artificial propagation programs: the Grays River, Sea Resources Hatchery, Peterson Coho Project, Big Creek Hatchery, Astoria High School (STEP) Coho Program, Warrenton High School (STEP) Coho Program, Elochoman Type-S Coho Program, Elochoman Type-N Coho Program, Cathlamet High School FFA Type-N Coho Program, Cowlitz Type-N Coho Program in the Upper and Lower Cowlitz Rivers, Cowlitz Game and Anglers Coho Program, Friends of the Cowlitz Coho Program, North Fork Toutle River Hatchery, Kalama River Type-N Coho Program, Kalama River Type-S Coho Program, Washougal Hatchery Type-N Coho Program, Lewis River Type-N Coho Program, Lewis River Type-S Coho Program, Fish First Wild Coho Program, Fish First Type-N Coho Program, Syverson Project Type-N Coho Program, Eagle Creek National Fish Hatchery, Sandy Hatchery, and the Bonneville/Cascade/Oxbow complex coho hatchery programs.

ESU/DPS Boundary Delineation

Utilizing new information, the ESU Boundaries Review Group (see ESU Boundaries above) undertook a revaluation of the boundary between all Lower Columbia and Mid-Columbia ESUs and DPSs. The review conclusions emphasize the transitional nature the boundary between the Lower Columbia ESUs and the Mid-Columbia ESUs. The original Lower Columbia coho ESU boundary was assigned based largely on extrapolation from information about the boundaries for Chinook and steelhead. The ESU Boundaries Review Group considered it reasonable to assign the Klickitat Chinook and steelhead populations the appropriate Lower Columbia ESU/DPS. The ESU Boundaries Review Group concludes, "It is therefore reasonable to assign the Klickitat population to the Lower Columbia coho ESU. This would establish a common boundary for Chinook salmon, coho salmon, chum salmon, and steelhead at the Celilo Falls (Dalles Dam)." This status evaluation was conducted using existing ESU boundaries.

Summary of Previous BRT Conclusions

NMFS reviewed the status of the Lower Columbia River coho salmon ESU in 1996 (NMFS 1996), again in 2001 (NMFS 2001), and most recently in 2005 (NMFS 2005). In the 2001 review, the BRT was very concerned that the vast majority (over 90%) of historical populations in the Lower Columbia River coho salmon ESU appear to be either extirpated or nearly so. The two populations with any significant production (Sandy and Clackamas rivers) were at appreciable risk because of low abundance, declining trends, and failure to

---

[23] Section author: Paul McElhany

respond after a dramatic reduction in harvest. The large number of hatchery coho salmon in the ESU was also considered an important risk factor. The majority of the 2001 BRT votes were for "at risk of extinction" with a substantial minority "likely to become endangered." An updated status evaluation was conducted in 2005, also with a majority of BRT votes for "at risk of extinction" and a substantial minority for "likely to become endangered."

Summary of Recent Evaluations

A report on the population structure of Lower Columbia salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The coho population designations in that report (Figure 131) are used in this status update and were used for status evaluations in recent recovery plans by ODFW and LCFRB.

In 2010, ODFW completed a recovery plan that included Oregon populations of Lower Columbia coho ESU. Also in 2010, the LCFRB completed a revision of its recovery plan that includes Washington populations of Lower Columbia coho. Both of these recovery plans include an assessment of current status of LCR coho populations. These assessments relied and built upon the viability criteria developed by the WLC-TRT (McElhany et al 2006) and an earlier evaluation of Oregon WLC populations (McElhany et al. 2007). These evaluations assessed the status of populations with regard to the VSP parameters of abundance and productivity, spatial structure and diversity (McElhany et al. 2000). The results of these analyses are shown in Figure 132 and Figure 133.

These analyses indicate that all of the Washington populations and all but two of the Oregon populations are in the overall "very high risk" category (also described as "extirpated or nearly so"). Two populations in Oregon, the Scappoose and Clackamas, were considered by ODFW to most likely be in the moderate risk category. As shown in Figure 132, these results differ somewhat from the McElhany et al. (2007) analysis, which found Scappoose and Sandy at high risk, Clackamas barely in the low risk category and all other Oregon populations considered very high risk. The results from Oregon and Washington are largely driven by the very low abundance and productivity of naturally produced LCR coho.

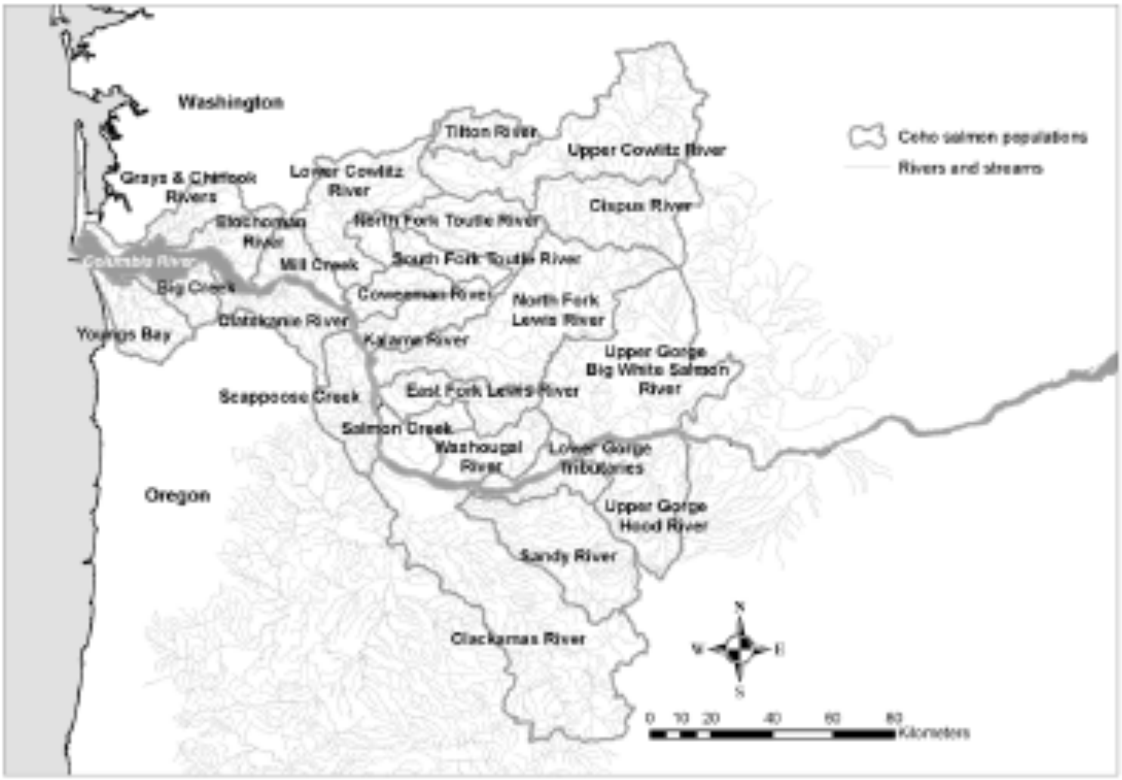


Figure 131 -- Historical populations of LC coho. From Myers et al. (2006).

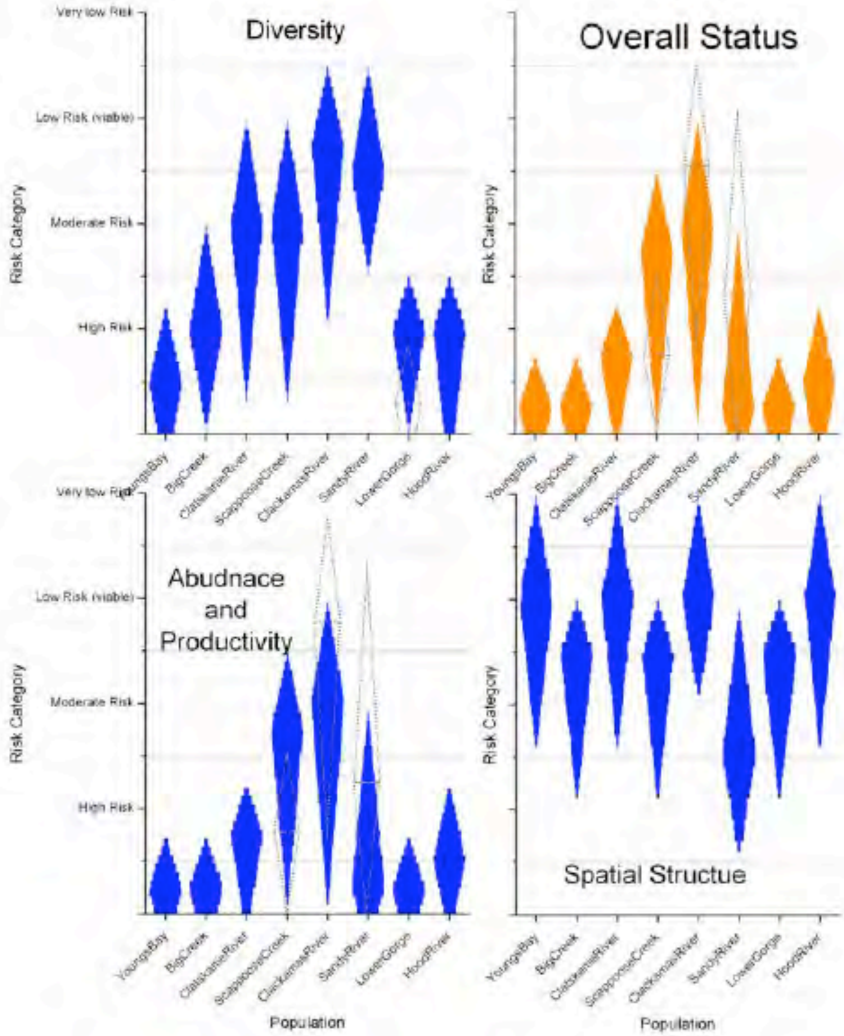


Figure 132 – Extinction risk ratings for LCR coho populations in Oregon for the assessment attributes abundance/productivity, diversity and spatial structure as well as an overall rating for populations that combines the three attributes ratings. Where updated ratings differ from those presented by McElhany et al. (2007), the older rating is shown as an open diamond with a dashed outline. Reproduced from ODFW (2010).

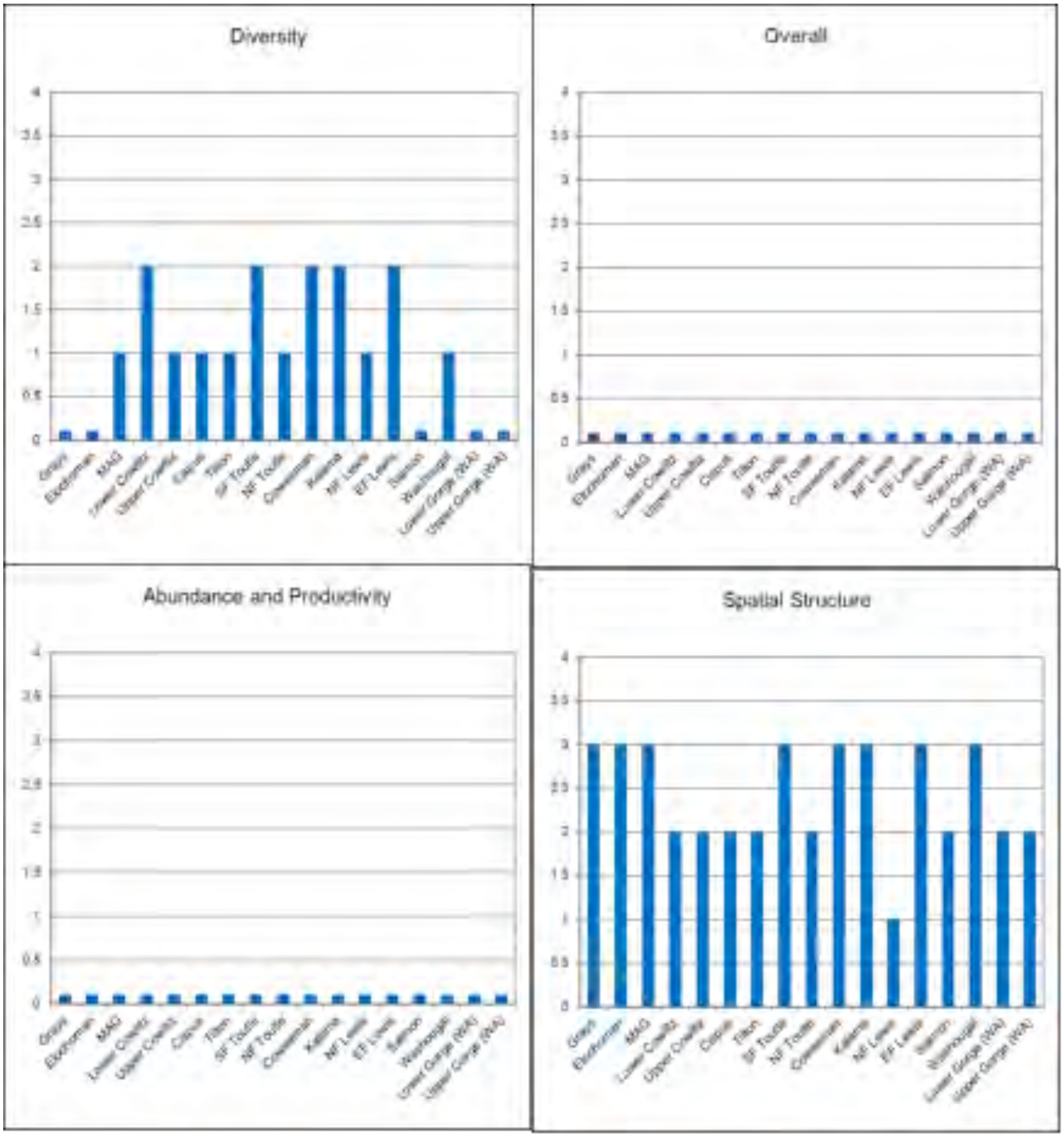


Figure 133 -- Current status of Washington LCR coho populations for the VSP parameters and overall population risk. (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk ("viable") and 4 is very low risk.

New Data and Analyses

Sandy and Clackamas

The 2005 BRT status evaluation included abundance data for the Clackamas population for the years 1957-2002 and for the Sandy population from 1977-2002. The time series used for this new status update is the same as that used for the 2010 Oregon recovery plan, which includes the years 1974-2008 for both the Sandy and Clackamas populations. These time series are shown in Figure 134, with summary statistics in Table 68. The total abundance over the years since the last status review (2003-2008) have remained within one standard deviation of each populations long-term mean, with the exception of 2008 in the Clackamas, which is slightly above one standard deviation. The geometric mean abundance for both populations is substantially below the long-term “Minimum Abundance Threshold” of 3,000 spawners identified in the McElhany et al. 2007 report using WLC-TRT methodology. Neither population shows a clear long term trend in log natural origin abundance over the entire time series, but both indicate a positive trend over the years 1995-2008. A negative growth rate (lambda) was observed when considering the entire time series assuming hatchery origin fish have the same reproductive success as natural origin fish. All other lambda estimates showed no trend. Note that the Clackamas abundance data combines spawners upstream of the North Fork Dam (which has relatively few hatchery origin spawners) and downstream of the dam (which has a higher fraction of hatchery origin spawners - see Tables 2-4).

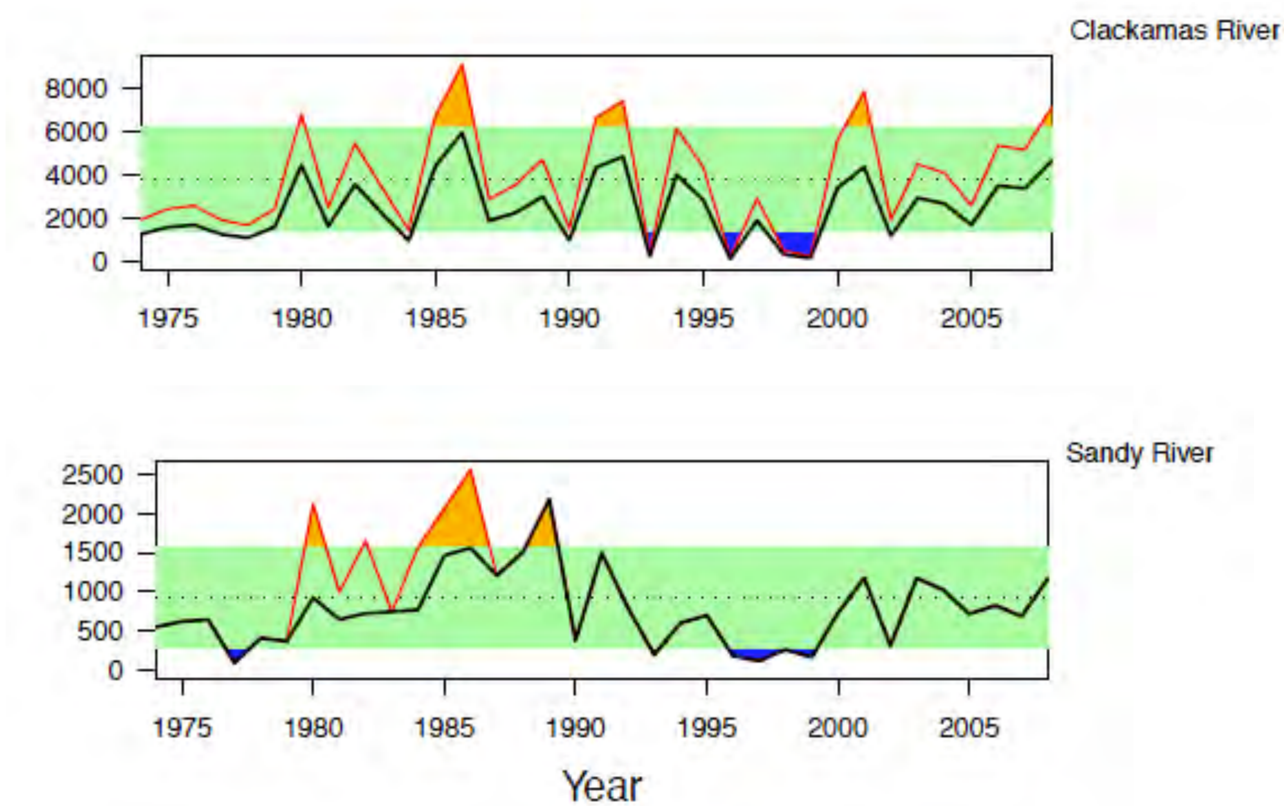


Figure 134 -- Abundance of Lower Columbia River coho populations. The red (upper) solid line indicates total spawners. The green (lower) solid line indicates natural origin spawners. The dash line indicates the over all geometric mean abundance of natural origin spawners with the green band showing one standard deviation about the mean.

Table 68 -- Summary statistics for Lower Columbia Coho. The 95% confidence intervals are shown in parentheses. Cells highlighted yellow indicate negative population indicators and blue cells indicate positive. The geometric mean natural origin spawners are highlighted based on comparison to the McElhany et al 2007 Minimum Abundance Threshold (MAT) of 3,000 fish for a viable population in a large watershed. The mean hatchery fraction is highlighted based on comparison to the viability standard of 10% hatchery origin spawners. The trend and lambda values are highlighted based on whether the 95% confidence interval is entirely above or below one.

Population	Analysis Window	Years	Geomean Nat. Or. Spawners	Trend in Log Nat. Or. Spawners	Lambda with Hat. Repro. = 0	Lambda with Hat. Repro. = 1	Mean hatchery fraction
Clackamas	last 3 years	2006 - 2008	3,799 (2,450 – 5,890)	---	---	---	0.35
	Since 1995	1995 - 2008	1,534 (752 – 3,130)	1.174 (1.006 - 1.37)	1.098 (0.448 - 2.694)	0.939 (0.388 - 2.27)	0.3621
	All Years	1974 - 2008	1,810 (1,297 – 2,526)	1.003 (0.969 - 1.037)	1.027 (0.911 - 1.158)	0.886 (0.788 - 0.995)	0.3554

Sandy	last 3 years	2006 - 2008	870 (445 - 1,702)	---	---	---	0
	Since 1995	1995 - 2008	515 (323 - 822)	1.13 (1.028 - 1.241)	1.105 (0.378 - 3.232)	1.105 (0.378 - 3.232)	0
	All Years	1974 - 2008	610 (468 - 796)	1.003 (0.977 - 1.03)	1.019 (0.873 - 1.19)	0.971 (0.845 - 1.115)	0.0763

Other Oregon Populations

(Youngs Bay, Big Creek, Clatskanie, Scappoose. Lower Gorge, Hood River)

In 2002, ODFW initiated as monitoring program for Lower Columbia coho spawners based on a stratified random sample survey design. A report covering monitoring results the years 2002-2004 was published in 2006 (Suring et al.). Abundance estimates and hatchery fish fractions from that study are summarized in Table 69 - Table 71. In 2010, ODFW published a report covering LCR coho monitoring for the years 2004-2008. The reports indicate overall relatively low abundance of natural origin in the Oregon portion of the LCR coho ESU. All of the populations except Sandy and Clackamas average less than 500 spawners. There are very high fractions of hatchery origin fish in the Youngs Bay, Big Creek, Lower Gorge and Hood River populations. It is doubtful that these populations are self-sustaining. The Clatskanie shows highly variable fractions of hatchery origin spawners, ranging from an estimate of 0% to 80%. The Scappoose shows consistently low fractions of hatchery origin spawners comparable to the low levels in the Sandy. It appears that some natural production is occurring in the Clatskanie and Scappoose populations, though the abundances are small relative to the Minimum Abundance Threshold (MAT) long term geometric mean of 1,000 spawners in a small watershed (McElhany et al. 2007).

Table 69 -- Lower Columbia River coho salmon escapement estimates for the 2002 – 2004 spawning seasons (estimates are derived from counts in random EMAP spawning surveys). Reproduced from Suring et al. 2006.

					Adult Coho Spawner Abundance[a]			
			Survey Effort		Total		Wild[b]	
Year	Population Complex	Spawning Miles[c]	Number of Surveys	Miles	Estimate	95% Confidence Interval	Estimate	95% Confidence Interval
2002	Astoria	71.3	15	16.2	4,472	2,760	281	173
	Clatskanie	36.9	17	13.4	229	164	104	74
	Scappoose	64.5	19	18.8	452	174	452	174
	Clackamas[d]	117.3	28	30.5	3,689	2,306	850	531
	Sandy[e]	26.3	4	3.4	339	530	0	0
	Total	**316.3**	**83**	**82.3**	**9,182**	**3,599**	**1,685**	**592**
	Bonneville	7.0	4	1.0	1,078	761	178	125
2003	Astoria	80.6	21	18.1	1,459	652	217	97
	Clatskanie	39.0	10	8.3	563	217	563	217
	Scappoose	60.2	16	15.0	354	164	319	148
	Clackamas	117.2	18	14.7	684	468	385	263
	Sandy	101.5	18	17.4	219	108	204	101
	Total	**398.5**	**83**	**73.5**	**3,280**	**862**	**1,687**	**397**
	Bonneville	10.5	1	0.4	12,050		3,040	
2004	Astoria	72.1	20	18.1	1,385	715	142	73
	Clatskanie	49.1	14	11.5	398	177	398	177
	Scappoose	66.3	18	16.7	786	269	722	247
	Clackamas[d]	132.9	28	25.0	1,511	722	963	460
	Sandy	108.0	22	19.1	320	200	320	200
	Total	**428.4**	**102**	**90.4**	**4,400**	**1,095**	**2,545**	**590**
	Bonneville	10.0	1	0.4	8,040		4,153	

a *Estimates derived using EMAP protocol and adjusted for visual observation bias.*

b *Estimates of wild spawners derived through application of carcass fin-mark recoveries in random survey sites, except in the Sandy complex in 2002 and 2003 where observations of live fin-marked fish were used and in the Bonneville complex where results of scale analysis were applied.*

c *EMAP sampling estimate of the total habitat.*

d *Excludes spawning habitat upstream of North Fork Dam.*

e *Excludes spawning habitat upstream of Marmot Dam.*

Table 70 -- Mark rates based on observations of adipose fin clips on live and dead coho coho spawners in random coho surveys during the 2002 – 2004 spawnings seasons. Reproduced from Suring et al. 2006.

Population Complex	2002 Live Total	2002 Live % Marked	2002 Carcasses Total	2002 Carcasses % Marked	2003 Live Total	2003 Live % Marked	2003 Carcasses Total	2003 Carcasses % Marked	2004 Live Total	2004 Live % Marked	2004 Carcasses Total	2004 Carcasses % Marked
Astoria	357	94.2%	214	93.7%	127	65.8%	63	85.2%	198	68.1%	96	89.7%
Clatskanie	10	80.4%	11	54.8%	73	0.0%	17	0.0%	44	9.1%	20	0.0%
Scappoose	66	0.0%	52	0.0%	69	0.0%	20	10.1%	136	3.0%	61	8.2%
Clackamas	342	29.4%	278	77.0%	55	7.7%	29	43.7%	113	28.1%	39	36.3%
Sandy	50	100.0%	1	0.0%	15	7.0%	3	34.8%	36	0.0%	12	0.0%
Bonneville[a]	202	82.9%	138	85.4%	192	34.0%	76	38.5%	317	23.4%	36	19.4%
Total	1027	64.5%	694	77.6%	531	29.0%	208	47.4%	844	29.5%	264	42.5%

a Live % Marked is corrected for scale analysis results which indicate that 76.5% in 2002, 28.4% in 2003, 19.4% in 2004 of unmarked coho were of hatchery origin. Carcasses % Marked is based on scale analysis.

Table 71 -- Lower Columiba coho ESU estimated abundance of adult coho spawning naturally by: ESU, stratum, and population for the 2004 – 2008 run years. Reproduced from Lewis et al. 2010.

Geographic Scale ESU/Stratum/Population		Spawning Year 2004	2005	2006	2007	2008
Lower Columbia ESU (Oregon Only)	**Wild**	**5,630**	**4,820**	**6,422**	**5,785**	**4,987**
	Hatchery	**1,882**	**3,432**	**12,230**	**1,820**	**1,718**
	% Hat.	**25.1%**	**41.6%**	**65.6%**	**23.9%**	**25.6%**
Coast Stratum	**Wild**	**1,414**	**1,140**	**1,439**	**1,191**	**1,729**
	Hatchery	**1,218**	**373**	**479**	**773**	**89**
	% Hat.	**46.3%**	**24.7%**	**25.0%**	**39.4%**	**4.9%**
Youngs Bay	Wild	149	79	74	21	82
	Hatchery	886	242	394	14	23
	% Hat.	85.6%	75.4%	84.2%	40.0%	21.9%
Big Creek	Wild	112	219	225	212	360
	Hatchery	265	124	n.a.s.	216	66
	% Hat.	70.3%	36.2%		50.5%	15.5%
Clatskanie	Wild	398	494	421	583	995
	Hatchery	0	7	46	543	0
	% Hat.	0.0%	1.4%	9.9%	48.2%	0.0%
Scappoose	Wild	755	348	719	375	292
	Hatchery	67	0	39	0	0
	% Hat.	8.2%	0.0%	5.1%	0.0%	0.0%
Cascade Stratum	**Wild**	**4,087**	**2,157**	**4,387**	**4,295**	**2,971**
	Hatchery	**664**	**504**	**10,871**	**648**	**1,410**
	% Hat.	**14.0%**	**18.9%**	**71.2%**	**13.1%**	**32.2%**
Clackamas	Wild	2,874	1,301	3,464	3,608	1,694
	Hatchery	537	504	10,871	582	1,410
	% Hat.	15.7%	27.9%	75.8%	13.9%	45.4%
Sandy	Wild	1,213	856	923	687	1,277
	Hatchery	127	0	0	66	0
	% Hat.	9.5%	0.0%	0.0%	8.8%	0.0%
Gorge Stratum	**Wild**	**129**	**1,523**	**596**	**299**	**287**
	Hatchery	**n.a.s.**	**2,555**	**880**	**399**	**219**
	% Hat.		**62.7%**	**59.6%**	**57.2%**	**43.3%**
Lower Gorge Tribs.	Wild	n.a.s.	263	226	126	223
	Hatchery	n.a.s.	1,512	538	261	191
	% Hat.		85.2%	70.4%	67.4%	46.1%
Hood River	Wild	129	1,260	370	173	64
	Hatchery	n.a.s.	1,043	342	138	28
	% Hat.		45.3%	48.0%	44.4%	30.4%

Washington populations

(*Grays, Elochoman, Mill/Germany/Abernathy, Cispsus, Tilton, Upper Cowlitz, Lower Cowlitz, NF Toutle, SF Toutle, Coweeman, Kalama, NF Lewis, EF Lewis, Salmon, Wahougal, Lower Gorge, White Salmon/Upper gorge*)

In the 2005 BRT report, no spawner data were available for any population in the Washington portion of this ESU. Starting in 2005 spawner surveys were initiated in the Mill/Germany/Abernathy coho population. Data from WDFW are available for the 2006 spawning year (Figure 135). These data show an estimated 3,150 spawners with slightly over half (51%) of hatchery origin. This is a large fraction of hatchery origin spawners for a population not receiving direct outplants of hatchery fish and suggests that other Washington populations that do have in-basin hatcheries have even higher fractions of hatchery origin spawners. This observation is consistent with the conclusion of the 2005 BRT report and the LCFRB analysis (2010) that Washington coho populations are dominated by hatchery origin spawners and are not demonstrably self-sustaining. Data on coho smolt production are also collected in the Mill/Germany/Abernathy population indicate some natural production does occur in these streams (Figure 136). The new Mill/Germany/Abernathy smolt production data (2003-2005) is similar to the data (2001-2002) considered in the 2005 BRT report

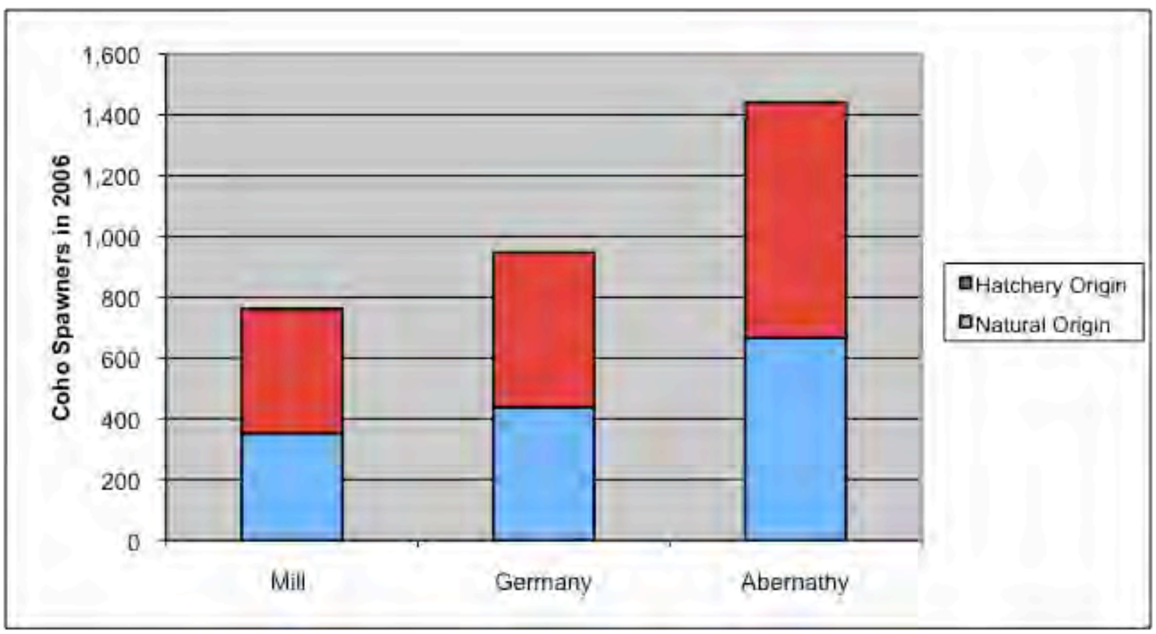


Figure 135 -- Coho spawner estimates for the Mill/Germany/Abernathy population in 2006. Total coho spanwer estimate for the population was 3,150 with 51% if hatchery origin. Data source: WDFW.

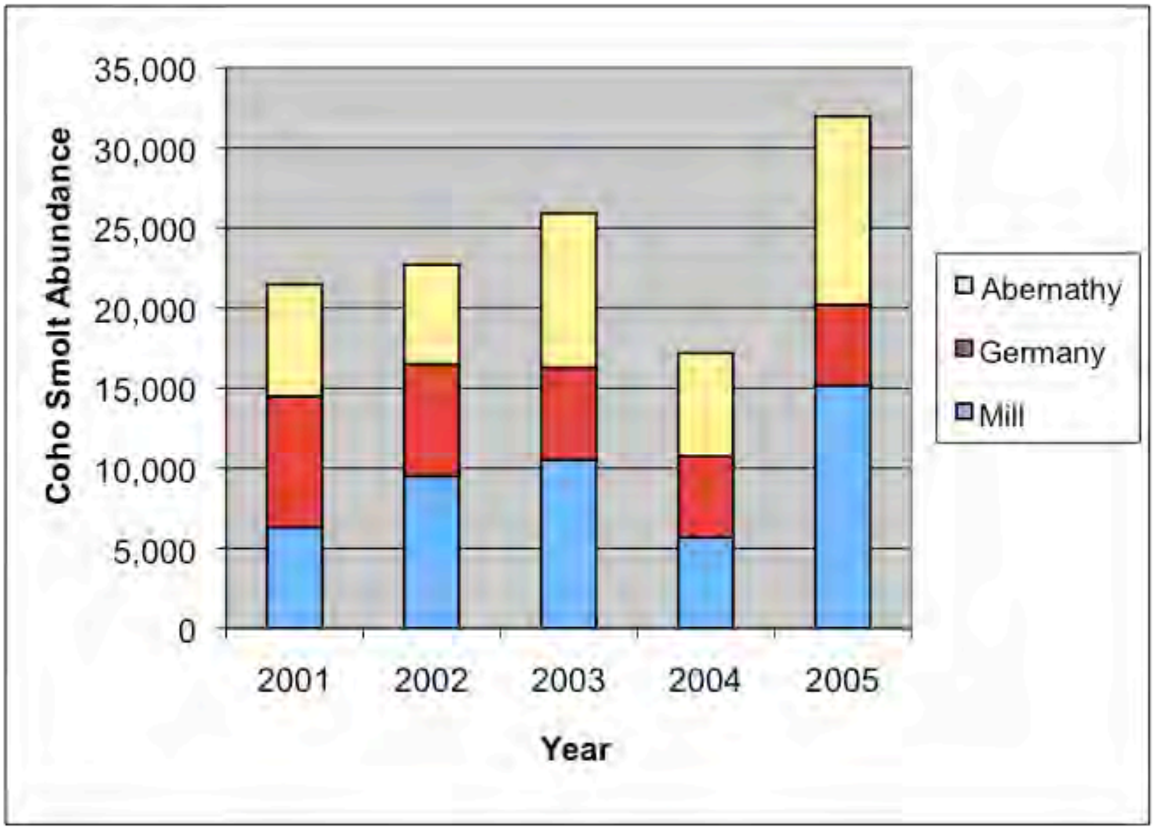


Figure 136 -- Coho smolt production estimates for Mill, Germany and Abernathy Creeks (data for 2001-2001 from 2005 BRT report; data for 2003-2005 from WDFW http://wdfw.wa.gov/fish/wild_salmon_monitor/lower_columbia.htm#mag)

Table 72 -- Coho smolt production from Cedar Creek (tributary in the NF Lewis population). Data for years 1998-2002 from (BRT report 2005); data for 2003 from (Seiler et al. 2004); data for 2004 from (Volkhardt et al. 2005); data for 2005 from (Volkhardt et al. 2006); data for 2006 from (Topping et al. 2008).

Year	Natural Origin	Hatchery Origin	Remote Site Incubator	Cedar Creek smolts	Percent Supplementation (Hatchery + Remote Incubator)
1998	38,354				?
1999	27,987				?
2000	20,282				?
2001	20,695				?
2002	32,695				?
2003	35,096	8,476		43,572	19%
2004	34,999	20,831	1,970	57,800	39%
2005	49,770		9,151	58,921	16%
2006	35,424		7,584	43,008	18%

Smolt trap data are also available for Cedar Creek, a tributary of the NF Lewis population (Table 72). The new data (2003-2006) show similar smolt production levels to the data (1998-2002) considered in the 2005 BRT report. Simple calculations suggest that more than a thousand coho spawned in Cedar Creek to produce the observed number of smolts (e.g. if the smolt to adult ratio is less than 30, there were on average at least 1,000 spawners; substantially more if the smolt to adult ratio is much lower.). There is a production hatchery in the NF Lewis and it is likely based on the high hatchery ratios observed in the Mill/Germany/Abernathy population (which does not have a production hatchery) that the majority of spawners in Cedar Creek are of hatchery origin. However, these data do suggest that the habitat is capable of supporting some natural production.

Smolt estimates are also available for the 2004 coho outmigrant year for the Coweeman population (Sharpe and Glaser 2007). They estimated 17,389 smolts (± 1,769), indicating some production potential for this basin.

Lower Columbia River Harvest

Lower Columbia River coho salmon are part of the Oregon Production Index, and are harvested in ocean fisheries primarily off the coasts of Oregon and Washington, with some harvest that historically occurred off of WCVI. Canadian coho salmon fisheries were severely restricted in the 1990s to protect upper Fraser River coho, and have remained so ever since. Ocean fisheries off California were closed to coho retention in 1993 and have remained close ever since. Ocean fisheries for coho off of Oregon and Washington were dramatically reduced in 1993 in response to the listing of Oregon Coast natural coho, and moved to mark-selective fishing beginning in 1999. Lower Columbia River coho benefitted from the more restrictive management of ocean fisheries. Overall exploitation rates regularly exceeded 80% in the 1980s, but have remained below 30% since 1993 (Figure 137).

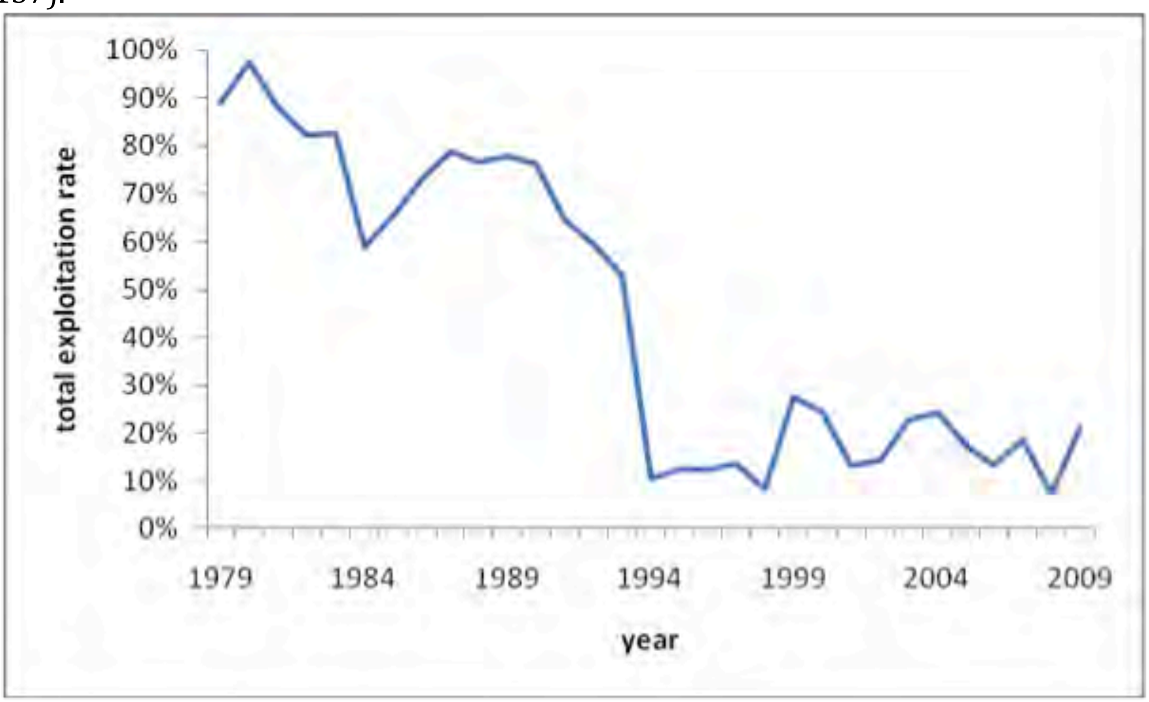


Figure 137 -- Total exploitation rate on lower Columbia River natural coho salmon. Data from TAC (2010).

LCR Coho Hatcheries
Hatchery releases have remained relatively steady at between 10 and 15 million since the 2005 BRT report (Figure 138). Overall hatchery production remains relatively high and most of the populations in the ESU contain a substantial fraction of hatchery origin spawners. In that regard, little has changed since the 2005 BRT report. Recent efforts to shift production into localized areas (e.g. Youngs Bay and Big Creek) in order to reduce hatchery fish pressure in other populations (e.g. Scapposse and Clatskanie) are considered as in transition at this time. It is important to note that direct data on the faction of hatchery origin spawner are available for only one of Washington's 17 coho populations only (Mill/Germany/Abernathy) for a single year (2006). This lack of data contributes greatly to uncertainty about the ESUs status.

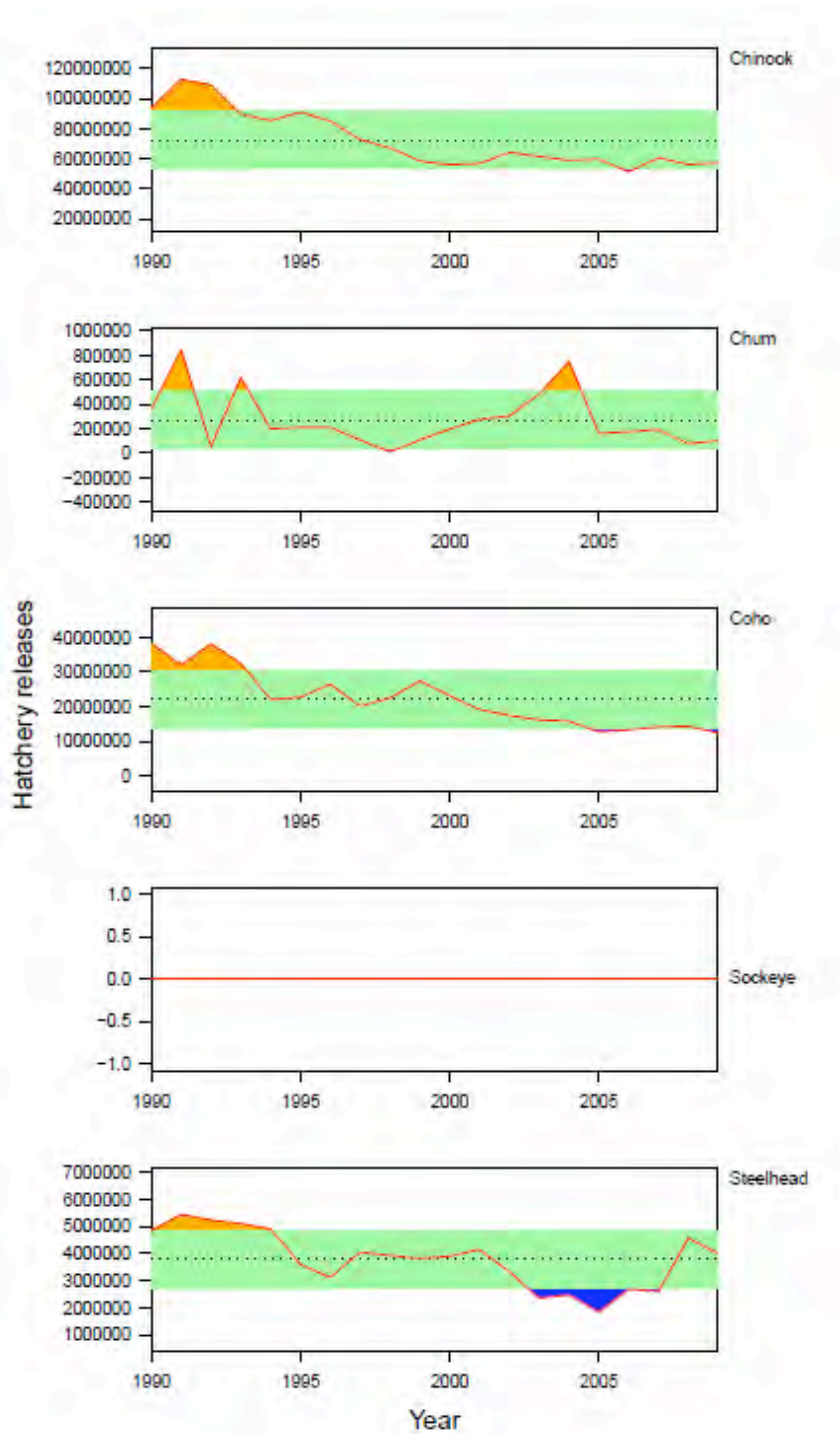


Figure 138 -- LCR hatchery releases for all salmon and steelhead species released within the spawning and rearing area of the LCR coho ESU. Dotted lines indicate means, and shaded areas indicate standard deviations.

Lower Columbia River Coho salmon: Updated Risk Summary

Three status evaluations of LCR coho status, all based on WLC-TRT criteria, have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, ODFW 2010, LCFRB 2010). All three evaluations concluded that the ESU is currently at very high risk of extinction. Of the 27 historical populations in the ESU, 24 are considered at very high risk. The remaining three (Sandy, Clackamas and Scapposse) are considered at high to moderate risk. All of the Washington side populations are considered at very high risk, although uncertainty is high because of a lack of adult spawner surveys. As was noted in the 2005 BRT evaluation, smolt traps indicate some natural production in Washington populations, though given the high fraction of hatchery origin spawners suspected to occur in these populations it is not clear that any are self-sustaining. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Lewis, M., E. Brown, B. Sounhein, M. Weeber, E. Suring, and H. Truemper. 2010. Status of Oregon stocks of coho salmon, 2004 through 2008: the Oregon plan for salmon and watersheds.in W. O. R. a. M. Program, editor. Oregon Department of Fish and Wildlife, Salem, OR.

Lower Columbia Fish Recovery Board. 2010. Washington lower Columbia salmon recovery and Fish and Wildlife subbasin plan. Lower Columbia Fish Recovery Board, Olympia, WA.

McElhany, P., M. Chilcote, J. M. Myers, and R. Beamesderfer. 2007. Viability status of Oregon salmon and steelhead populations in the Willamette and Lower Columbia Basins. NOAA-Northwest Fisheries Science Center, Seattle, WA.

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. Technical Memorandum NMFS-NWFSC-42, NOAA, Seattle.

Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. Van Doornik, and M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. NMFS-NWFSC-73, NOAA NWFSC, Seattle, WA.

Oregon Department of Fish and Wildlife, R. Beamesderfer, L. Berg, M. Chilcote, J. Firman, E. Gilbert, K. Goodson, D. Jepsen, T. Jones, S. Knapp, C. Knutsen, K. Kostow, B. McIntosh, J. Nicholas, J. Rodgers, T. Stahl, and B. Taylor. 2010. Lower Columbia river conservation and recovery plan for Oregon populations of salmon and steelhead. Oregon Department of Fish and Wildlife, Salem, OR.

Seiler, D., G. Volkhardt, A. Murdoch, S. Hawkins, H. Fuss, and B. Ehinger. 2002. 2002 Index watershed salmon recovery monitoring report. Washington Department of Fish and Wildlife and Washington Department of Ecology, Olympia, WA.

Seiler, D., G. Volkhardt, P. Topping, L. Fleischer, T. Miller, S. Schonning, D. Rawding, M. Groesbeck, R. Woodard, and S. Hawkins. 2004. 2003 Juvenile salmonid production evaluation report: Green river, Wenatchee river, and Cedar creek.in F. S. D. a. F. M. Division, editor. Washington Department of Fish and Wildlife, Olympia, Wa.

Sharpe, C. and B. Glaser. 2007. 2005 Coweeman river juvenile salmonid production evaluation.in F. P. S. Division, editor. Washington Department of Fish and Wildlife, Olympia, WA

Takata, T. T. 2008. Oregon lower Columbia river fall and winter Chinook spawning ground surverys, 1952-2008: focus on 2008.in C. R. Management, editor. Oregon Department of Fish and Wildlife, Salem, OR.

Topping, P., L. Kishimoto, J. Holowatz, D. Rawding, and M. Groesbeck. 2008. 2006 Juvenile salmonid production evaluation report: Green river, Dungeness river, and Cedar creek.in R. Fish Program and F. S. Division, editors. Washington Department of Fish and Wildlife, Olympia, WA.

Volkhardt, G., P. Topping, L. Fleischer, T. Miller, S. Schonning, D. Rawding, and M. Groesbeck. 2005. 2004 Juvenile salmonid production evaluation report: Green river, Wenatchee river, and Cedar creek.in S. D. a. F. M. Division, editor. Washington Department of Fish and Wildlife, Olympia, Washington.

Volkhardt, G., P. Topping, L. Kishimoto, D. Rawding, and M. Groesbeck. 2006. 2005 Juvenile salmonid production evaluation report: Green river, Dungeness river, and Cedar creek.in S. D. a. F. M. Division, editor. Washington Department of Fish and Wildlife, Olympia, WA.

Middle Columbia River steelhead[24]

The Middle Columbia River steelhead distinct population segment (DPS) includes all naturally spawning populations of steelhead (*Oncorhynchus mykiss*) using tributaries upstream and exclusive of the Wind River (Washington) and the Hood River (Oregon), excluding the Upper Columbia River tributaries (upstream of Priest Rapids Dam) and the Snake River. The Middle Columbia River steelhead DPS was listed as threatened by NOAA Fisheries in 1999, with that listing designation being affirmed in 2006. NOAA Fisheries has defined DPSs of steelhead to include only the anadromous members of this species (70 FR 67130). Our approach to assessing the current status of a steelhead DPS is based evaluating information the abundance, productivity, spatial structure and diversity of the anadromous component of this species (Good et al. 2005; 70 FR 67130). Many steelhead (*O. mykiss*) populations along the West Coast of the U.S. co-occur with conspecific populations of resident rainbow trout. We recognize that there may be situations where reproductive contributions from resident rainbow trout may mitigate short-term extinction risk for some steelhead DPSs (Good et al. 2005; 70 FR 67130). We assume that any benefits to an anadromous population resulting from the presence of a conspecific resident form will be reflected in direct measures of the current status of the anadromous form.

Summary of previous BRT conclusions

Results of the previous BRT review of the status of the Middle Columbia Steelhead DPS were summarized in Good et al. 2005. A slight majority (51%) of the cumulative scores across the BRT were for assigning this DPS to the "threatened but not endangered" category. The remaining votes (49%) were for the "not likely to become endangered" designation. The BRT noted that this particular DPS was difficult to score. Reasons cited included: the wide range in relative abundance for individual populations across the DPS (e.g., spawning abundance in the John Day and Deschutes basins has been relatively high, while returns to much of the Yakima River drainage have remained relatively low); chronically high levels of hatchery strays into the Deschutes River, and a lack of consistent information on annual spawning escapements in some tributaries (e.g. Klickitat River). Resident *O. mykiss* are believed to be very common throughout this DPS. The BRT assumed that the presence of resident *O. mykiss* below anadromous barriers mitigated extinction risk to the DPS to some extent, but the majority of BRT members concluded that significant threats to the anadromous component remained.

Brief Review: Recovery Planning

The Interior Columbia Technical Recovery Team (ICTRT) has identified 17 extant populations in this DPS (ICTRT, 2003). The populations fall into four major population groups: the Yakima River Basin (four extant populations), the Umatilla/Walla-Walla drainages (3 extant and 1 extirpated populations); the John Day River drainage (5 extant populations) and the Eastern Cascades group (5 extant and 2 extirpated populations).

NOAA Fisheries (National Marine Fisheries Service) recently adopted a recovery plan for the Mid-Columbia Steelhead Distinct Population Segment (DPS). The NOAA Fisheries Mid-Columbia Steelhead Recovery Plan (www.nwr.noaa.gov/Salmon-Recovery-

[24] Section author: Tom Cooney

Planning/Recovery-Domains/Interior-Columbia/Mid-Columbia/Mid-Col-Plan.cfm) summarizes information from four regional management unit plans covering the range of tributary habitats associated with the DPS in Washington and Oregon. Each of the management unit plans are incorporated as appendices to the recovery plan, along with modules for the mainstem Columbia hydropower system and the estuary, where conditions affect the survival of steelhead production from all of the tributary populations comprising the DPS. The recovery objectives defined in the plan are based on the biological viability criteria developed by the ICTRT. The plan also incorporates information on current status developed through the ICTRT (ICTRT, 2010b).

TRT and Recovery Plan Criteria

Recovery strategies outlined in the plan and its management unit components are targeted on achieving, at a minimum, the ICTRT biological viability criteria for each major population grouping in the DPS *".....to have all four major population groups at viable (low risk) status with representation of all the major life history strategies present historically, and with the abundance, productivity spatial structure and diversity attributes required for long-term persistence*." The plan recognizes that, at the major population group level, there may be several specific combinations of populations that could satisfy the ICTRT criteria. Each of the management unit plans identifies particular combinations that are the most likely to result in achieving viable major population group status. The recovery plan recognizes that the management unit plans incorporate a range of objectives that go beyond the minimum biological status required for delisting.

The ICTRT recovery criteria are hierarchical in nature, with ESU/DPS level criteria being based on the status of natural origin steelhead assessed at the population level. A detailed description of the ICTRT viability criteria and their derivation (ICTRT, 2007) can be found at www.nwfsc.noaa.gov/trt/col/trt_viability.cfm.

Under the ICTRT approach, population level assessments are based on a set of metrics designed to evaluate risk across the four viable salmonid population elements – abundance, productivity, spatial structure and diversity (McElany et al. 2000). The ICTRT approach calls for comparing estimates of current natural origin abundance (measured as a 10 year geometric mean of natural origin spawners) and productivity (estimate of return per spawner at low to moderate parent spawning abundance) against predefined viability curves. In addition, the ICTRT developed a set of specific criteria (metrics and example risk thresholds) for assessing the spatial structure and diversity risks based on current information representing each specific population. The ICTRT viability criteria are generally expressed relative to particular risk threshold - 5% risk of extinction over a 100 year period.

<u>Mid Columbia Recovery Plan Major Population Group Recovery Scenarios</u>

The Mid-Columbia Recovery Plan identifies a set of most likely scenarios to meet the ICTRT recommendations for low risk populations at the major population group level. In addition, the management unit plans generally call for achieving moderate risk ratings (Maintained status) across the remaining extant populations in each MPG.

<u>Cascades Eastern Slopes Tributaries MPG</u>

....the Klickitat, Fifteen Mile and both the Deschutes Eastside and Westside populations should reach at least viable status. The management unit plans also call for at least one population to be highly viable, consistent with ICTRT recommendations. The Rock Creek population should reach maintained status (25% or less risk level). MPG viability could be

futher bolstered if reintroduction of steelhead into the Crooked River succeeds and if the White Salmon population successfully recolonizes its historical habitat following the upcoming removal of Condit Dam.

John Day River MPG

.....(t)he Lower Mainstem John Day River, North Fork John Day River and either the Middle Fork John Day River or Upper Mainstem John Day River populations should achieve at least viable status. The management unit plan also calls for at least one population to be highly viable, consistent with ICTRT recommendations.

Yakima River MPG

...to achieve viable status, two populations should be rated as viable, including at least one of the two classified as Large – the Naches River and the Upper Yakima River. The remaining two populations should, at a minimum meet the Maintained criteria. The management unit plan also calls for at least one population to be highly viable, consistent with ICTRT recommendations.

Umatilla/Walla Walla MPG

..two populations should meet viability criteria. The management unit plan also calls for at least one population to be highly viable, consistent with ICTRT recommendations. The Umatilla River is the only large population, and therefore needs to be viable. In addition either the Walla Walla or Touchet River also needs to be viable.

New Data and Updated Analyses

The 2005 BRT status assessment of the Mid-Columbia DPS included quantitative estimates of population abundance, trends and hatchery/natural spawner compositions based on a set of available indices representing natural production performance in specific tributaries. Since that review, the ICTRT has worked with regional biologists to document and develop a standard set of population level estimates of spawning abundance and hatchery/natural proportions representing all of the extant populations in the basin (ICTRT, 2010b). In some cases the new methods represent an expansion from data sets representing specific reaches within populations to to estimates of the annual number of total spawners in a population (e.g., Fifteen Mile Creek, the John Day drainage populations). In other cases the current data series represent a breakout of aggregate run estimates that include contributions from multiple ICTRT populations (e.g., the Deschutes River and the Yakima River). In addition, the 2005 review was based on returns through the 2001 spawning year. Currently available data series for Mid-Columbia steelhead populations generally extend through the 2007/2008 return/spawn cycle year with some series including an additional year, the 2008/2008 return (Figure 139 - Figure 146).

Standard abundance and trends

Abundance data series are available for three of the five extant populations in the North Cascades MPG (Table 73) along with two years of estimates for a fourth population (Klickitat River). Total spawning abundance for the most recent five year series (2005-2009) are below the levels reported in the 2005 BRT analysis for all three population series. However, natural origin spawner abundance is higher for the more recent estimates for all three series. Based on mark-recapture analysis, 1,577 natural and hatchery steelhead passed upstream of the falls and into spawning reaches in 2006-2007 in the Klickitat River. Estimates of the proportion natural origin spawners were higher for all three populations in the most recent brood cycle.

Total escapement and natural origin escapements were down from the levels reported in the 2005 BRT report in four out of the five John Day populations. Both total and natural origin spawning escapements in the South Fork John Day River were higher in the more recent brood cycle than in 1997-2001. Estimates of the fraction natural origin spawners were relatively unchanged for the upstream John Day populations, but had increased for the Lower Mainstem John Day River (Table 73).

Total and natural origin escapement estimates were higher in the most recent brood cycle for all four of the Yakima River populations than in the cycle associated with the 2005 BRT review (Table 73, Figure 1). Steelhead escapements into the Upper Yakima River, although increased relative to the previous review, remain very low relative to the total amount of habitat available. Proportion natural origin remained high in the Yakima Basin (estimated for aggregate run at Prosser Dam).

Total spawning escapements have increased in the most recent brood cycle over the period associated with the 2005 BRT review for all three populations in the Umatilla-WallaWalla MPG (Table 73). Natural origin escapements are higher for two populations (Umatilla River and Walla Walla River) while remaining at the approximately the same level as in the prior review for the Touchet River.

Relative to the brood cycle just prior to listing (1992-1996 spawning year) current brood cycle (five year geometric mean) natural abundance is substantially higher (more than twice) for seven of the Mid-Columbia steelhead population data series, lower for three populations and at similar levels for the remaining 4 populations.

Short term trends for all populations in the Yakima River MPGs were strongly positive over the period 1995-2009 (Figure 143). Trends for East Cascades, John Day and Umatilla/Walla Walla populations were generally positive with three exceptions. The geometric mean trend estimates for Fifteen Mile Creek, the Middle Fork John Day and the Touchet River were at or slightly below one, with the confidence bounds for all three estimates including 1.0.

Populations in all four of the Mid-Columbia steelhead MPGs exhibited similar temporal patterns in returns per spawner (Figure 140, Figure 142, Figure 144, Figure 146). Return rates for brood years 1995-1999 were generally exceeded replacement (1:1). Spawner to spawner ratios for brood years 2001-2003 were generally well below replacement for many populations. Brood year productivity estimates returned levels at or above 1:1 for the most recent 1-2 brood years for populations in the Yakima and John Day River MPGs but remained below replacement for the Eastern Cascades and Umatilla/Walla Walla populations. Brood year return rates reflect the combined impacts of year to year patterns in marine life history stages, upstream and downstream passage survivals as well as density dependent effects resulting from capacity or survival limitations on tributary spawning or juvenile rearing habitats.

Table 73 -- Summary of abundance and hatchery proportions for Mid-Columbia Steelhead populations organized by MPG. Estimates for brood cycle prior listing (1992-1996) and the 2005 BRT review included for comparison. Estimates for all series calculated using current data sets.

Population (organized by major population group)	**Natural Spawning Areas**								
	Total Spawners (5 year geometric mean, *range*)			**Natural Origin** (5 year geometric mean)			**% Natural Origin** (5 year average)		
	Listing *(1992-1996)*	*Prior* *(1997-2001)*	**Current** (2005-2009)	*Listing* *(1992-1996*	*Prior* *(1997-2001)*	**Current** (2005-2009)	*Listing* *(1992-1996*	*Prior* *(1997-2001)*	**Current** (2005-2009)
East Side Deschutes MPG									
Fifteen Mile Cr.	*396*	*571* *(234-974)*	***452*** ***(225-1,956)***	*396*	*571* *(234-974)*	***452*** ***(225-1,956)***			
East Side Deschutes	*651*	3,114 *(1,829-10,005)*	**2,457** ***(1,720-4,151)***	*421*	1,753 *(475-8,637)*	**1,945** ***(1,600-2,395)***	65%	62%	**80%**
West Side Deschutes	*248*	594 *(417-920)*	**574** ***(408-780)***	*175*	414 *(290-766)*	**472** ***(314-567)***	71%	70%	**82%**
John Day MPG									
Upper Mainstem	*601*	699 *(333-1,771)*	**500** ***(166-980)***	*578*	651 *(326-1,593)*	**459** ***(149–910)***	*96%*	*93%*	***92%***
North Fork	*1,242*	2,134 *(1021–4,539)*	**1,618** ***(789–4,072)***	*1,196*	1,988 *(978–4,083)*	**1,484** ***(707–3,878)***	*96%*	*93%*	***92%***
Middle Fork	*926*	1,169 *(477-3,478)*	**400** ***(238–770)***	*891*	1,089 *(457-3,129)*	**367** ***(213–707)***	*96%*	*93%*	***92%***
South Fork	*302*	293 *(105-1094)*	**434** ***(232–662)***	*290*	273 *(103-984)*	**398** ***(207-630)***	*96%*	*93%*	***92%***
Lower Mainstem	*1,001*	2,139 *(652-6,096)*	**1,382** ***(749-4,324)***	*964*	2,013 *(625–5,553)*	**1,006** ***(508-3,480)***	*96%*	*94%*	***73%***
Yakima MPG									
Satus Creek	*347*	365 *(310–413)*	**831** ***(524–1129)***	*317*	337 *(269–398)*	**809** ***(519–1121)***	*91%*	92%	**97%**
Toppenish Creek	*131*	345 *(156-1229)*	**482** ***(265-820)***	*119*	318 *(132-1208)*	**469** ***(262-802)***	*91%*	92%	**97%**
Naches River	*278*	471 *(346–1000)*	**848** ***(496–1199)***	*254*	435 *(304–983)*	**825** ***(491–1190)***	*91%*	92%	**97%**
Upper Yakima	*53*	66 *(42-171)*	**158** ***(80-226)***	*51*	65 *(42-162)*	**156** ***(80-223)***	*91%*	99%	**99%**
Umatilla/Walla Walla MPG									
Umatilla River	*1,549*	2163 *(1527-3360)*	**2893** ***(1654-4667)***	*1,118*	1288 *(769-2451)*	**2273** ***(1373–3625)***	*72%*	61%	**79%**
Touchet River	*511*	382 *(286–559)*	**497** ***(385–626)***	*449*	345 *(252–493)*	**347** ***(277–438)***	*88%*	90%	**70%**
Walla Walla River	*772*	631 *(421-1172)*	**838** ***(472-1658)***	*765*	618 *(419-1118)*	**815** ***(464-1623)***	*99%*	98%	**97%**

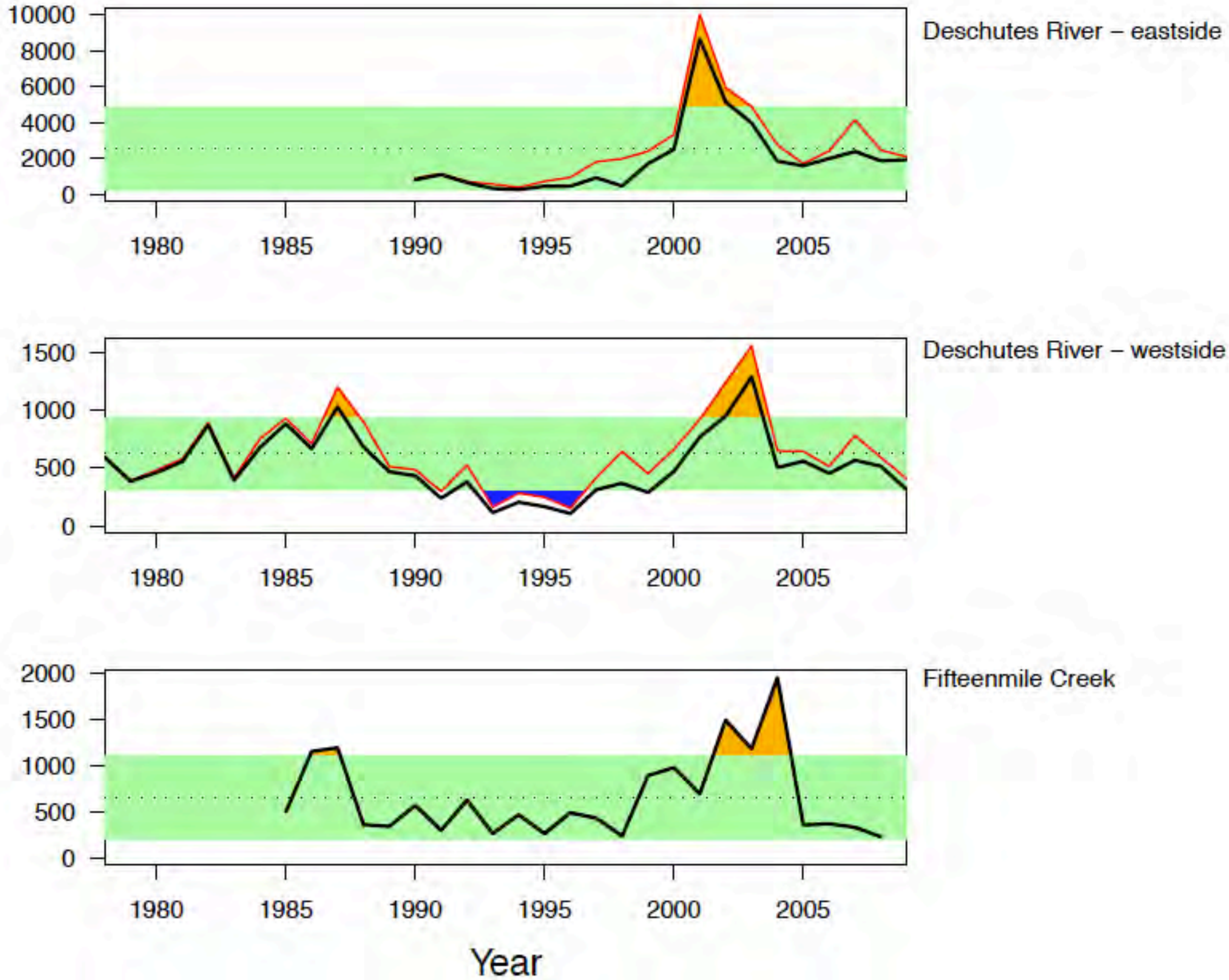


Figure 139 – Spawning abundance for the East Cascades Major Population Group in the Middle Columbia steelhead DPS. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

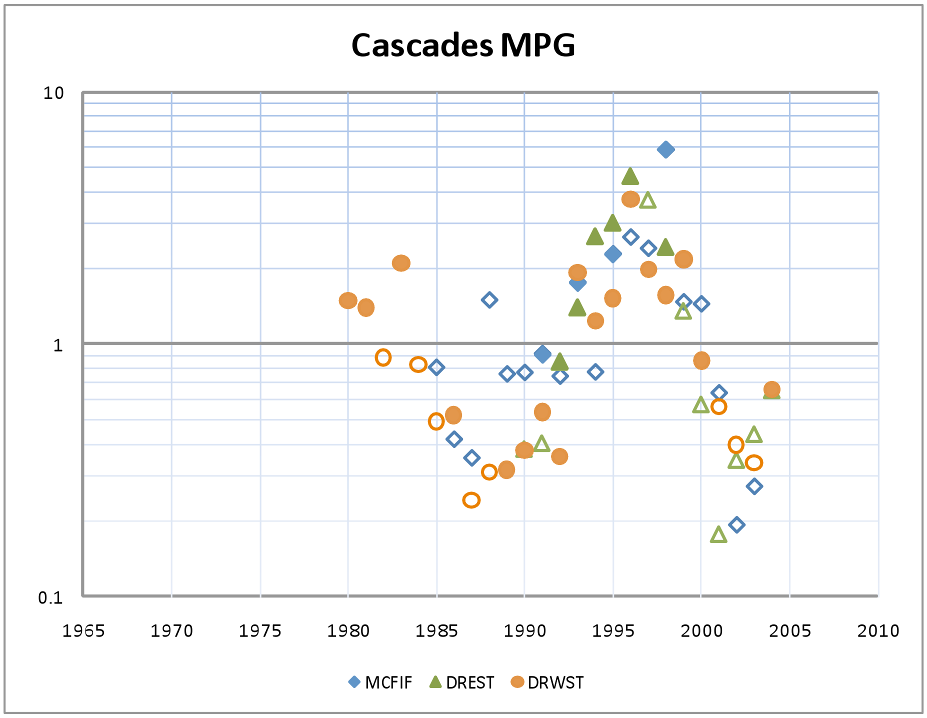


Figure 140 – Productivity of the East Cascades Major Population Group in the Middle Columbia steelhead DPS. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.

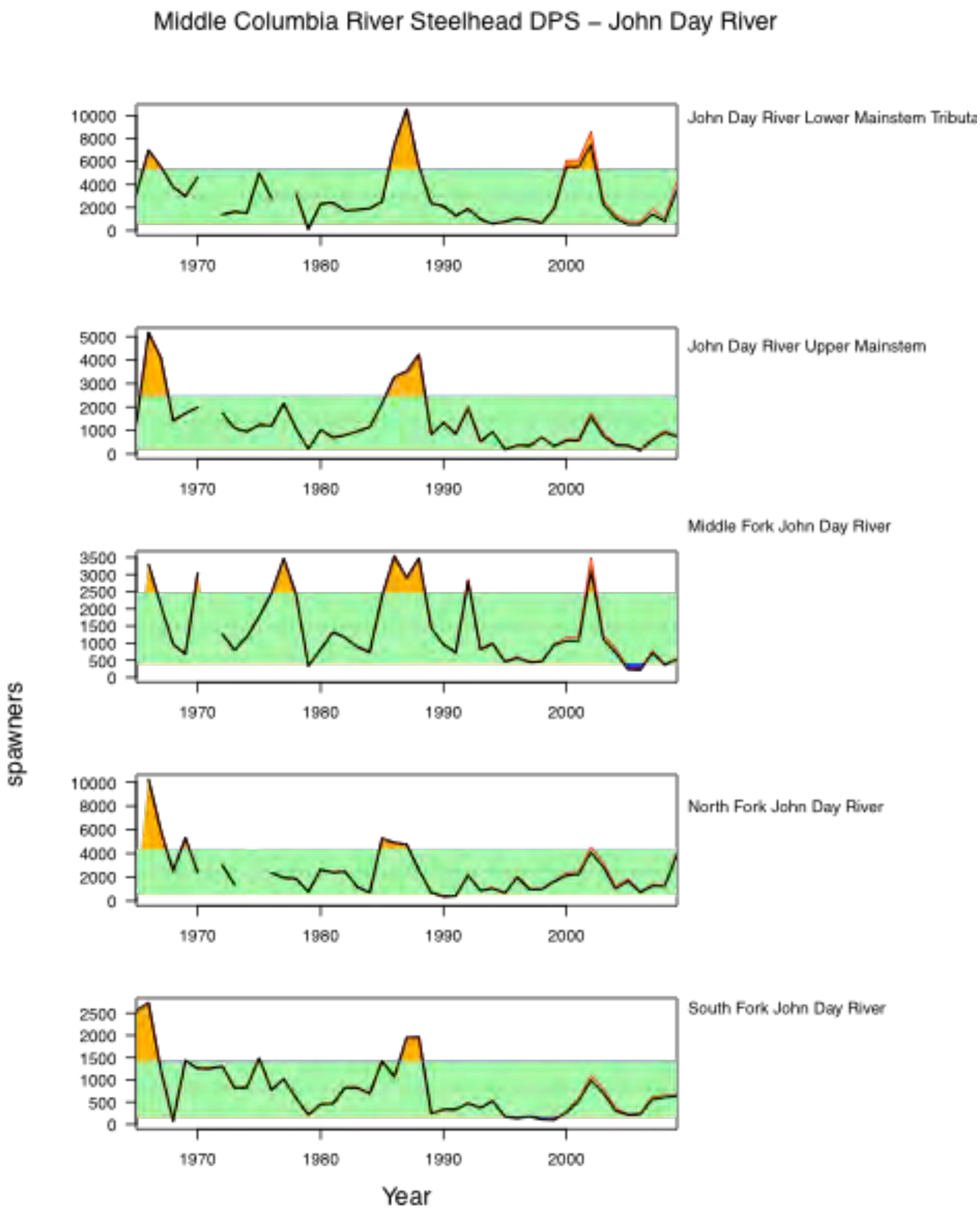


Figure 141 -- Spawning abundance for the John Day Major Population Group in the Middle Columbia steelhead DPS. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

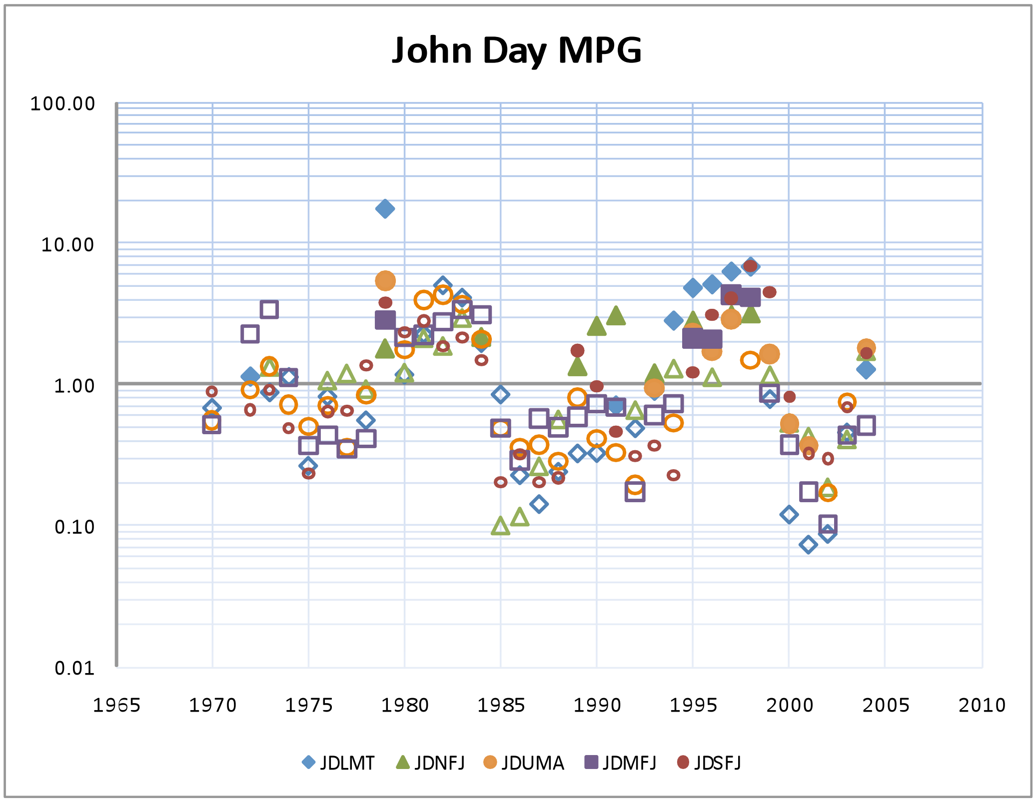


Figure 142 -- Productivity of the John Day Major Population Group in the Middle Columbia steelhead DPS. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.

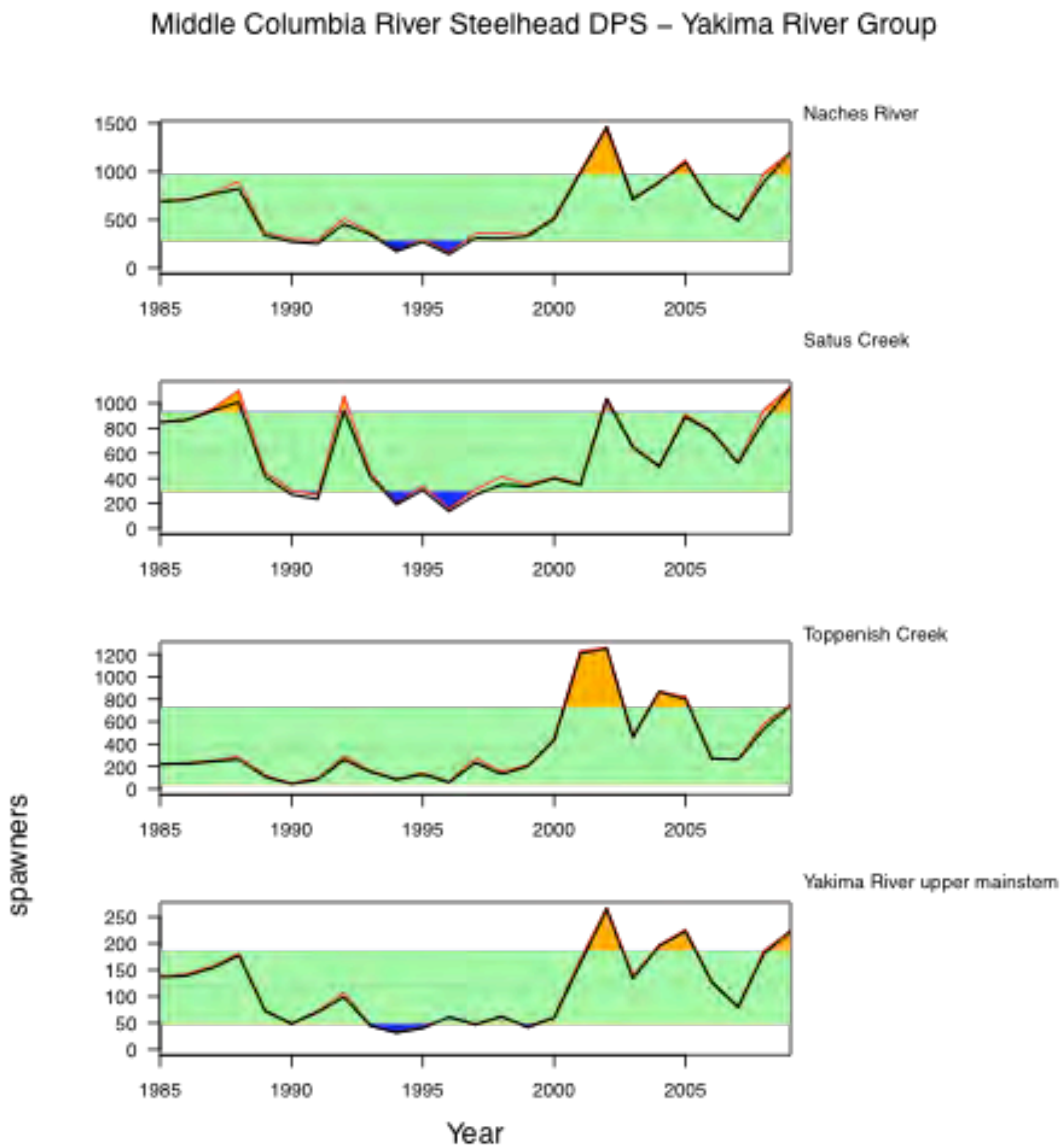


Figure 143 -- Spawning abundance for the Yakima Major Population Group in the Middle Columbia steelhead DPS. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

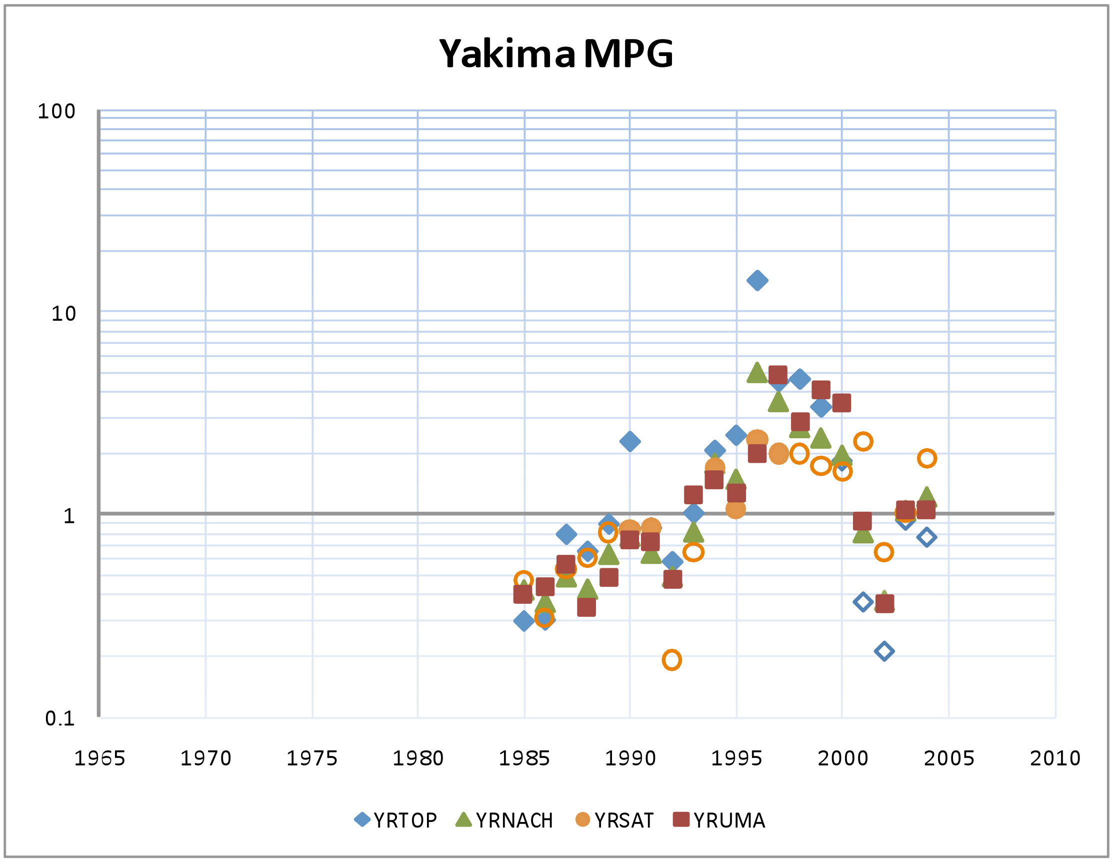


Figure 144 -- Productivity of the Yakima Major Population Group in the Middle Columbia steelhead DPS. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.

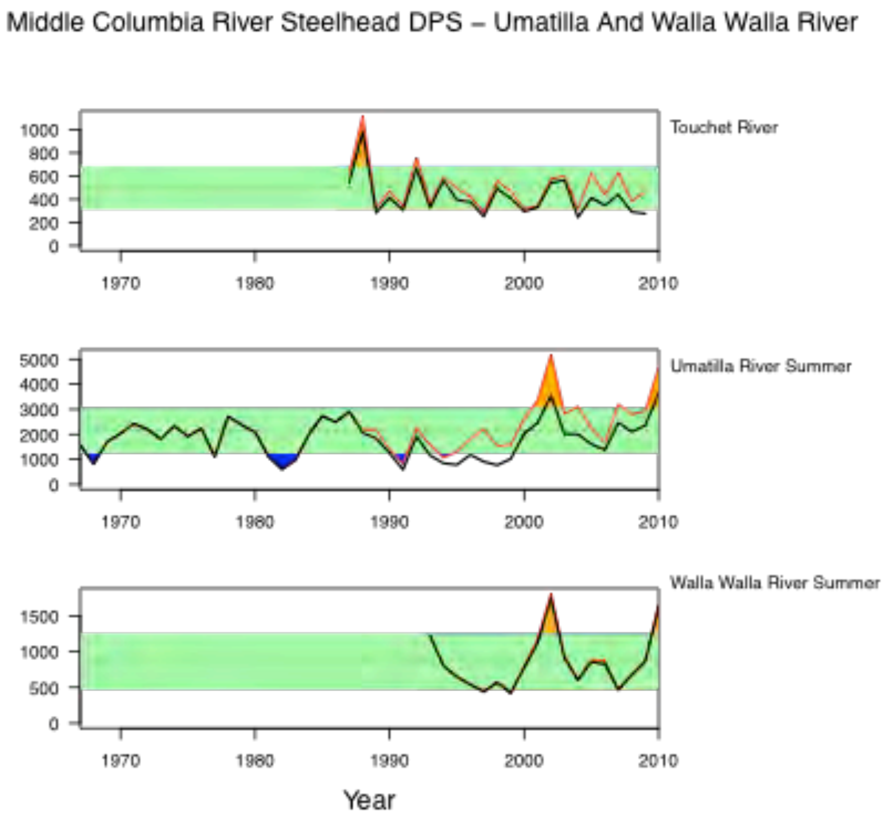


Figure 145 -- Spawning abundance for the Umatilla/Walla Walla Major Population Group in the Middle Columbia steelhead DPS. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

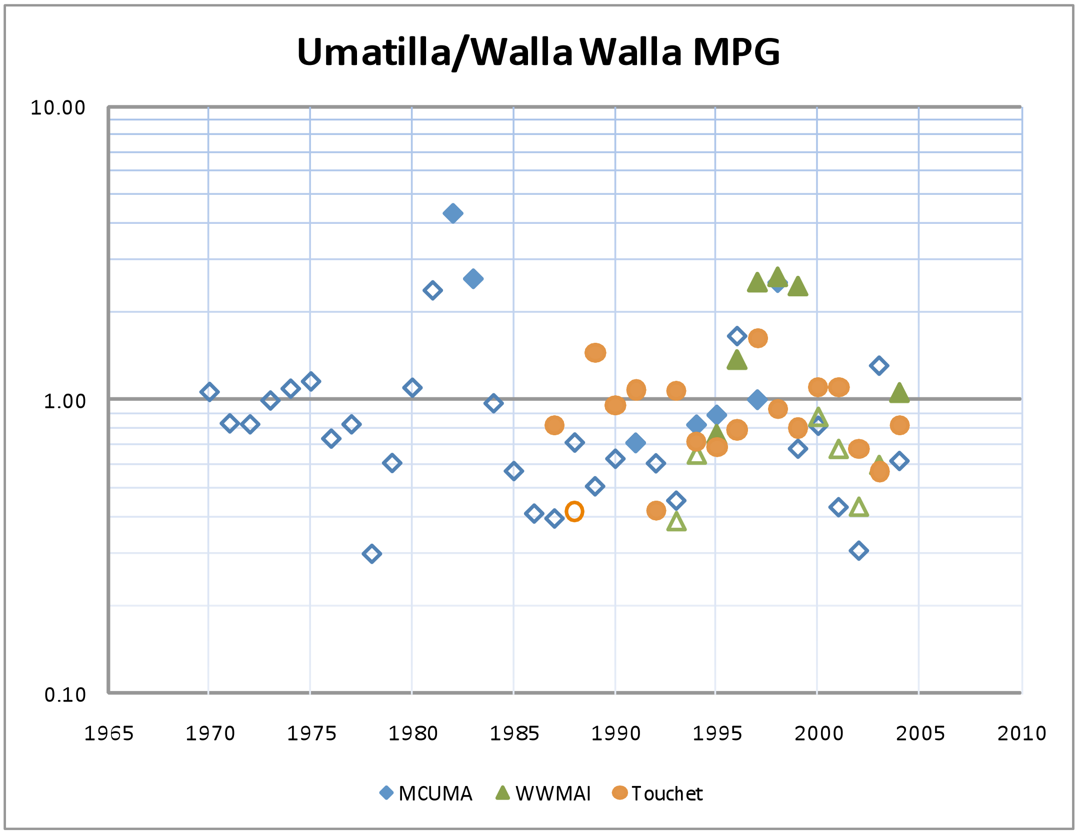
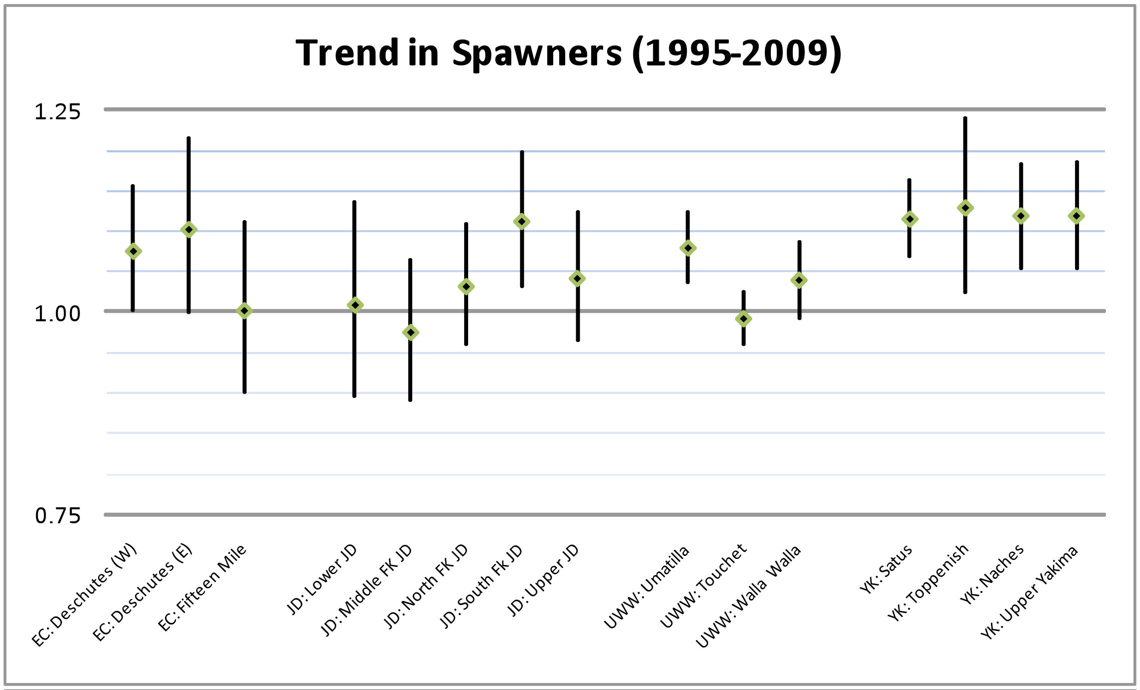
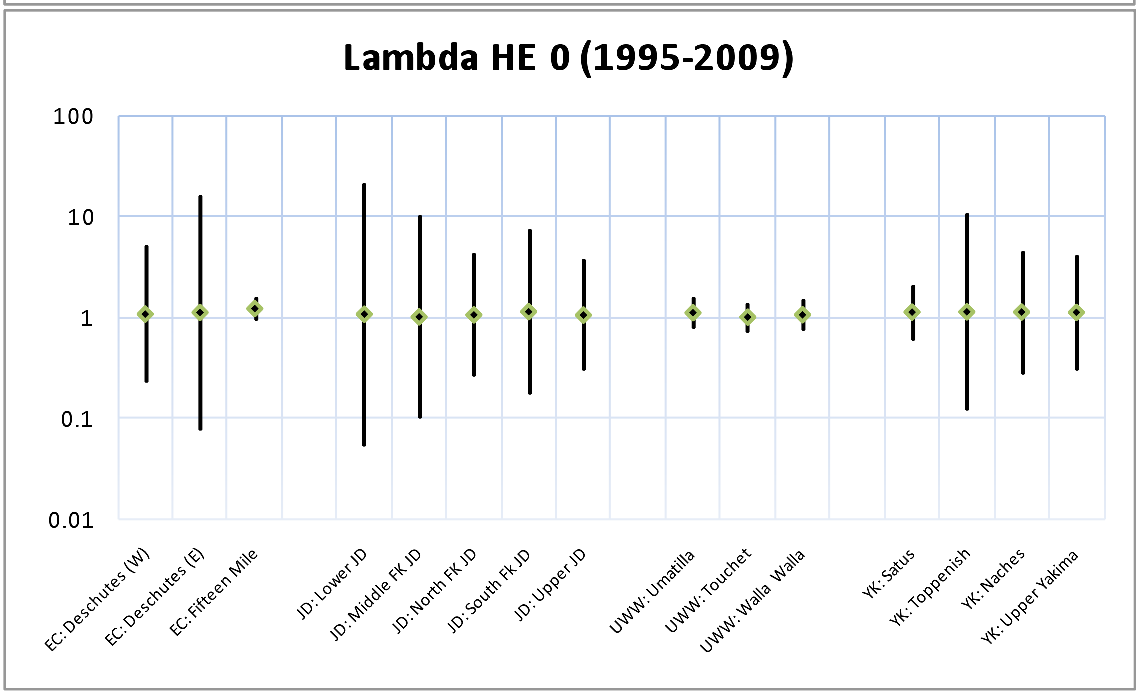


Figure 146 -- Productivity of the Umatilla/Walla Walla Major Population Group in the Middle Columbia steelhead DPS. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.


Trend in Spawners (1995-2009)
1.25
1.00
0.75
EC: Deschutes (W)
EC: Deschutes (E)
EC: Fifteen Mile
JD: Lower JD
JD: Middle FK JD
JD: North FK JD
JD: South Fk JD
JD: Upper JD
UWW: Umatilla
UWW: Touchet
UWW: Walla Walla
YK: Satus
YK: Toppenish
YK: Naches
YK: Upper Yakima


Lambda HE 0 (1995-2009)
100
10
1
0.1
0.01
EC: Deschutes (W)
EC: Deschutes (E)
EC: Fifteen Mile
JD: Lower JD
JD: Middle FK JD
JD: North FK JD
JD: South Fk JD
JD: Upper JD
UWW: Umatilla
UWW: Touchet
UWW: Walla Walla
YK: Satus
YK: Toppenish
YK: Naches
YK: Upper Yakima

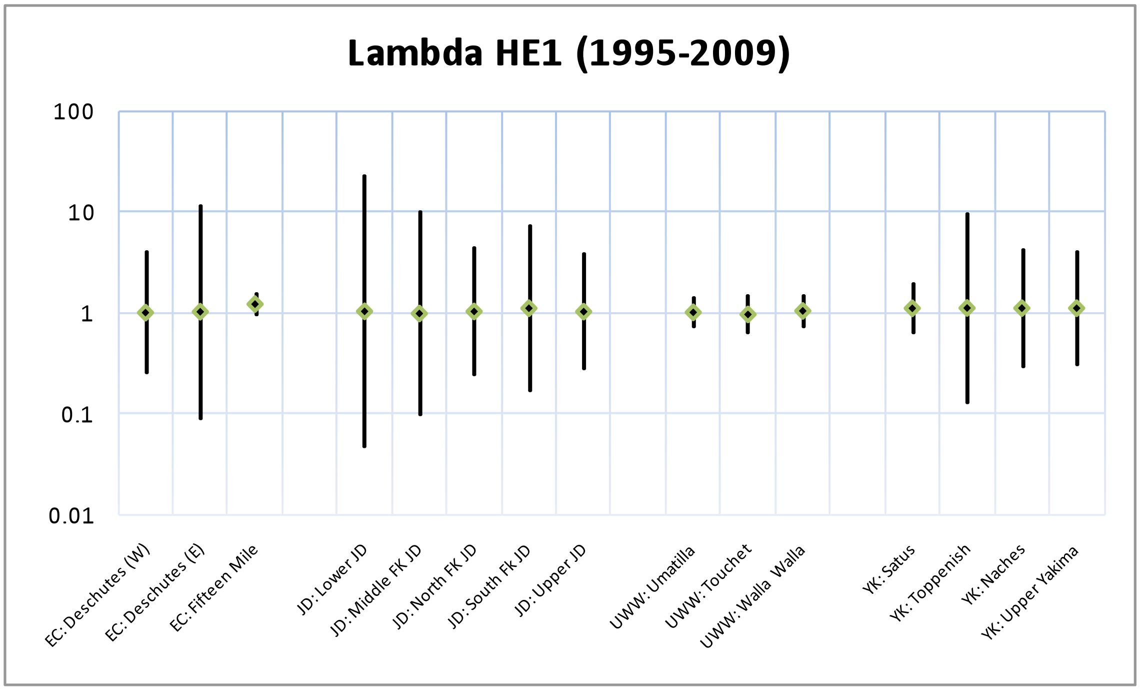


Figure 147 – The top panel illustrates the short-term (1995-2009) trends in natural origin spawners. Estimated as slope of ln(natural origin abundance) vs. year. Population estimates organized by Major Population Group (MPG). Eastern Cascades (EC); John Day River (JD); Umatilla/Walla Walla (UWW), Yakima River (YK). Lines: upper and lower 95% confidence limits. Point estimates are exp(ln(trend)). The middle panel illustrates short term population growth rate (lambda) estimates for Mid-Columbia steelhead populations. Relative hatchery effectiveness set to 0.0. Solid diamond/bar: point estimate and 95% cf for 1995-2009. The bottom panel illustrates short term population growth rate (lambda) estimates for Mid-Columbia steelhead populations. Relative hatchery effectiveness set to 1.0. Solid diamond/bar: point estimate and 95% cf for 1995-2009.

Current Status: Recovery Plan Viability Criteria

The current status of two of the five populations in the Cascades Eastern Slope MPG, Fifteen Mile Creek and the Deschutes River (Eastside), are rated as viable using the ICTRT criteria incorporated into the Mid-Columbia Steelhead Recovery Plan. The Deschutes (Westside) population remains rated at High Risk driven by relatively low estimates for current productivity and natural origin abundance vs. the DPS specific viability curve for Intermediate sized populations. The data series for the Klickitat River population is not sufficient to allow a rating, however available mark-recapture based estimates for two recent years indicate that the population may be functioning at or near viable levels. Data are not available for the remaining extant population (Rock Creek). The current ratings against spatial structure and diversity criteria reflect the assessments done for the 2008 ICTRT status assessments.

Table 74 -- Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the Cascades Eastern Slope MPG.

Cascades Eastern Slope MPG	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
Population	***ICTRT Minimum Threshold***	***Natural Spawning Abundance***	***ICTRT Productivity***	***Integrated A/P Risk***	***Natural Processes Risk***	***Diversity Risk***	***Integrated SS/D Risk***	
Fifteen Mile 1999-2008 1995-2004	**500**	**675** (225-1946) *695* (236-1946)	**1.83** (0.95-3.54) *1.83* (0.95-3.54)	Low	Very Low	Low	Low	Viable
Klickitat	**1000**	*Insufficient data*	*Insufficient data*	Moderate[25]	Low	Moderate	Moderate	Maintained?
East Side Deschutes 2000-2009 1995-2004	**1000**	**2,730** (1600-8637) *1633* (462-8637)	**2.31** (1.49-3.60) *2.31* *(1.49-3.60)*	Low	Low	Moderate	Moderate	Viable
West Side Deschutes 2000-2009 1995-2004	**1000**	**591** (314-1284) *410* (108-1284)	**0.96** (0.68-1.37) *1.08* *(0.82-1.42)*	High	Low	Moderate	Moderate	High Risk
Rock Creek	**500**	*Insufficient data*	*Insufficient data*	High[26]	Moderate	Moderate	Moderate	High Risk?
White Salmon River	**500**	*N/A*	*N/A*	Extinct[27]	*N/A*	*N/A*	*N/A*	Extinct
Crooked River	**2,250**	*N/A*	*N/A*	Extinct	*N/A*	*N/A*	*N/A*	Extinct

[25] Moderate rating (provisional) for Klickitat River population based on redd counts in some years, relative hatchery/natural-origin fractions in catch samples, and extrapolation from other DPS populations.
[26] Annual surveys not conducted; therefore we assumed a provisional A/P rating of High.
[27] Assumed to be functionally extinct (upstream habitat cut off by Condit Dam).

The North Fork John Day population continues to be rated Highly Viable when the data updates through the 2009 spawning year are incorporated into the assessment against recovery plan/ICTRT criteria. The remaining four populations in the John Day River MPG remain rated as Maintained. Natural origin abundance estimates (ten year geometric means) are higher in the current assessments for four populations and lower for the Middle Fork John Day River. Productivity estimates (geometric mean brood year spawner/spawner at low to moderate parent escapements) were generally lower in the updated data series than the estimates generated for the ICTRT status reviews ending in spawning year 2005. The current ratings against spatial structure and diversity criteria reflect the assessments done for the 2008 ICTRT status assessments.

Table 75 -- Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the John Day River MPG.

John Day MPG	**Abundance/Productivity Metrics**				**Spatial Structure and Diversity Metrics**			**Overall Viability Rating**
Population	***ICTRT Minimum Threshold***	***Natural Spawning Abundance***	***ICTRT Productivity***	***Integrated A/P Risk***	***Natural Processes Risk***	***Diversity Risk***	***Integrated SS/D Risk***	
Upper Mainstem 2000-2009	**1000**	**558** (149-1593)	**0.90** (1.83-2.83)	Moderate	Very Low	Moderate	Moderate	Maintained
1995-2004		*524* (185-1593)	*2.14* (1.04-2.31)	Moderate				
North Fork 2000-2009	**1500**	**1826** (707-4083)	**2.53** (1.57-4.08)	Very Low	Very Low	Low	Low	Highly Viable
1995-2004		*1740* (640-4083)	*2.41* (1.54-3.63)	Very Low				
Middle Fork 2000-2009	**1000**	**672** (213-3129)	**2.28** (1.79-2.90)	Moderate	Low	Moderate	Moderate	Maintained
1995-2004		*756* (436-3129)	*2.45* *(1.84-2.71)*	Moderate				
South Fork 2000-2009	**500**	**443** (207-984)	**1.52** (1.00-2.30)	Moderate	Very Low	Moderate	Moderate	Maintained
1995-2004		*259* (103-984)	*2.06* *(1.23-2.80)*	Moderate				
Lower Mainstem 2000-2009	**2250**	**1881** (508-7419)	**2.55** (1.51-4.32)	Moderate	Very Low	Moderate	Moderate	Maintained
1995-2004		*1800* (625-7419)	*2.99* (1.96-4.88)	Moderate				

Table 76 -- Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the Umatilla/Walla Walla MPG.

Umatilla/Walla Walla MPG	**Abundance/Productivity Metrics**				**Spatial Structure and Diversity Metrics**			**Overall Viability Rating**
Population	***ICTRT Minimum Threshold***	***Natural Spawning Abundance***	***ICTRT Productivity***	***Integrated A/P Risk***	***Natural Processes Risk***	***Diversity Risk***	***Integrated SS/D Risk***	
Willow Creek	**N/A**	*N/A*	*N/A*	Extinct	*N/A*	*N/A*	*N/A*	**Extinct**
Umatilla River 2000-2009	**1500**	**2257** (1654-5176)	**1.21** (0.48-3.07)	Moderate	Moderate	Moderate	Moderate	**Maintained**
1995-2004		1472 (1074-3360)	1.50 (1.10-1.91)	Moderate				
Touchet River 2000-2009	**1000**	**394** (316-626)	**0.96** (0.64-1.46)	**High**	Low	Moderate	Moderate	**High Risk**
1995-2004		414 (245-563)	1.19 (1.08-2.20)	Moderate?[28]				
Walla Walla River 2000-2009	**1000**	**894** (472-1811)	**1.15** (0.69-1.92)	Moderate	Moderate	Moderate	Moderate	**Maintained**
1995-2004		650 (464-1746)	1.34 (1.05-1.68)	Moderate				

The ratings for individual populations in the Yakima MPG should be interpreted with caution given the basis for estimating population specific returns from Prosser Dam counts. The overall viability ratings have increased from Maintained to Viable for the two basic sized populations in this MPG, remaining at Maintained for the Naches River and High Risk for the Upper Yakima River population. The changes in ratings reflect the relatively high annual returns in most years since 2001. Productivity estimates based on the return series updated through 2009 (previously through 2005) have increased or remained at approximately the same levels as estimated in the recovery plan/ICTRT status assessments. The current ratings for spatial structure and diversity criteria reflect the assessments done for the 2008 ICTRT status assessments.

[28] Annual abundance data series for the Touchet River steelhead population is relatively short and has several missing years. Productivity estimates of A/{ rating are provisional and should be interpreted with caution. – From 2007 CSA

Table 77 -- Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the Yakima MPG.

Yakima MPG	Abundance/Productivity Metrics				Spatial Structure and Diversity Metrics			Overall Viability Rating
Population	***ICTRT Minimum Threshold***	***Natural Spawning Abundance***	***ICTRT Productivity***	***Integrated A/P Risk***	***Natural Processes Risk***	***Diversity Risk***	***Integrated SS/D Risk***	
Satus Creek 2000-2009	**500**	**660** (347-1121)	**1.79** (1.42-2.26)	Moderate	Low	Moderate	Moderate	Viable *(Maintained)*
1995-2004		*379* (138-1032)	1.73 (1.33-2.25)	Moderate				
Toppenish Creek 2000-2009	**500**	**599** (262-1252)	**2.84** (1.81-4.45)	Moderate	Low	Moderate	Moderate	Viable *(Maintained)*
1995-2004		*322* (57-1252)	1.60 (0.94-2.71)	Moderate				
Naches River 2000-2009	**1,500**	**840** (491-1454)	**1.59** (1.25-2.01)	High	Low	Moderate	Moderate	High Risk
1995-2004		*472* (142-1454)	1.12 **(0.75-1.65)**	High				
Upper Yakima 2000-2009	**1,500**	**151** (60-265)	**1.52** (1.17-1.98)	High	Moderate	High	High	High Risk
1995-2004		*85* (40-265)	1.12 (0.76-1.64)	High				

Overall status ratings for the Umatilla River and Walla Walla populations remained at Maintained after incorporation of the updated abundance and productivity data. The current status of the Touchet River population remained at High Risk, primarily driven by relatively low geometric mean productivity. Natural origin abundance estimates have increased for the Umatilla River and the Walla Walla River populations relative to the levels reported in the recovery plan/ICTRT current status reviews (through return year 2005). Productivity estimates for all three extant populations in this MPG are lower than in the previous reviews. The current ratings against spatial structure and diversity criteria reflect the assessments done for the 2008 ICTRT status assessments.

<u>Harvest</u>

Summer-run steelhead from the upper basin are divided into 2 runs by managers: The A-run, and the B-run. These runs are believed have differences in timing, but managers separate them on the basis of size alone in estimating the size of the runs. The A-run is believed to occur throughout the Middle Columbia, Upper Columbia, and Snake River Basins, while the B-run is believed to occur naturally only in the Snake River ESU, in the Clearwater River, Middle Fork Salmon River, and South Fork Salmon River.

Steelhead were historically taken in tribal and non-tribal gillnet fisheries, and in recreational fisheries in the mainstem Columbia River and in tributaries. In the 1970s, retention of steelhead in non-tribal commercial fisheries was prohibited, and in the mid-1980s, tributary recreational fisheries in Washington adopted mark-selective regulations. Steelhead are still harvested in tribal fisheries, in mainstem recreational fisheries, and there is incidental mortality associated with mark-selective recreation recreational fisheries. The majority of impacts on the summer run occur in tribal gillnet and dip net fisheries targeting Chinook salmon. Because of their larger size, the B-run fish are more vulnerable to the gillnet gear. Consequently, this component of the summer run experiences higher fishing mortality than the A-run component (Figure 148). In recent years, total exploitation rates on the A-run have been stable at around 5%, while exploitation rates on the B-run have generally been in the range of 15% to 20%.

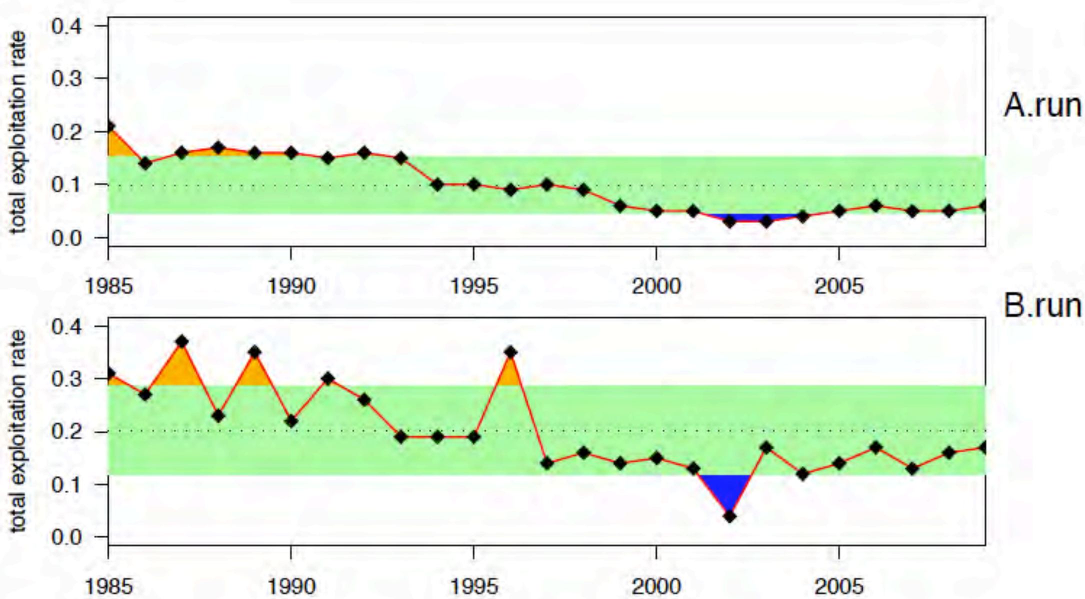


Figure 148 -- Total harvest impacts on natural summer steelhead above Bonneville Dam. Data for 1985-1998 from NMFS biological opinion (Peter Dygert, NMFS, personal communication), and for 1999-2008 from TAC run reconstruction (Cindy LeFleur, WDFW personal communication).

Hatchery releases

Total hatchery releases of steelhead, Chinook and coho have remained similar since 2005. Releases for coho and steelhead fell substantially from their levels in the mid-1990s (Figure 149).

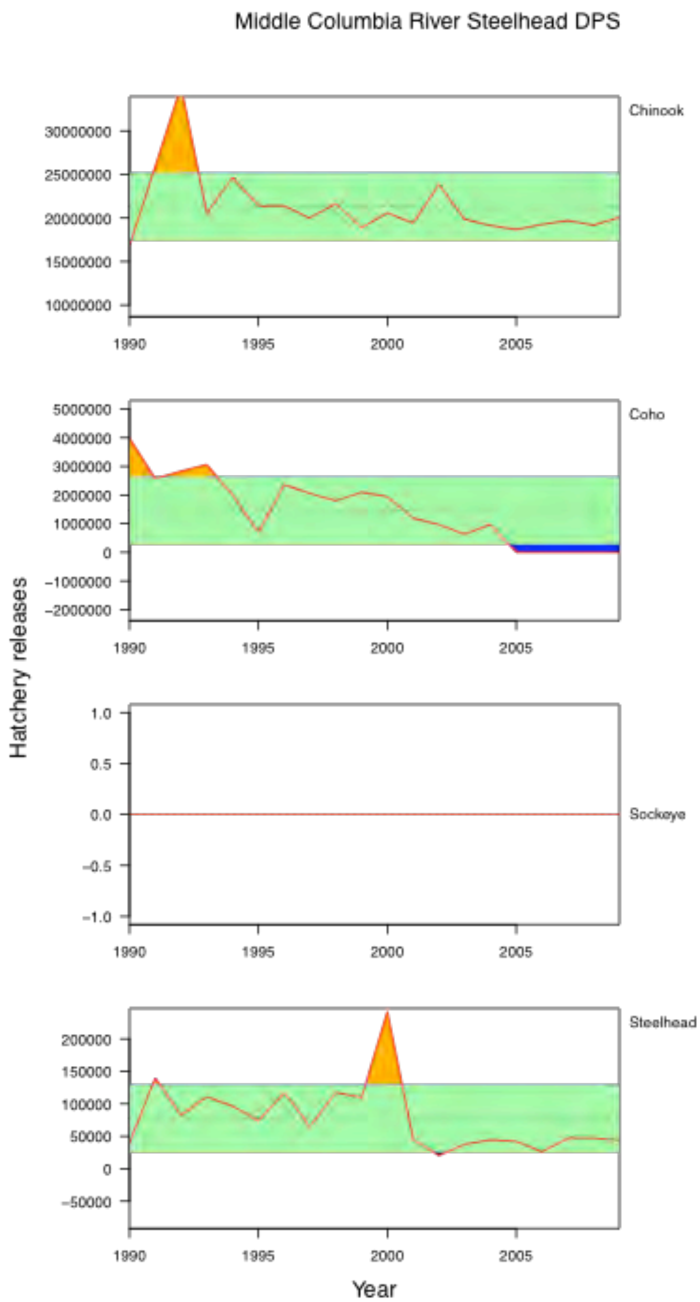


Figure 149 – Summary of hatchery releases by species within the spawning and rearing boundaries of the Mid-Columbia River steelhead ESU. Data source: RMIS.

Middle Columbia steelhead: Updated Risk Summary

There have been improvements in the viability ratings for some of the component populations, but the Mid-Columbia Steelhead DPS is not currently meeting the viability criteria (adopted from the ICTRT) in the Mid-Columbia Steelhead Recovery Plan. In addition, several of the factors cited by the 2005 BRT (Good et al. 2005) remain as concerns or key uncertainties. Natural origin spawning estimates are highly variable relative to minimum abundance thresholds across the populations in the DPS. Updated information indicates that stray levels into at least the Lower John Day River population are also high. Returns to the Yakima River basin and to the Umatilla and Walla Walla Rivers have been higher over the most recent brood cycle while natural origin returns to the John Day River have decreased. Out of basin hatchery stray proportions, although reduced, remain very high in the Deschutes River basin. Overall the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Good, T.P., R.S. Waples and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

ICTRT, 2003. Independent populations of chinook, steelhead and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Interior Columbia Basin Technical Recovery Team Technical Review Draft. July 2003. 171 p.

ICTRT, 2007. Viability criteria for application to interior Columbia Basin salmonid ESUs. Interior Columbia Basin Technical Recovery Team. Technical Review Draft. March 2007. 91 p + appendices and attachments.

ICTRT (2008) Current status reviews: Interior Columbia Basin salmon ESUs and steelhead DPSs. Vol. 3. Middle Columbia River steelhead distinct population segment. 300 p.

Lower Columbia River steelhead[29]

Listed ESU/DPS

The DPS includes all naturally spawned anadromous *O. mykiss* (steelhead) populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between the Cowlitz and Wind Rivers, Washington (inclusive), and the Willamette and Hood Rivers, Oregon (inclusive), as well as ten artificial propagation programs: the Cowlitz Trout Hatchery (in the Cispus, Upper Cowlitz, Lower Cowlitz, and Tilton Rivers), Kalama River Wild (winter- and summer-run), Clackamas Hatchery, Sandy Hatchery, and Hood River (winter- and summer-run) steelhead hatchery programs. Excluded are O. mykiss populations in the upper Willamette River Basin above Willamette Falls, Oregon, and from the Little and Big White Salmon Rivers, Washington.

ESU/DPS Boundary Delineation

Utilizing new information, the ESU Boundaries Review Group (Myers et al, this report) undertook a revaluation of the boundary between all Lower Columbia and Mid-Columbia ESUs and DPSs. The review conclusions emphasize the transitional nature the boundary between the Lower Columbia ESUs and the Mid-Columbia ESUs. After considering new DNA data, the review concludes, "it is reasonable to include the Klickitat in the Lower Columbia ESUs and DPS, thus establishing a common boundary for Chinook salmon, Chum salmon, coho salmon and steelhead at the historical location of Celilo Falls (currently the Dalles Dam)." This status evaluation is based on the existing Lower Columbia ESU boundaries that do not include the Klickitat population.

Summary of Previous BRT Conclusions

NMFS initially reviewed the status of the Lower Columbia River steelhead ESU in 1996 (Busby et al. 1996) and most recently in 1998 (NMFS 1998). In the 1998 review, the BRT noted several concerns for this ESU, including low abundance relative to historical levels, universal and often drastic declines observed since the mid-1980s, and widespread occurrence of hatchery fish in naturally spawning steelhead populations. Analysis also suggested that introduced summer-run steelhead may negatively affect native winter-run steelhead in some populations. A majority of the 1998 BRT concluded that steelhead in the Lower Columbia River steelhead ESU were at risk of becoming endangered in the foreseeable future.

LCR steelhead were most recently reviewed by the BRT in 2005 (Good et al. 2005). A large majority (over 73%) of the BRT votes for this ESU fell in the "likely to become endangered" category, with small minorities falling in the "danger of extinction" and "not likely to become endangered" categories. The BRT found moderate risks in all the VSP categories. All of the major risk factors identified by previous BRTs still remained. Most populations were at relatively low abundance, and those with adequate data for modeling were estimated to have a relatively high extinction probability. Some populations, particularly summer run, had higher returns in the most recent years included in the 2005 report (years 2001 and 2002). TheWLC-TRT (Myers et al. 2002) estimated that at least four historical populations were extirpated. The hatchery contribution to natural spawning remained high in many populations.

---

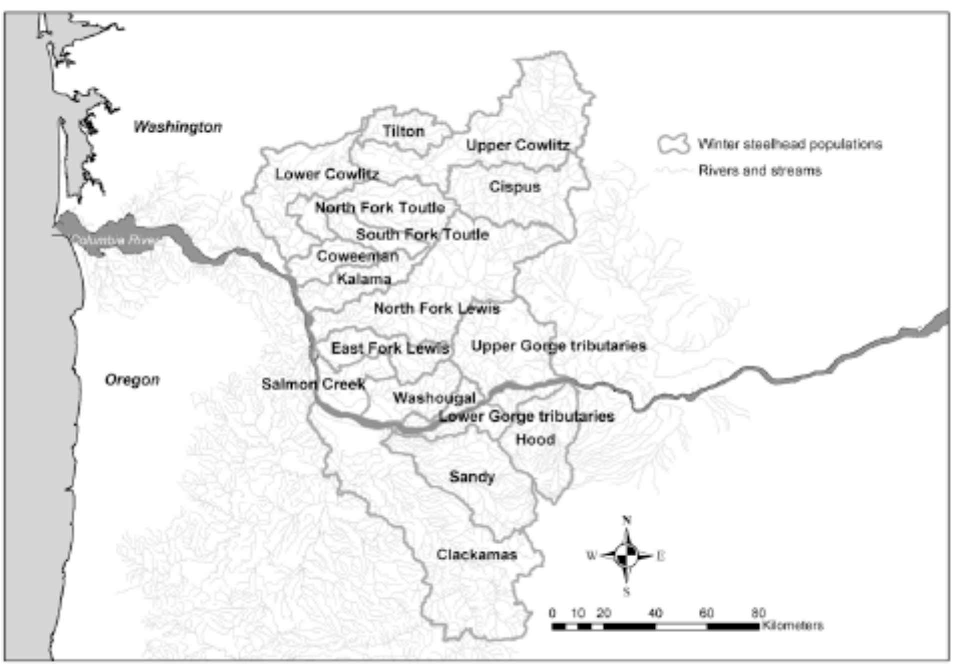
[29] Section author: Paul McElhany

Summary of Recent Evaluations

A report on the population structure of Lower Columbia salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The steelhead population designations in that report (Figure 150) are used in this status update and were used for status evaluations in recent recovery plans by ODFW and LCFRB. LCR Chinook populations exhibit two different life history types base on return timing and other features: winter run and summer run.

In 2010, ODFW completed a recovery plan that included Oregon populations of Lower Columbia steelhead DPS. Also in 2010, the LCFRB completed a revision of its recovery plan that includes Washington populations of Lower Columbia steelhead. Both of these recovery plans include an assessment of current status of LCR steelhead populations. These assessments relied and built upon the viability criteria developed by the WLC-TRT (McElhany et al 2006) and an earlier evaluation of Oregon WLC populations (McElhany et al. 2007). These evaluations assessed the status of populations with regard to the VSP parameters of abundance and productivity, spatial structure and diversity (McElhany et al. 2000). The results of these analyses are shown in Figure 151 and Figure 152.

These analyses indicate that only two of the 26 LCR steelhead populations (Wind summer and Clackamas winter) are currently considered "viable" (i.e. < 95% risk of extinction). 17 of the 26 populations (65%) are in the very high or high risk category, with 11 of the populations most likely in the very high risk category (also described as "extirpated or nearly so"). The poorest performing populations were those habitat is above impassible dams (e.g. NF Lewis) or in highly urbanized watersheds (e.g. Salmon Creek).



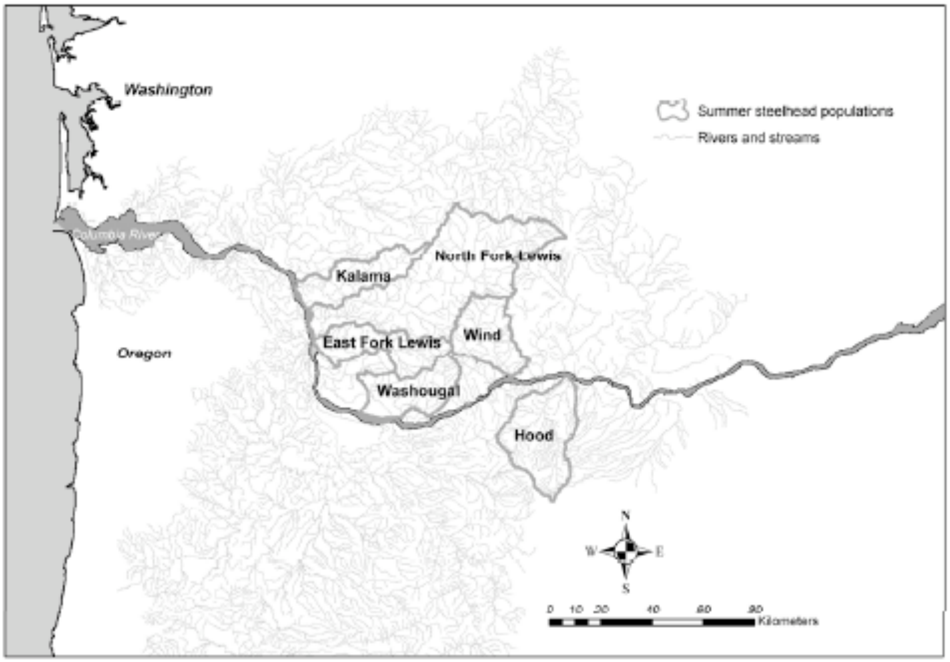


Figure 150 -- Populations of LCR winter steelhead (upper) and summer steelhead (Lower). From Myers et al. (2006).

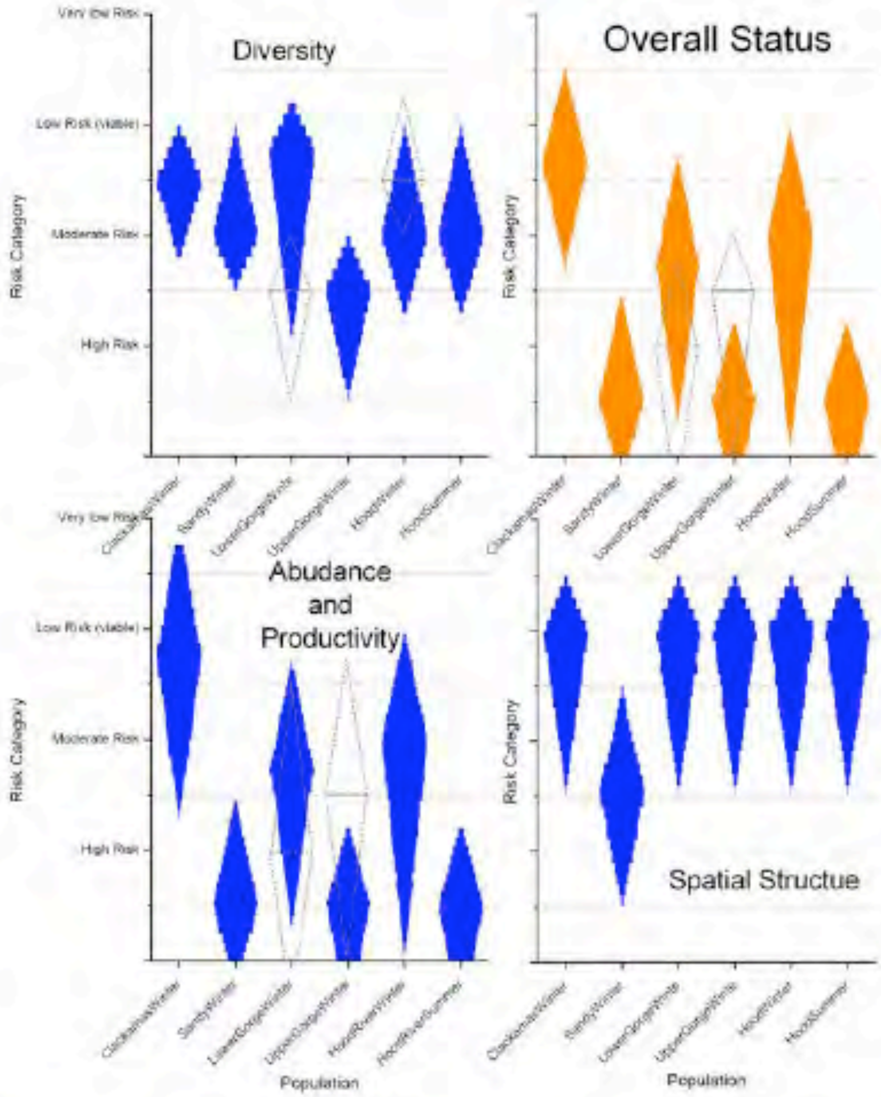


Figure 151 -- Oregon LCR steelhead population status from ODFW LCR recovery plan (2010).

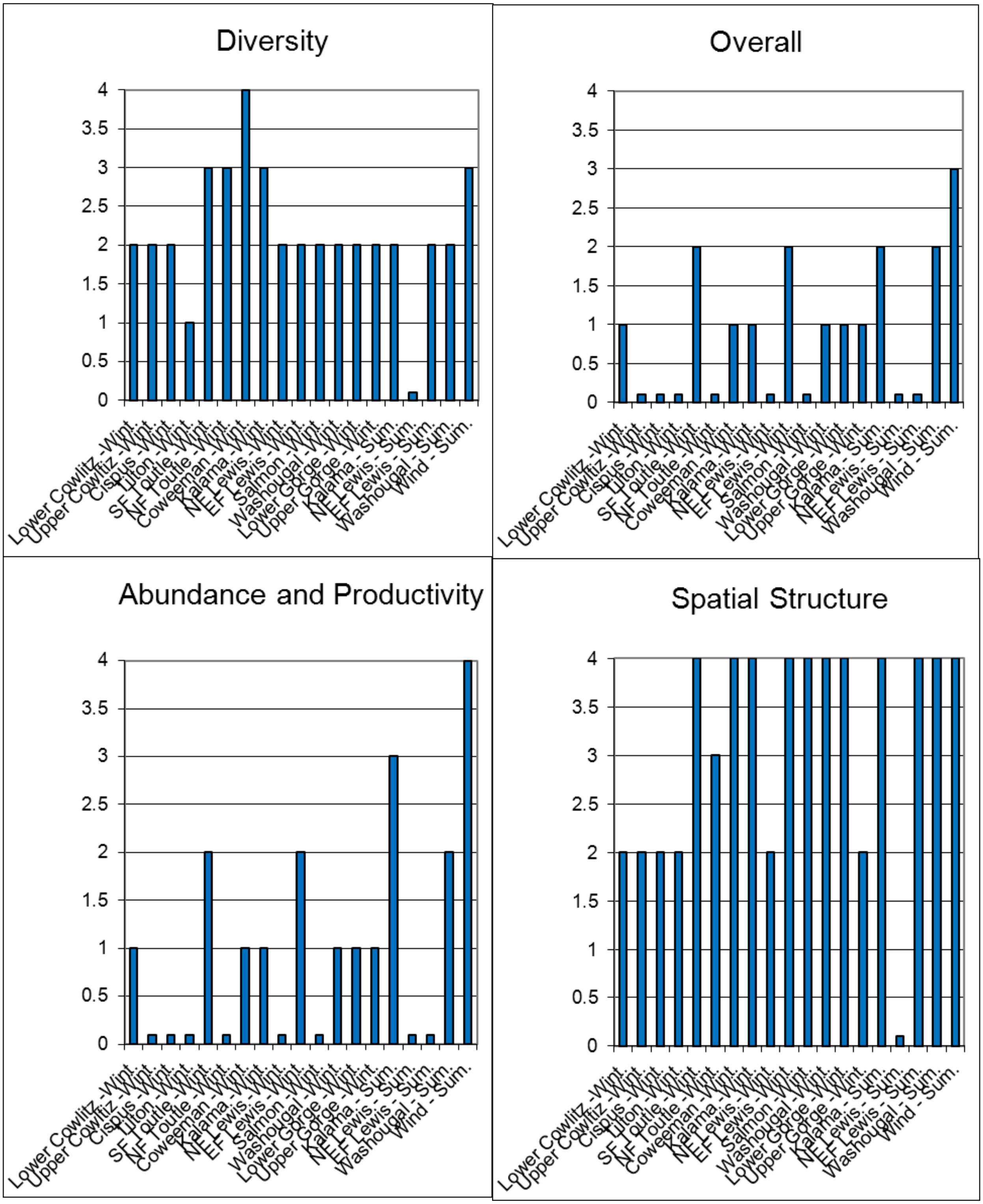
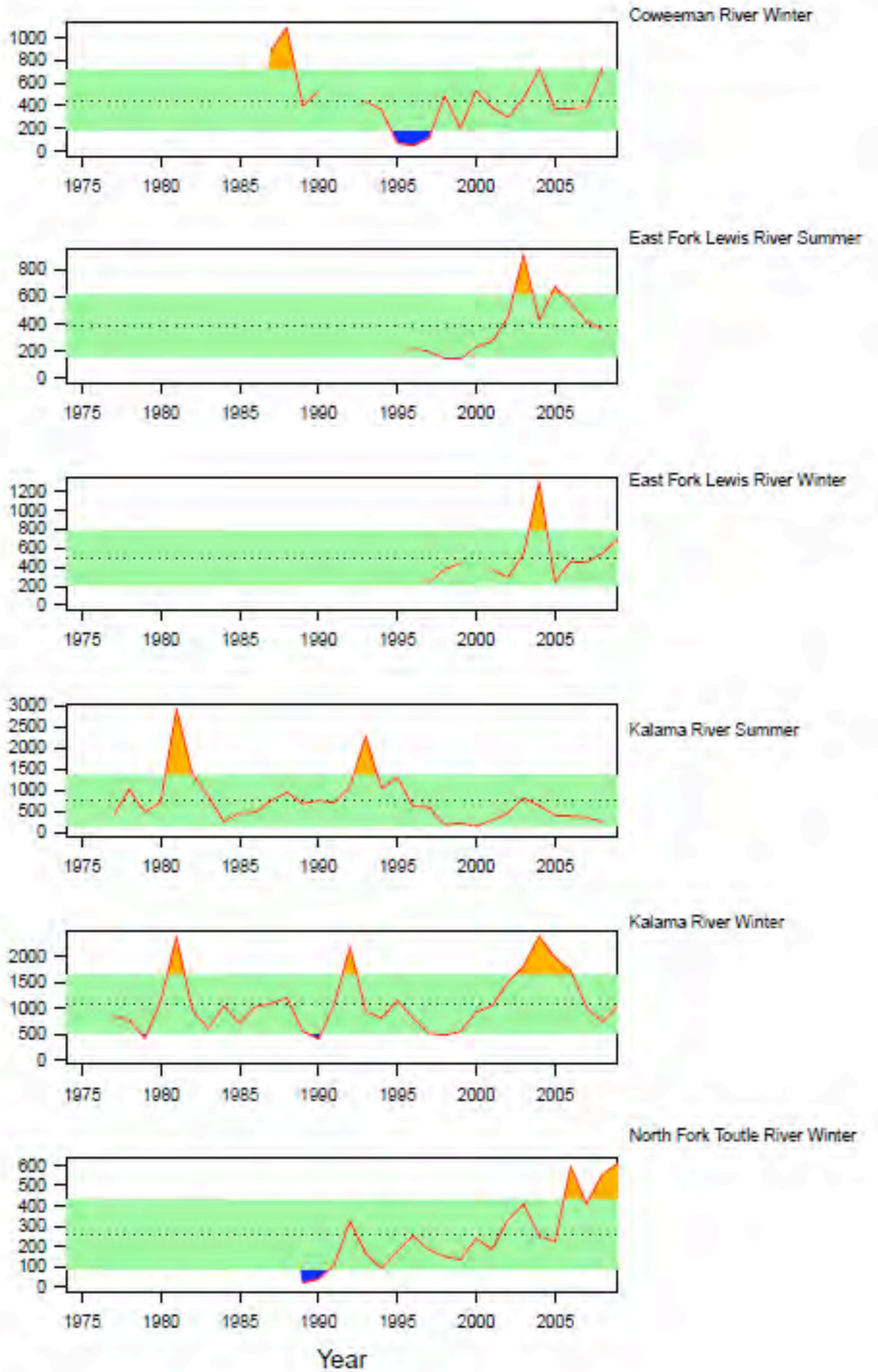
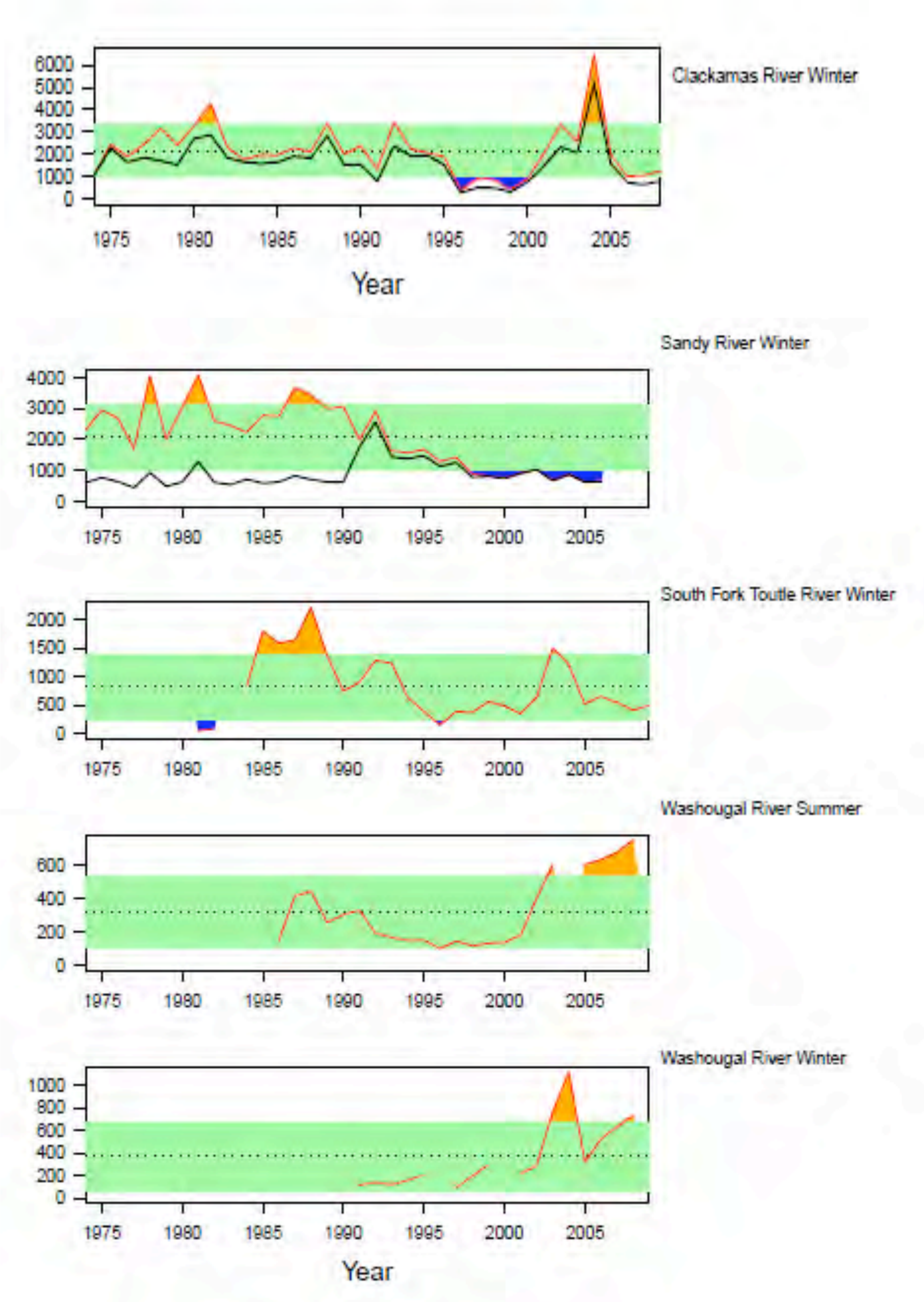


Figure 152 -- Current status of Washington LCR steelhead populations for the VSP parameters and overall population risk. (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk ("viable") and 4 is very low risk.

New Data and Analyses

The 2005 BRT status evaluation included abundance data for most of the LCR steelhead populations up to the year 2001. For the current evaluation, we have compiled data through 2008 for most populations. Trend data are presented in Figure 153, with statistical summary in Appendix A. Since the last status evaluations, all of the populations increased in abundance during the early 2000's, generally peaking in 2004. Most populations have since declined back to levels within one standard deviation of the long term mean. Exceptions are the Washougal summer run and NF Toutle winter run, which are still higher than the long term average and the Sandy which is lower. The NF Toutle winter run appears to be experiencing an longer term increasing trend since 1990, which is partially attributed to watershed recovery from the eruption of Mt. St. Helens in 1980. The Sandy winter steelhead population is below one standard deviation from the long-term mean and did not so the 2004 increase spike of the other populations in the ESU, suggesting that the population lack resilience. In general, the populations do not show any sustained dramatic changes in abundance or fraction of hatchery origin spawners since the 2005 BRT evaluation.


Coweeman River Winter
East Fork Lewis River Summer
East Fork Lewis River Winter
Kalama River Summer
Kalama River Winter
North Fork Toutle River Winter
1975
1980
1985
1990
1995
2000
2005
Year


Clackamas River Winter
Sandy River Winter
South Fork Toutle River Winter
Washougal River Summer
Washougal River Winter
Year
Year

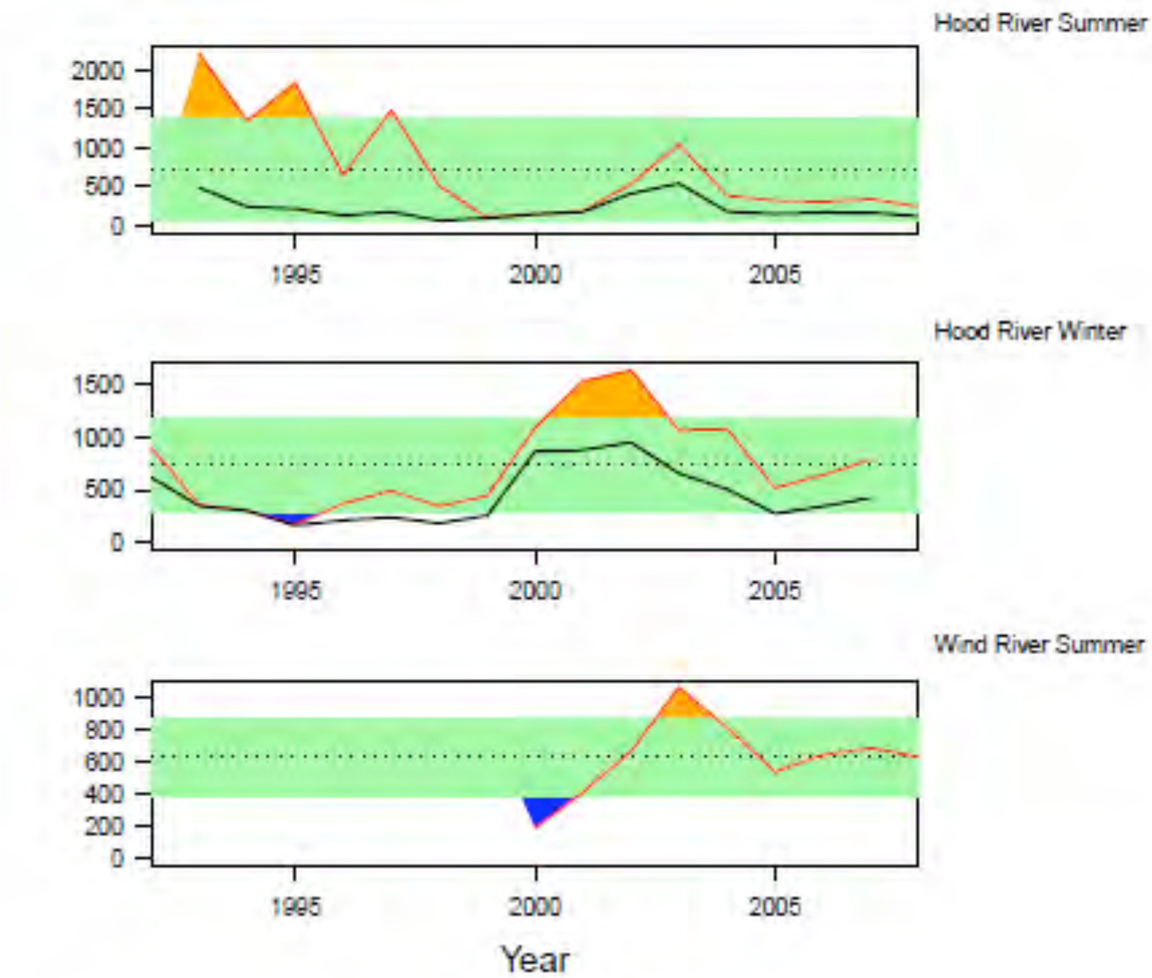
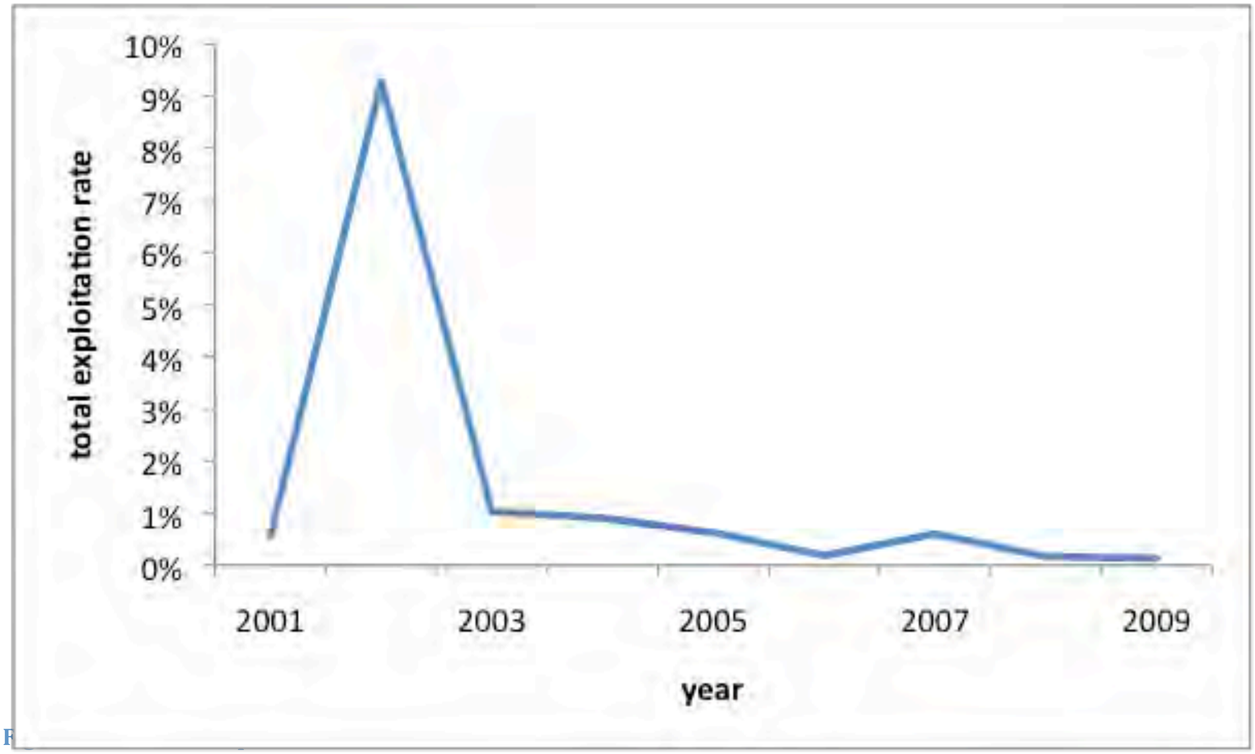


Figure 153 -- LCR steelhead trends in abundance. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawers, and the green shaded area indicates +/- 1 standard deviation around the mean.

Harvest

Winter Run

Few winter-run fish migrate above Bonneville Dam where tribal fisheries occur. In addition, winter-run steelhead are in the mainstem river at a time when there is generally little or no fishing occurring there. Recreational fisheries in Washington tributaries have been mark selective since the mid-1980s. There is no directed winter steelhead fishery in the Willamette River. Winter steelhead fisheries used to target hatchery runs that had an earlier run timing but those hatchery programs were discontinued in the period from 1989-1999. Because very few of the fish ascend above Bonneville Dam, there was little focus on this run prior to listing. Total fishery exploitation rates for the natural component are only available back to 2001 (Figure 154). In that time period exploitation rates have been below the consultation standard of 2% in all years except 2002.



F
include the Lower Columbia River ESU, Upper Willamette River ESU, and portions of the Middle Columbia River and Washington Coastal ESUs. Data from TAC (2010).

Hatcheries

The total steelhead hatchery releases in the LCR ESU have increased since the last status evaluation in 2005 from about 2 million to around 3 million (Figure 155). Some populations (e.g. Hood River, Kalama) have relatively high fractions of hatchery origin spawners where as others (e.g. Wind) have relatively few hatchery origin spawners. Although recovery plans and the HSRG recommend some changes in hatchery programs, there have not been substantial changes from the last status review.

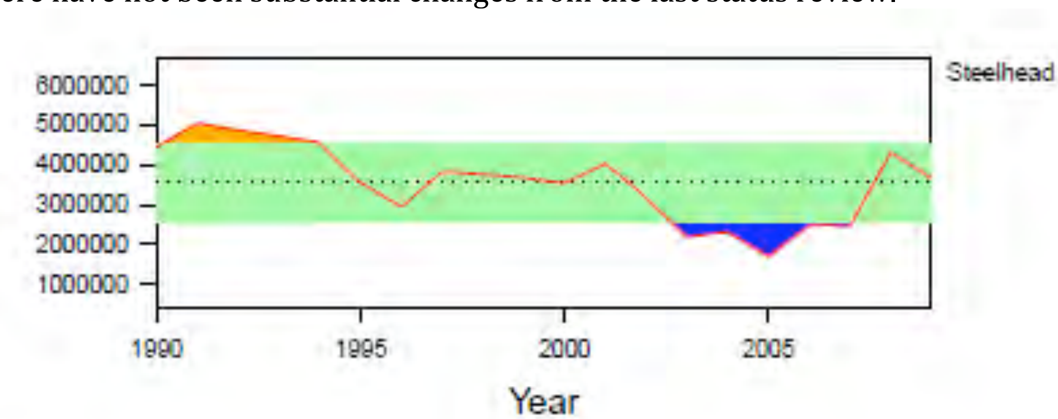


Figure 155 – Annual LCR steelhead hatchery releases. The dotted line indicates the mean and the shaded area the standard deviation. Data source: RMIS.

Lower Columbia River steelhead: Updated Risk Summary

Three status evaluations of LCR steelhead status, all based on WLC-TRT criteria, have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, ODFW 2010, LCFRB 2010). All three evaluations concluded that the ESU is currently at high risk of extinction. Of the 26 historical populations in the ESU, 17 are considered at high or very high risk. Populations in the upper Lewis, Cowlitz and White Salmon watersheds remain cut-off from access to essential spawning habitat by hydroelectric dams. Projects to allow access have been initiated in the Cowlitz and Lewis systems but these have not yet produced self-sustaining populations. The populations generally remain at relatively low abundance with relatively low productivity. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-27.

Good, T. P., R. S. Waples, and P. Adams, editors. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, Seattle.

Lower Columbia Fish Recovery Board. 2010. Washington lower Columbia salmon recovery and Fish and Wildlife subbasin plan. Lower Columbia Fish Recovery Board, Olympia, WA.

McElhany, P., C. Busack, M. Chilcote, S. Kolmes, B. McIntosh, J. M. Myers, D. Rawding, A. Steel, C. Steward, D. Ward, T. Whitesel, and C. Willis. 2006. Revised viability criteria for salmon and steelhead in the Willamette and Lower Columbia Basins. Report, NOAA Northwest Fisheries Science Center, Seattle.

McElhany, P., M. Chilcote, J. M. Myers, and R. Beamesderfer. 2007. Viability status of Oregon salmon and steelhead populations in the Willamette and Lower Columbia Basins. NOAA-Northwest Fisheries Science Center, Seattle, WA.

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. Technical Memorandum NMFS-NWFSC-42, NOAA, Seattle.

Myers, J. M., C. Busack, D. Rawding, and A. R. Marshall. 2002. Identifying historical populations of Chinook and chum salmon and steelhead within the Lower Columbia River and Upper Willamette River evolutionarily significant units. May 10 draft report to the comanagers from the Willamette/Lower Columbia River Technical Recovery Team, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.

Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. Van Doornik, and M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. NMFS-NWFSC-73, NOAA NWFSC, Seattle, WA.

NMFS. 1998. Status review update for deferred and candidate ESUs of West Coast steelhead (Lower Columbia River, Upper Willamette River, Oregon Coast, Klamath Mountains Province, Northern California, Central Valley, and Middle Columbia River ESUs). Predecisional ESA document, National Marine Fisheries Service.
Oregon Department of Fish and Wildlife, R. Beamesderfer, L. Berg, M. Chilcote, J. Firman, E. Gilbert, K. Goodson, D. Jepsen, T. Jones, S. Knapp, C. Knutsen, K. Kostow, B. McIntosh, J. Nicholas, J. Rodgers, T. Stahl, and B. Taylor. 2010. Lower Columbia river conservation and recovery plan for Oregon populations of salmon and steelhead. Oregon Department of Fish and Wildlife, Salem, OR.

Upper Willamette steelhead[30]

Listed ESU/DPS

The DPS includes all naturally spawned anadromous *O. mykiss* (steelhead) populations below natural and manmade impassable barriers in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River (inclusive).

ESU/DPS Boundary Delineation

The ESU Boundaries Review Group (see ESU Boundaries above) did not identify any new information suggesting a revaluation of the Upper Willamette steelhead ESU. This status evaluation was conducted based on existing ESU boundaries.

Summary of Previous BRT Conclusions

NMFS initially reviewed the status of the Upper Willamette River steelhead ESU in 1996 (Busby et al. 1996), with an update in 1999 (NMFS 1999). In the 1999 review, the BRT noted several concerns for this ESU, including relatively low abundance and steep declines since 1988. The previous BRT was also concerned about the potential negative interaction between non-native summer-run steelhead and native winter-run steelhead. The previous BRT considered the loss of access to historical spawning grounds because of dams to be a major risk factor. The 1999 BRT reached a unanimous decision that the Upper Willamette River steelhead ESU was at risk is of becoming endangered in the foreseeable future.

In the most recent status update (Good et al. 2005), a majority (over 71%) of the BRT votes for this ESU fell in the "likely to become endangered" category, with small minorities falling in the "danger of extinction" and "not likely to become endangered" categories. The BRT did not identify any extreme risks for this ESU but found moderate risks in all the VSP categories. On a positive note, the 2005 BRT noted that after a decade in which overall abundance (Willamette Falls count) hovered around the lowest levels on record, adult returns for 2001 and 2002 were up significantly, on par with levels seen in the 1980s. Still, the total abundance was considered small for an entire ESU, resulting in a number of populations that were each at relatively low abundance.

Summary of Recent Evaluations

A report on the population structure of Lower Columbia and Willamette salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The UW steelhead population designations in that report (Figure 156) are used in this status update and were used for status evaluations in a recent recovery plan by ODFW (2010).

A draft recovery plan for UW Chinook and Steelhead was released for comment by ODFW in 2010. The status evaluation in the ODFW recovery plan provided an update of the status evaluation of McElhany et al. (2007), which relied on methods and viability criteria developed by the WLC-TRT (McElhany et al. 2006). The results of the McElhany et al. (2007) evaluation are summarized in Figure 157. These results indicate that the most likely overall status of all populations was in the "moderate risk" category. The ODFW recovery plan update analysis (2010) indicated that the most likely category for the North and South

---

[30] Section author: Paul McElhany

Santiam populations was "low risk" rather than "moderate risk". The McElhany et al. analysis used data up to 2005, whereas the ODFW analysis used data through 2008. Extinction risk modeling in the ODFW 2010 recovery plan suggests that, based only on biological information, the ESU is viable. However, the recovery plan indicates that increasing threats to ESU place it at considerable risk.

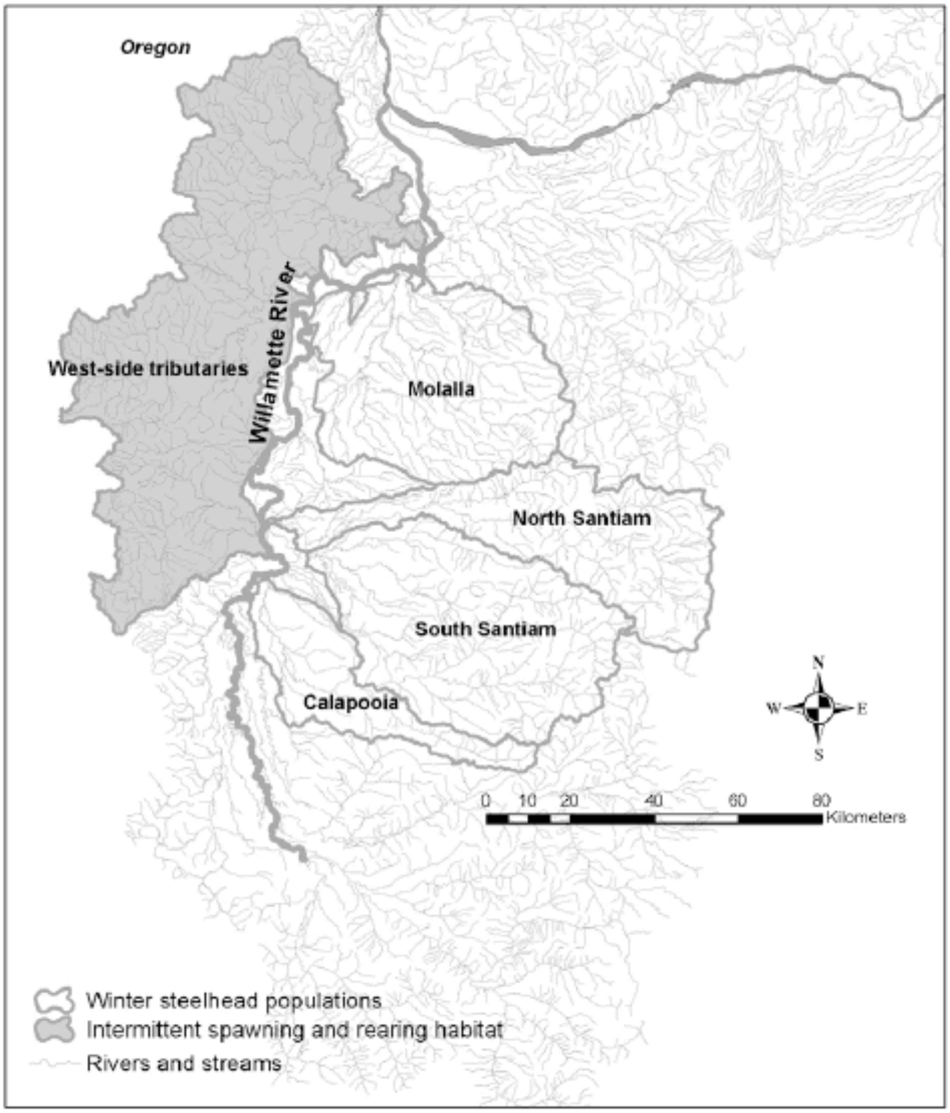


Figure 156 -- Upper Willamette steelhead populations (from Myers et al. 2006)

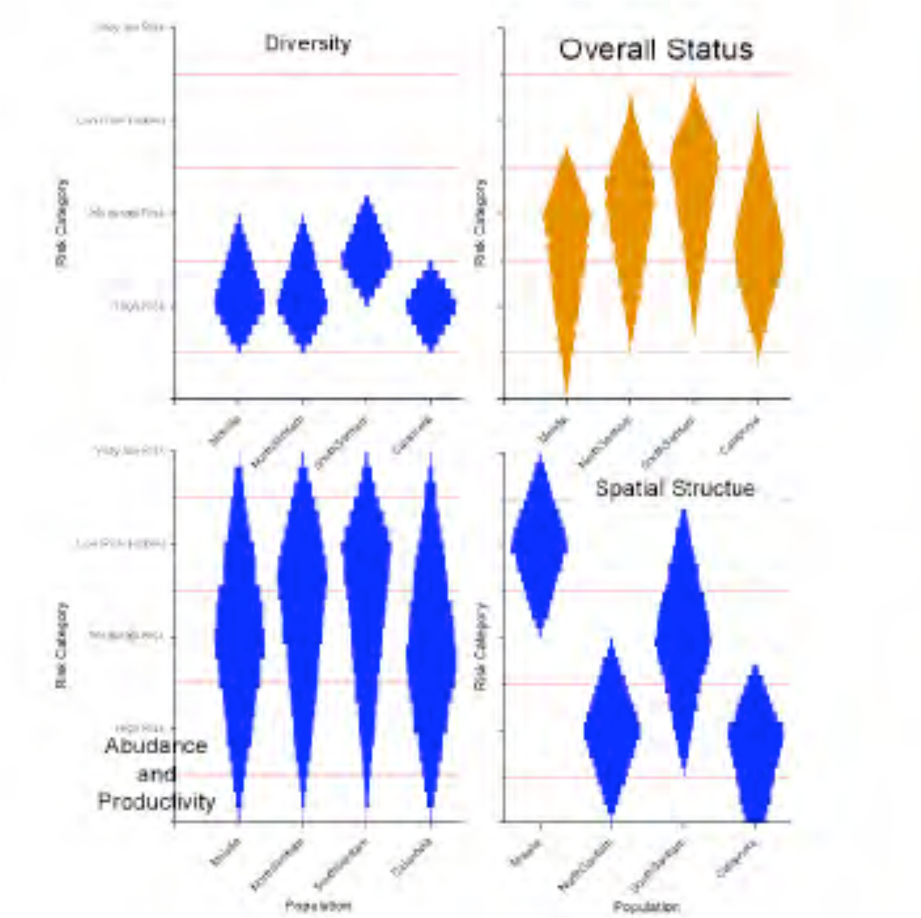


Figure 157 -- Status of UW steelhead populations (from McElhany et al. 2007).

New Data and Analysis

Willamette Falls

All steelhead in the UW steelhead ESU pass Willamette Falls (Figure 158). In the 2005 BRT report, data were only available to the year 2002 when the ESU appeared to be increasing. However, population abundance peaked in 2002 and since returned to the relatively low abundance of the 1990s. The late-returning abundance for the entire ESU in 2009 was 2,110 fish.

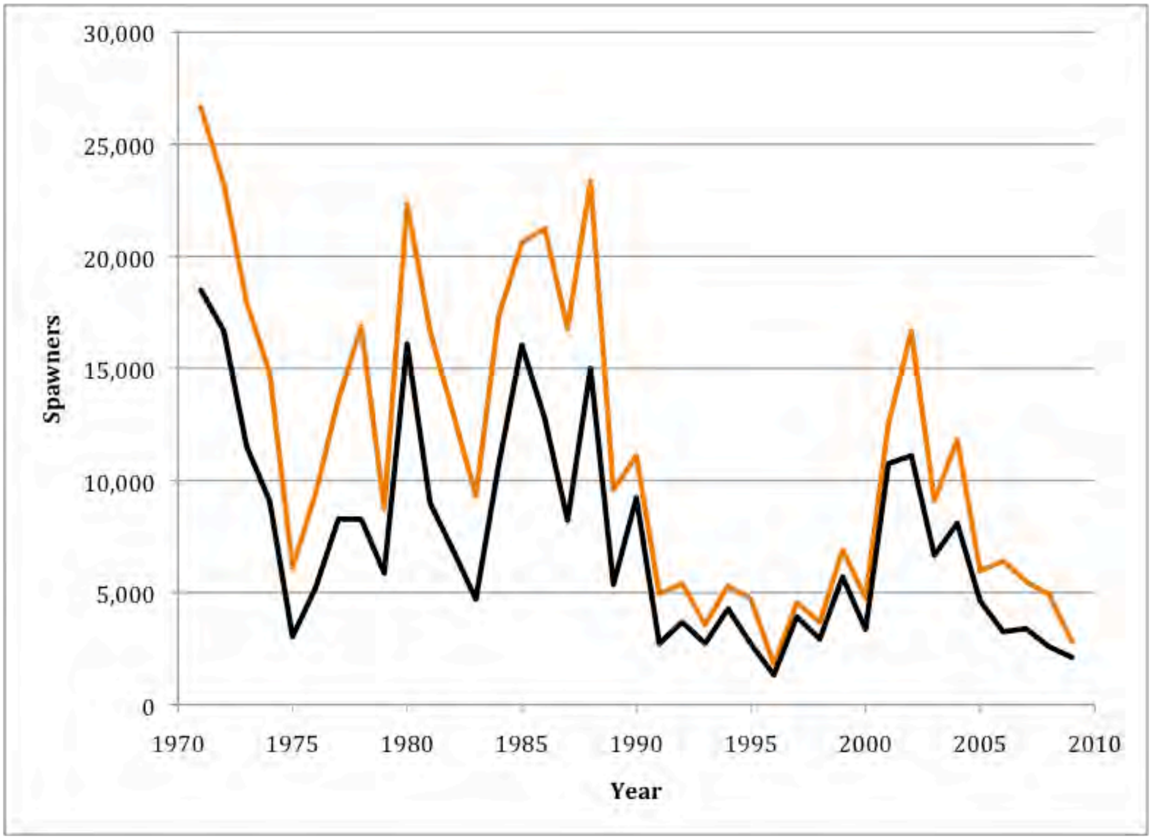


Figure 158 -- Count of winter steelhead at Willamette falls. The upper (orange) line shows the total winter steelhead run. The lower (black) line show the "late" winter steelhead run, which is considered the native life history. Hatchery releases of winter run steelhead in the Willamette were discontinued in 1999. Data from ODFW online Willamette Falls count database (http://www.dfw.state.or.us/fish/fish_counts/willamette%20falls.asp).

Steelhead Populations

The 2005 BRT report used abundance data for the years 1980-2000 for the Mollala population and years 1980-2001 for the other three populations. The current analysis uses data through 2008 (Figure 159). The population estimates mirror the patterns at Willamette Falls with declines in the most recent years. In the 2008, the total abundance of winter steelhead at Willamette Falls was 4,915, which were distributed (minus in basin mortality) into the four populations.

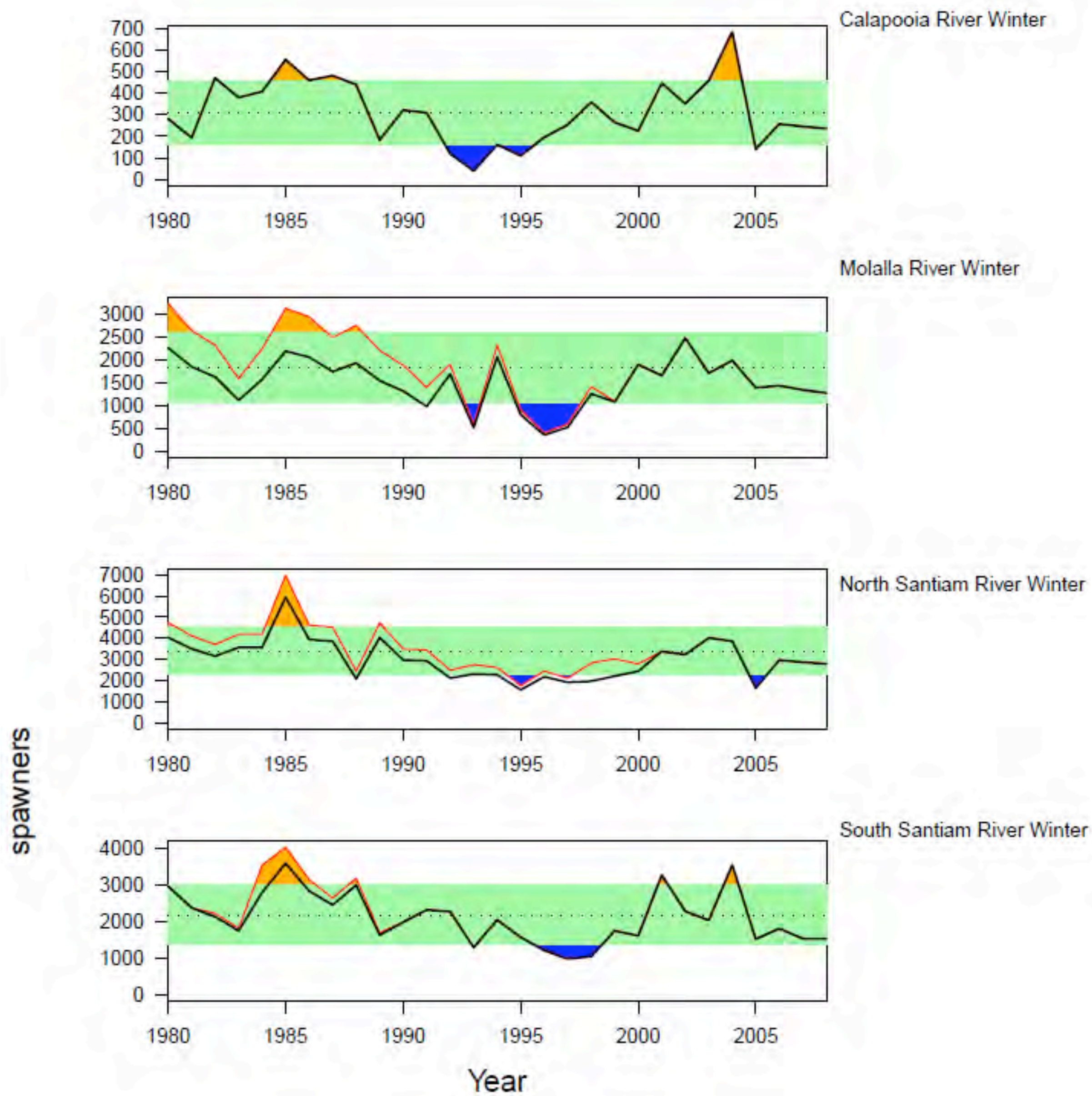


Figure 159 -- Spawner abundance of UW steelhead populations. The dark line indicates natural origin spawner numbers, light (red) line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners, and the green shaded area indicates +/- 1 standard deviation around the mean.

Harvest

There is no directed winter steelhead fishery in the Willamette River. Winter steelhead fisheries used to target hatchery runs that had an earlier run timing but those hatchery programs were discontinued in the period from 1989-1999. Total fishery exploitation rates for the natural component are only available back to 2001 (Figure 160). In that time period exploitation rates have been below the consultation standard of 2% in all years except 2002.

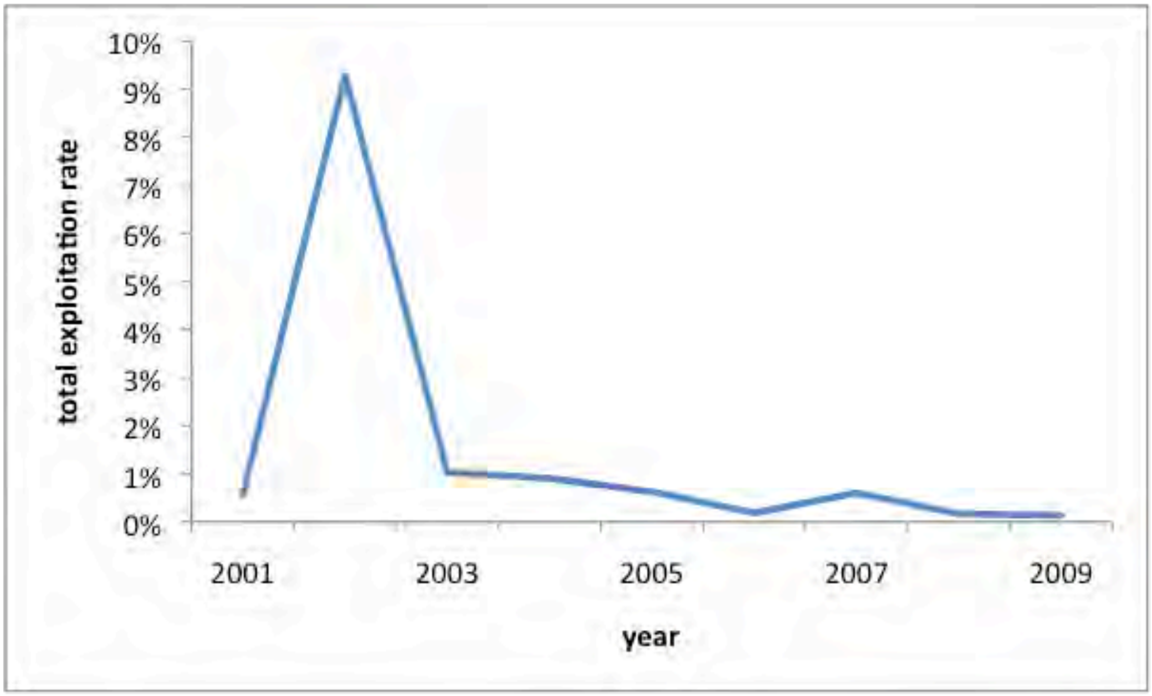


Figure 160 -- Figure #.5: Total exploitation rates on natural winter steelhead from the Columbia Basin. Winter steelhead include the Lower Columbia River ESU, Upper Willamette River ESU, and portions of the Middle Columbia River and Washington Coastal ESUs. Data from TAC (2010).

Hatcheries

Winter steelhead hatchery releases in the UW ceased in 1999. However, there is still a substantial hatchery program for non-native summer steelhead. In recent years, returning summer steelhead have outnumber the native winter run steelhead, which raises genetic and ecological concerns (Figure 161). Total steelhead releases in the basin are shown in Figure 162.

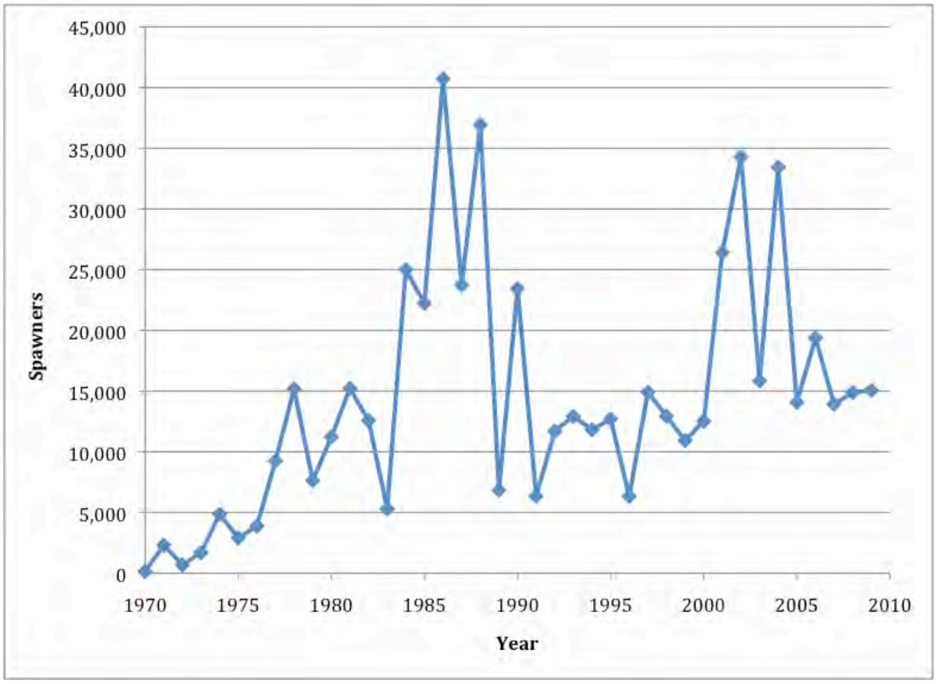


Figure 161 – Non-native, summer steelhead count at Willamette Falls. (data from ODFW online Willamette Falls count database.)

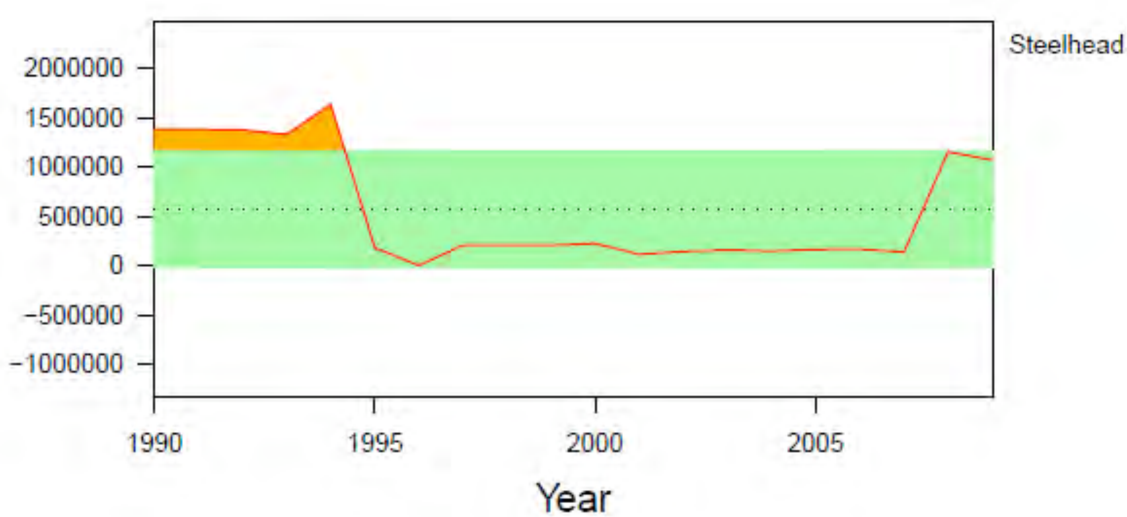


Figure 162 -- Steelhead hatchery releases in the upper Willamette basin.

Upper Willamette steelhead: Updated Risk Summary

Since the last BRT status update, UW steelhead initially increased in abundance but subsequently declines and current abundance is at the levels observed in the mid-1990s when the DPS was first listed. The DPS appears to be at lower risk than the Upper Willamette Chinook ESU, but continues to demonstrate the overall low abundance pattern that was of concern during the last BRT review. The elimination of winter run hatchery release in the basin reduces hatchery threats, but non-native summer steelhead hatchery releases are still a concern. Human population growth within the Willamette Basin constitutes a significant risk factor for these populations. Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

References

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-27.

Good, T. P., R. S. Waples, and P. Adams, editors. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, Seattle.

McElhany, P., C. Busack, M. Chilcote, S. Kolmes, B. McIntosh, J. M. Myers, D. Rawding, A. Steel, C. Steward, D. Ward, T. Whitesel, and C. Willis. 2006. Revised viability criteria for salmon and steelhead in the Willamette and Lower Columbia Basins. Report, NOAA Northwest Fisheries Science Center, Seattle.

McElhany, P., M. Chilcote, J. M. Myers, and R. Beamesderfer. 2007. Viability status of Oregon salmon and steelhead populations in the Willamette and Lower Columbia Basins. NOAA-Northwest Fisheries Science Center, Seattle, WA.

Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. Van Doornik, and M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. NMFS-NWFSC-73, NOAA NWFSC, Seattle, WA.

NMFS. 1999. Updated review of the status of the Upper Willamette River and Middle Columbia River ESUs of steelhead. Memorandum for W. Stelle and W. Hogarth from M. Schiewe, 12 January 1999. (Available from National Marine Fisheries Service, 525 NE Oregon St., Suite 500, Portland, OR 97232.).

ODFW. 2010. Upper Willamette conservation and recovery plan for Chinook and steelhead (Draft February 23, 2010). Oregon Department of Fish and Wildlife.

Climate Change

Climatic conditions affect anadromous salmonid abundance, productivity, spatial structure and diversity either directly or indirectly throughout their habitats in the Pacific Northwest and in the estuarine and marine environments (e.g. ISAB 2007, Mantua et al. 2009). Changes to local and regional climatic conditions due to anthropogenic global climate change thus have potential to affect long-term viability and sustainability of these populations, although the magnitude of those possible effect is likely to vary substantially between regions. Changes in snow-pack, for instance, are likely to be most strongly felt in snow-melt driven systems, while changes in patterns of fresh-water flow are most likely in systems that are already hot, dry, and at relatively low elevations.. Our description of these potential effects is drawn largely from the Oregon Coastal Coho BRT's comprehensive review of climate impacts on salmonids (Stout et al. 2010, especially Appendix C). We have condensed their description, expanded it to include all Pacific Northwest ESUs and updated it with information published after the May 2010 release of the OCC BRT report.

Known Climate-Linked Effects on Anadromous Salmonid Populations

Ocean and estuarine life stages – climate links. In the last decade, associations between climatic and ocean conditions in the North Pacific and salmonid population abundance in the Pacific Northwest and Alaska have been well-documented (Mantua et al. 1997, Hare et al. 1999, Mueter et al. 2002, Francis and Mantua 2003, Stout et al. 2004). Specifically, the Pacific Decadal Oscillation, characterized by 15-30 year periods of alternating relatively warm and relatively cool conditions in the North Pacific, appears to be strongly linked to salmonid returns (Mantua et al. 1997, Zabel et al. 2006, Petrosky and Schaller 2010), with relatively cool ocean temperatures off the Pacific Northwest associated with generally high salmon productivity in that area. The mechanisms underlying this association are unclear but may involve both increased food availability, resulting from increased upwelling bringing higher levels of nutrients to surface waters and changes in the abundance and composition of fish communities and predator populations during warmer periods (Cheung et al. 2009, Wing 2006, Pearcy 2002).

On an annual scale, coastal upwelling brings cold, nutrient-rich waters to the surface, and is the primary source of nutrients for coastal productivity. In the Pacific Northwest, the winter winds primarily produce a down-welling pattern; this transitions in the spring to a summer upwelling (Checkley & Barth 2009). The strength of upwelling is also associated with salmonid productivity (Zabel et al. 2006, Petrosky and Schaller 2010).

Freshwater life stages – climate links. There are also links between climatic conditions and freshwater survival and productivity. In particular, the warm phases of the El Niño Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO) generally produce warmer, drier years in terrestrial habitats. This in turn leads to below-average snowpack, and stream flow (Mote et al. 2003), which both have effects on salmonid populations.

Below average snowpack and stream flow lead to higher stream temperatures, taxing these cold-water obligate fishes. In addition, these changes lead to altered hydrographic patterns. Lower summer flows (due to reduced snowpack) can reduce juvenile survival; changed timing of peak flow can affect migrational timing for both adults and juveniles (ISAB 2007). Overall, salmonid productivity tends to be lower in these warmer, drier conditions (Mote et al. 2003). Winter flooding is another climate and weather-related risk for salmonids, as winter floods can scour stream beds and destroy redds (Waples et al. 2008).

Projected Climate Changes in the Pacific Northwest

There have been several reviews of climate change patterns in the Pacific Northwest (Mote et al. 2003; Leung et al. 2004; Mote et al. 2008b; Karl et al. 2009), corroborated in a broader-scale review for all of North America (Christensen et al. 2007, section 11.5). All of these are based on global climate models that were included in assessments by the U.S. Global Change Research Program (USGCRP) and the International Panel on Climate Change (IPCC). These "ensemble" forecasts result in fairly broad ranges of estimates for future conditions, due to differences in model formulation and greenhouse gas emission scenarios. A summary of the likely effects of climate change in the Pacific Northwest is presented in Table 78, originally presented in Stout et al. (2010).

Table 78 -- Summary of expected physical and chemical climate changes in the Pacific Northwest. (*from Stout et al. 2010).*

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

Ocean and marine environments. Anticipated and highly certain changes in the marine environment include higher sea level, higher ocean temperatures and increased ocean acidity (Bindoff et al. 2007). Higher sea levels will result in decreases and changes to existing estuarine and nearshore habitats. In the short-term, at least, wetland habitats will be less available. Increased ocean temperatures and acidity have the potential to result in unknown changes to foodweb and ecosystem structure (Feely et al. 2004; Fabry et al. 2008). This is likely to include the northward migration of warm-water species. Higher sea-surface temperatures are also associated with lower salmonid productivity (ICTRT and Zabel, 2007, Petrosky and Schaller 2010).

Less certain, but still possible, are intensified upwelling patterns and a delayed transition to spring ocean conditions. Bakun (1990) first proposed that climate change would cause an intensification of upwelling in the California Current (including the Pacific Northwest), due to increased contrast between oceanic-continental temperatures, which would strengthen the pressure gradient that drives the winds. Some recent modeling exercises and analyses of upwelling data (Snyder et al. 2003) support this hypothesis and suggest that upwelling is continuing to intensify, although the onset of upwelling also changed. In addition, Bograd et al. (2009) observed a trend towards later and shorter upwelling in the northern California Current, resulting in a shorter upwelling season. Large-scale models (which do not resolve fine-scale upwelling well) do not suggest substantial changes in coastal upwelling timing or intensity under global warming scenarios (Mote & Mantua, 2002, Diffenbaugh 2005). However, even if upwelling persists, changes to sea surface temperatures will increase the depth of the thermocline (the boundary between warm, nutrient-poor waters with cold, nutrient-rich waters). Therefore, it is not clear whether the thermocline depth will be sufficiently shallow so that upwelling is able to bring nutrient rich water to the surface, rather than warm, nutrient-poor water.

There are indications in the climate models that future conditions in the North Pacific region will trend toward conditions during the warm phase of the Pacific Deacadal Oscillations, but the models in general do not reliably reproduce the oscillation patterns (Overland et al. 2009).

Freshwater and terrestrial habitats. Increased air temperatures and consequent reductions in winter and spring snowpack and reduced summer flows are almost certain to occur in the Pacific Northwest. Reductions in snowpack will result in lower summer flows (greater than 30% reduction by mid century) and earlier peak flows (20 to 40 days earlier by the end of the century) for snowmelt-driven rivers; for predominantly rain-fed coastal rivers, the shift in peak flow timing is not expected to be substantial, but there is an expectation of greater winter flooding and lower summer flows (Karl et al. 2009; Mote et al. 2003). Another consequence of increased air temperatures, reduced snowpack and changes in hydrograph are likely increases in stream temperature (ISAB 2007). Potentially exacerbating these effects is an expectation (though an uncertain expectation) that precipitation will increase in the winter and decrease in the summer (Karl et al. 2009, pp. 135).

Likely impacts on Anadromous Salmonid ESUs.

A variety of studies examining the effects of long-term climate change to salmon populations 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). However, the direct and indirect effects of global climate change on Pacific Northwest salmonid ESUs will vary among ESUs, and even, in some cases, among populations, depending on the local consequences of climate change, ESU-specific characteristics, local habitat quality and other smaller-scale characteristics.

We summarize the likely effects in Table 79 (adapted from Stout et al. 2010). Importantly, while many of the individual effects of climate change on Pacific Northwest ESUs are expected to be weak or are uncertain, we need to consider the cumulative impacts across the 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 larger changes in the overall dynamics of populations. This means the mostly negative effects predicted for individual life history stages may potentially result in a negative overall effect of climate change on Pacific Northwest salmonids over the next few decades, although the magnitude of effects is likely to vary considerably among regions.

In the long-term, some habitats currently occupied by anadromous salmonids may become uninhabitable due to the cumulative effects of climate change, and species may exhibit elevational and latitudinal shifts in distribution (e.g. Battin et al. 2007). This raises the possibility that some ESUs may have significant abbreviations of or changes to their current range in comparison with their historical distribution. This also raises a number of risks related to spatial structure (curtailment of range), diversity (mixing of ESUs or populations previously geographically segregated), and abundance and productivity (potentially insufficient habitat to sustain viable populations in the long-term). In addition, salmonids are highly plastic and have shown remarkable ability to adapt to local conditions. Ongoing work to track evolutionary, adaptive (or maladaptive) change in response to climate changes will be an important component of evaluating long-term viability of Pacific Northwest salmonid ESU viability.

Table 79 -- Summary of expected climate effects on Pacific Northwest ESUs. Effect ratings are: + +, strongly positive; +, positive; 0, neutral; -, negative, - -, strongly negative. Certainty level combines the certainty of the physical change (Table A) with the certainty of the effect. Table adapted from Stout et al. (2010).

Habitat	Physical Change	Process Affecting Salmon	Effect on Pacific Northwest Salmonid ESUs	Certainty	Main Sources
Terrestrial	Warmer, drier summers	Increased fires, increased tree stress & disease affect LWD, sediment supplies, riparian zone structure	- - to 0 Largest effects likely to be felt in Interior Columbia populations, particularly in areas at lower and mid- elevations	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
Freshwater	Reduced summer flow	Less accessible summer rearing habitat	- - to - Effects most pronounced in areas of currently low flow, particularly in Interior Columbia populations.	Moderate	Crozier & Zabel, 2006; Crozier et al., 2008; ISAB, 2007; Mantua et al., 2009
	Earlier peak flow	Potential migration timing mismatch	-- to 0 Largest effects in 'transition' areas that move from a snow-melt dominated hydrograph to rain-driven	Moderate	Crozier et al., 2008
	Increased floods	Redd disruption, juvenile displacement, upstream migration	- - to 0 Largest effects in 'transition' areas that move from a snow-melt dominated hydrograph to rain-driven	Moderate	ISAB, 2007; Mantua et al., 2009

	Higher stream temperature	Thermal stress, restricted habitat availability, increased susceptibility to disease and parasites	- - to – Largest effects likely in currently high temperature areas of the Interior Columbia and low elevation areas	Moderate	Marine & Cech, 2004; ISAB, 2007; Crozier et al., 2008; Farrell et al., 2008; Marcogliese, 2008; Mantua et al., 2009;
Estuarine	Higher Sea Level	Reduced availability of wetland habitats	-- to – Largest effects on ESUs with a life history highly dependent upon relatively long-term rearing in estuarine and tidally influenced areas.	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 – Largest effects on ESUs with highly estuarine-dependent life cycles and ESUs subject to stress at earlier life stages	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
Marine	Higher ocean temperature	Thermal stress, shifts in migration, susceptibility to disease & parasites	-- to – Effects likely to vary by ESU, dependent upon ocean distribution	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 ++ Effects likely to vary by ESU and correspondence of outmigration with upwelling patterns.	Moderate	Nickelson, 1986; Fisher & Pearcy, 1988
	Delayed spring transition	Food timing mismatch with outmigrants, ecosystem shifts	- - to 0 Effects likely to vary by ESU dependent upon correspondence of	Moderate	Schwing et al., 2006; Brodeur et al., 2005; Emmett et al., 2006

		outmigration with upwelling patterns.		
Increased acidity	Disruption of food supply, ecosystem shifts	-- to – Effects likely to vary by ESU, dependent upon age and size at outmigration and ocean distribution	Moderate	Fabry et al., 2008
Combined effects	Changing composition and structure of ecosystem; changing food supply and predation	-- to + Effects likely to vary by ESU dependent upon age and size at outmigration and ocean distribution	Low	Fabry et al., 2008; Peterson & Schwing, 2003; Brodeur et al., 2005; Emmett et al., 2006; Bograd et al., 2009

References

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.

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.

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.

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.

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.

Checkley, D. M., and J. A. Barth. 2009. Patterns and processes in the California Current System. Progress in Oceanography xxx:(in press).

Cheung, W. W. L., V. W. Y. Lam, et al. (2009). "Projecting global marine biodiversity impacts under climate change scenarios." Fish and Fisheries 10(3): 235-251.

Christensen, J. H., B. Hewiston, A. Busuioc, 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.

Cole, J. 2000. Coastal sea surface temperature and coho salmon production off the north-west United States. Fisheries Oceanography 9:1-16.

Crozier, L. G., R. W. Zabel, and A. F. Hamlet. 2008. 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.

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.

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.

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 CO_2 on the CaCO_3 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.

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.

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.

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.

Hare, S. R., N. J. Mantua, et al. (1999). "Inverse production regimes: Alaska and West Coast Pacific salmon." Fisheries 24(1): 6-14.

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]

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.

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.

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.

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.

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.

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.

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/moteetalslr579.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]

Mueter, F. J., R. M. Peterman, et al. (2002). "Opposite effects of ocean temperature on survival rates of 120 stocks of Pacific salmon (Oncorhynchus spp.) in northern and southern areas." Canadian Journal of Fisheries and Aquatic Sciences 59(3): 456-463.

Nickelson, T. E. 1986. Influences of upwelling, ocean temperatrue, 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.

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.

Pearcy, W. G. 2002. Marine nekton off Oregon and the 1997–98 El Niño. Progress in Oceanography 54(1-4):399-403.

Peterson, T. C., D. M. Anderson, S. J. Cohen, M. Cortez-Vázquez, R. J. Murname, 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.

Petrosky CE, Schaller HA. (*in press*) Influence of river conditions during seaward migration and ocean conditions on survival rates of Snake River Chinook salmon and steelhead. Ecology of Freshwater Fish.

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

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.

Stout, H.A., P.W. Lawson, D. Bottom, T. Cooney, M. Ford, C. Jordan, R. Kope, L. Kruzic, G.Pess, G. Reeves, M. Sheuerell, T. Wainwright, R. Waples, L. Weitkamp, J. Williams and T. Williams. 2010. Scientific conclusions of the status review for Oregon Coast coho salmon (Oncorhynchus kisutch). Draft report from the Biological Review Team. Northwest Fisheries Science Center, Seattle, WA. May 20, 2010.

Waples, R. S., G. R. Pess, et al. (2008). "Evolutionary history of Pacific salmon in dynamic environments." Evolutionary Applications 1(2): 189-206.

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.

Zabel, Richard, Mark Scheuerell, Michelle McClure and John G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology 20(1):190-200.