NOAA Technical Memorandum NMFS-NWFSC-113

Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest

November 2011

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest

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Executive Summary

This technical memorandum summarizes updated information on West Coast Pacific salmon (*Oncorhynchus* spp.) since the last status review in 2005 related to evolutionarily significant unit/distinct population segment (ESU/DPS) boundaries, status, and trends in abundance, productivity, spatial structure, and diversity. The current report focuses solely on the ESUs/DPSs in the northwest region. A similar report has been compiled by the Southwest Fisheries Science Center summarizing status information for ESUs/DPSs in the southwest region.

In the last formal status review in 2005, the biological review team categorized each ESU as either 1) in danger of extinction, 2) likely to become endangered, or 3) not likely to become endangered, based on the ESU's abundance, productivity, spatial structure, and diversity. In the current report, for each listed ESU/DPS, we summarize whether there is new information since 2005 to indicate that the ESU is likely to have moved from one of the three biological risk categories to another. We focus only on the biological risk category and recognize that listing status is a function of the biological status and trends of the listed species as well ongoing protective efforts, which were not evaluated in this report.

One of the notable differences between 2010/2011 and the last status review in 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 and launched a series of regional technical recovery teams (TRTs) to develop viability criteria for each listed ESU/DPS. However, at the time of the 2005 status review, only one TRT (for Puget Sound Chinook salmon [*O. tshawytscha*]) 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. Where possible, therefore, our review summarizes current information with respect to the viability criteria developed by the TRTs or the recovery goals identified in final recovery plans.

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. Some of the information we reviewed indicates that a further review of ESU/DPS boundaries may be appropriate, particularly the northern boundary of Puget Sound coho salmon (*O. kisutch*) and the boundaries between lower and middle Columbia River ESUs/DPSs of Chinook and coho salmon and steelhead (*O. mykiss*).

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Acknowledgments

We are grateful to the large number of regional biologists who provided raw data and information used in this report. It was improved as a result of comments provided by state, tribal, and federal comanagers on an earlier draft. The effort to update the status of all listed ESUs of West Coast salmon and steelhead would not have been possible without the help of many, including Paul Moran, Melanie Paquin, Heather A. Stout, Mari Brick, Krista Bartz, and Mindy Rowse.

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Abbreviations and Acronyms

A/P	abundance and productivity
AEQ ER	adult equivalent exploitation rate
BRT	biological review team
CI	confidence interval
CRITFC	Columbia River Inter-Tribal Fish Commission
CTC	Chinook Technical Committee
CU	conservation unit
CWT	coded-wire tag
DIP	demographically independent population
DPS	distinct population segment
EDT model	ecosystem diagnostic and treatment model
ESA	U.S. Endangered Species Act of 1973
ESU	evolutionarily significant unit
HSRG	Hatchery Scientific Review Group
ICTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
LFA	limiting factors analysis
LSRB	Lower Snake River Recovery Board
MAL	major ancestral lineage
MAT	minimum abundance threshold
MDS	multidimensional scaling
MPG	major population group
MSY	maximum sustained yield
NFH	national fish hatchery
NMFS	National Marine Fisheries Service
NWIFC	Northwest Indian Fisheries Commission
ODFW	Oregon Department of Fish and Wildlife
PDO	Pacific Decadal Oscillation
PFC	proper functioning condition
PGE	Portland General Electric
PIT tag	passive integrated transponder tag
PSC	Pacific Salmon Commission
PSMFC	Pacific States Marine Fisheries Commission
PVA	population viability analysis
QET	quasi-extinction threshold
R/S	recruits per spawner
RMIS	Regional Mark Information System
RMPC	Regional Mark Processing Center
SAR	smolt to adult return ratio
SaSI	salmonid stock inventory (WDFW)

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SBSTOC	Stanley Basin Sockeye Technical Oversight Committee
SS/D	spatial structure/diversity
TRT	technical recovery team
UCSRB	Upper Columbia Salmon Recovery Board
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid population
WCVI	West coast of Vancouver Island
WDFW	Washington Department of Fish and Wildlife
WLC	Willamette/Lower Columbia

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Introduction and Summary of Conclusions

The U.S. Endangered Species Act (ESA) requires that the National Marine Fisheries Service (NMFS) review the status of listed species under its authority at least every 5 years and determine whether any species should be removed from the list or have its listing status changed. In June 2005 NMFS issued final listing determinations for 16 evolutionarily significant units (ESUs) of Pacific salmon (*Oncorhynchus* spp.) and in January 2006 NMFS issued final listing determinations for 10 distinct population segments (DPSs) of steelhead (*O. mykiss*, the anadromous form of rainbow trout).[1] NMFS therefore conducted 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).[2]

The review was conducted by the NMFS northwest and southwest regions. This report is in response to a 23 February 2010 request from the regions to the Northwest Fisheries Science Center and the Southwest Fisheries Science Center 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 1) in danger of extinction, 2) likely to become endangered, or 3) not likely to become endangered, based on the ESU's abundance, productivity, spatial structure, and diversity. In the current 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 information on ESU/DPS boundaries and 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 (TRTs) to develop viability criteria for each listed ESU/DPS (see http://www.nwfsc.noaa.gov/trt/index.cfm). However, at the time of the 2005 status review, only one TRT (for Puget Sound

[1] For Pacific salmon, NMFS uses its 1991 ESU policy that states a population or group of populations will be considered a distinct population segment if it is an ESU. The species *O. mykiss* is under the joint jurisdiction of NMFS and the U.S. Fish and Wildlife Service, so in making its listing January 2006 determinations, NMFS elected to use the 1996 USFWS/NMFS DPS policy for this species.
[2] The Oregon Coast Coho Salmon ESU was reviewed in 2010 and therefore is not included in this report.

Chinook salmon [*O. tshawytscha*]) 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.[3] 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 "Hs," 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 the ESU and the types of activities that have been conducted to address those threats. That 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 for 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.

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 ESUs/DPSs.

[3] Recovery plan goals were based on 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.

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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 ESU	2002
Puget Sound, Hood Canal summer chum (*O. keta*)	Determination of independent populations and viability criteria for the Hood Canal summer chum salmon ESU	2009
Puget Sound, Lake Ozette sockeye (*O. nerka*)	Viability criteria for the Lake Ozette sockeye salmon ESU	2009
Willamette, lower Columbia	Revised viability for salmon and steelhead in the Willamette and lower Columbia basins 2003 and 2006	2006
Oregon coast	Biological recovery criteria for the Oregon coast coho (*O. kisutch*) salmon ESU	2007
Interior Columbia basin	Viability criteria for application to interior Columbia basin salmonid ESUs	
North central California coast	A framework for assessing the viability of threatened and endangered salmon and steelhead in the north central California coast recovery domain	2007
Southern Oregon, northern California coast	Framework for assessing viability of threatened coho salmon in the southern Oregon and northern California coast ESU	2007
Southern and 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

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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 and 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

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Methods

This report includes 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 analyses; see the individual ESU/DPS subsections for a description of the analysis that pertain to specific ESUs/DPSs.

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 on which the spawning abundance estimates were developed consist of numerous types of data including redd counts, dam counts, carcass surveys, information on prespawning mortality, and spawning distributions within populations that 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 of natural origin are not 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 (Good et al. 2005). Recent abundance of natural spawners is reported as the geometric mean (and range) of the most recent 5 years of data. 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-term 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 the exponentiated slope, such that a value greater than 1 indicates an upward trend and a value less than 1 indicates a downward trend. 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

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error of the estimate of the slope, b_1. We also calculated short-term 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).

We plotted trends in hatcheries releases within the geographic boundaries of the spawning populations of each ESU. All data were 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 the Pacific Salmon Commission (PSC), Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), U.S. Fish and Wildlife Service (USFWS), tribes, and Idaho Department of Fish and Game (IDFG), it was determined that all data, or nearly all data in the case of ODFW, have 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 coded-wire tag (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, Northwest Indian Fisheries Commission (NWIFC), Columbia River Inter-Tribal Fish Commission (CRITFC), and IDFG, were queried in Washington, Oregon, and Idaho to obtain all releases of all species in the RMIS and create a master data set. 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 four 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 (broodyear) 1 for fall spawners (most salmon) and as release year (broodyear) for spring spawners (steelhead). Age-zero releases were considered subyearlings and age-1 or greater were considered yearlings.

Determining release location by ESU and PSC basin was a multistep 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 the 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.

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 subsections for details.

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ESU Boundaries

ESU and DPS Definition

In establishing whether a petitioned biological entity can be listed under the ESA, it must first be determined whether the entity can be considered a species under ESA. The ESA allows listing not only of full taxonomic species, but also named subspecies and 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 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 population 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 an important component in the evolutionary legacy of the species.

In 2006 NMFS departed from its practice of applying the ESU policy to steelhead populations, and instead applied the joint USFWS-NMFS DPS definition in determining species of steelhead for listing consideration (71 FR 834, 5 January 2006). This change was initiated because steelhead are jointly administered with USFWS, which does not use the ESU policy in its listing decisions (71 FR 834, 5 January 2006). Under the joint USFWS 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 steelhead are discrete (and hence are different DPSs), whereas BRTs have generally concluded that resident and anadromous steelhead 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 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, and

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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 BRTs 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 on, 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 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 coast-wide 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 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 the last 15 years have expanded the existing databases 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 TRTs in their identification of populations within listed ESUs and DPSs (Table 3). This review will not explicitly discuss all of

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Table 3. TRT reports on population structure within listed Pacific Northwest ESUs and distinct population segments. 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 ESU	2009
Puget Sound, Lake Ozette sockeye	Identification of an independent population of sockeye salmon in Lake Ozette, Washington	2009
Willamette and 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 in the Oregon coast ESU	2007
Interior Columbia basin	Independent populations of Chinook, steelhead, and sockeye for listed ESUs within the interior Columbia River domain	2003

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.

Coho Salmon—Puget Sound and Washington Coast ESUs

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 the Columbia River portion was listed under the 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 (Stout et al. in press) and therefore will not be discussed here.

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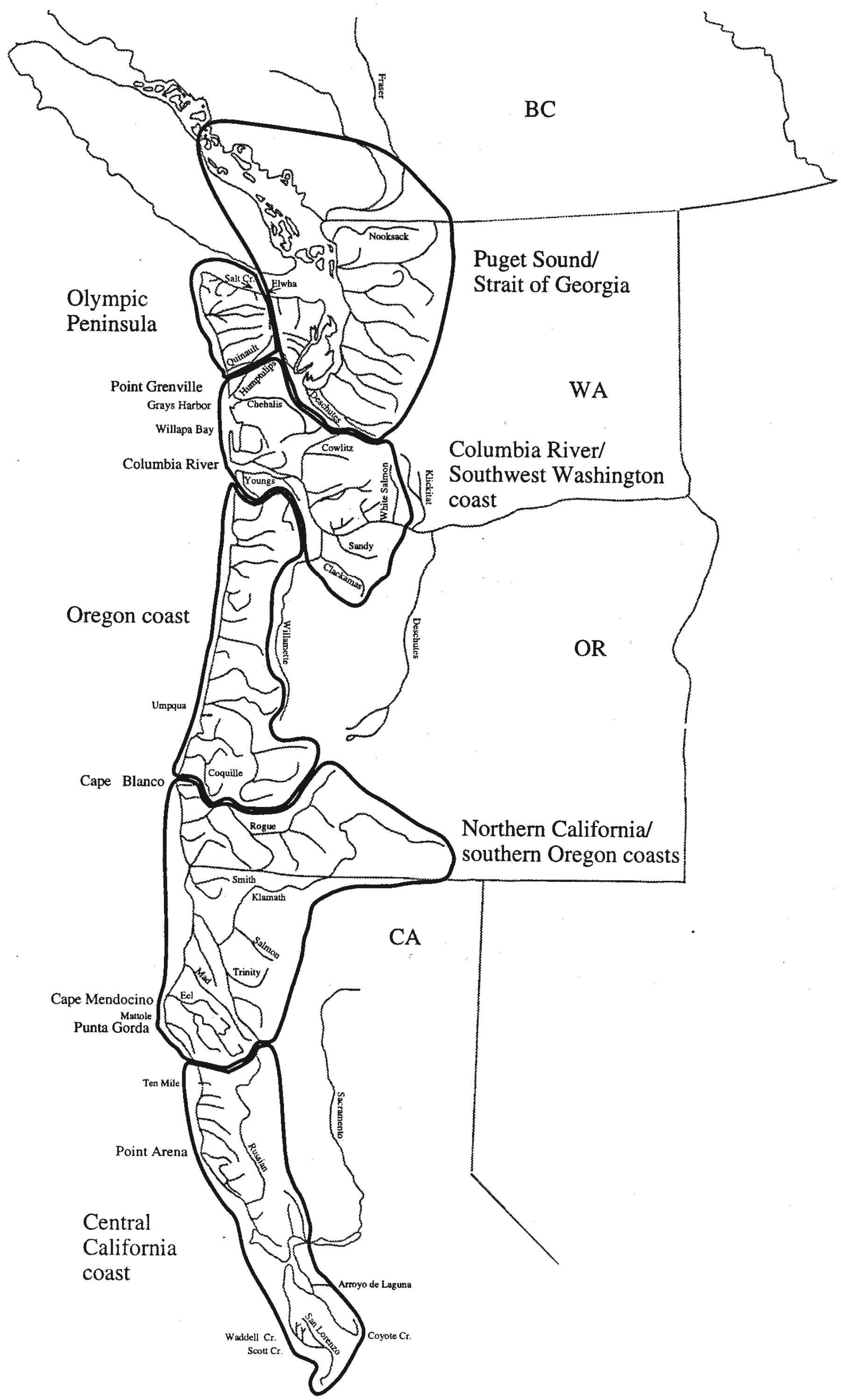

Figure 1. ESUs for coho salmon proposed in 1995. Since 2005 lower Columbia River coho salmon form their own ESU. (Reprinted from Weitkamp et al. 1995.)

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Information Related to the Original Delineation of Coho ESU Boundaries in 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 (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) and rainfall is considerable. At the south end of this range, there are extensive mudflats or sandflats within the Columbia River estuary, Willapa Bay, and Grays Harbor due to the shared geology of the Willapa Hills area 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, colder, glacially influenced headwaters, and high average flows with a relatively long duration of peak flows, including a second summer peak resulting from snowmelt. 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 rain shadow 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 rain forest 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 snowmelt peak, although flow levels per basin area are much lower than in the Olympic Peninsula (Weitkamp et al. 1995).

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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 ESU boundaries. A thorough review of coho salmon population 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 a marine distribution pattern based on recoveries of CWTs 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 coast wide, 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 data set 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 and an analysis of genetic distances identified seven major genetic clusters (Figure 2).

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 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 Weitkamp et al. (1995) analysis, 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.

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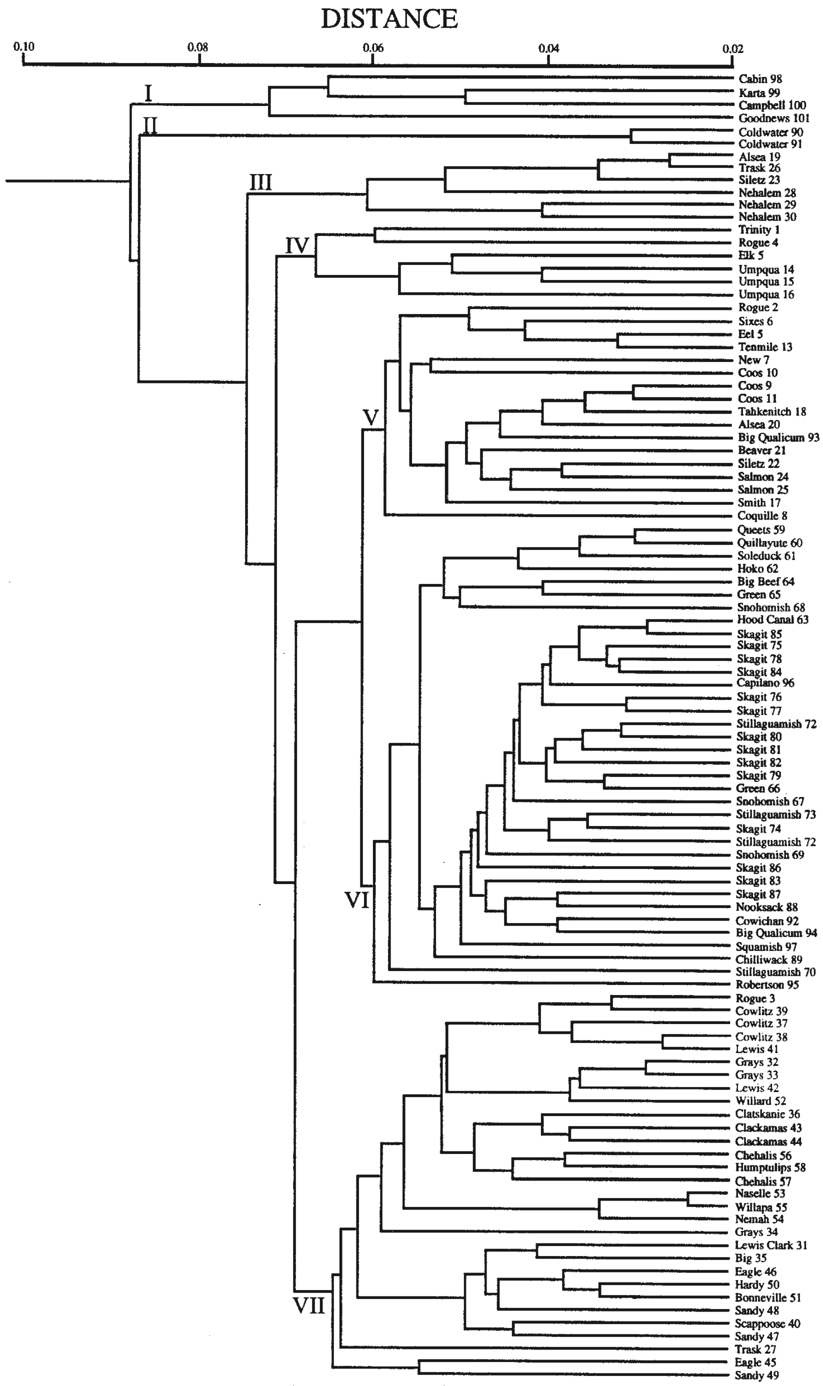

Figure 2. Dendrogram using 53 polymorphic allozymes loci and based on pairwise genetic distance values (Cavalli-Sforza Edwards chord distance) between 101 samples of coho salmon from the Pacific Northwest. Cluster VI includes populations from the northern Washington coast, Strait of Juan de Fuca, Puget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

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2006). Myers et al. (2006) reviewed a study conducted by geneticists at the Department of Fisheries and Oceans Canada that used four microsatellite DNA loci and one histocompatibility locus (Shaklee et al. 1999). Although the Shaklee et al. (1999) data set included only two lower Columbia River (Cowlitz and Lewis rivers) studies, 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 data set 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 characteristics

As described above, one line of life history evidence that indicated major changes coast wide was the marine distributions of coho salmon based on recoveries of CWT hatchery fish. Weitkamp and Neely (2002) redid this analysis, using the same 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 in the earlier analysis, they found that wild and hatchery salmon from the

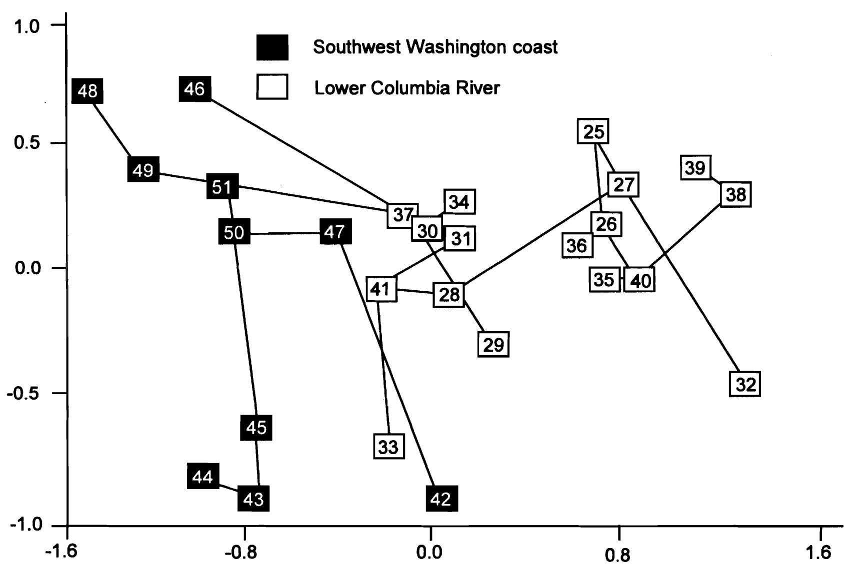

Figure 3. Multidimensional scaling and minimum spanning tree of pairwise chord distance values (Cavalli-Sforza and Edwards 1967) among 27 samples of coho salmon from lower Columbia River and southwest Washington coast. Analysis was based on data for 61 gene loci. Samples from lower Columbia River populations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

same freshwater region shared a common recovery pattern and that the recovery patterns abruptly changed across regions, with little or no transition between regions.

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

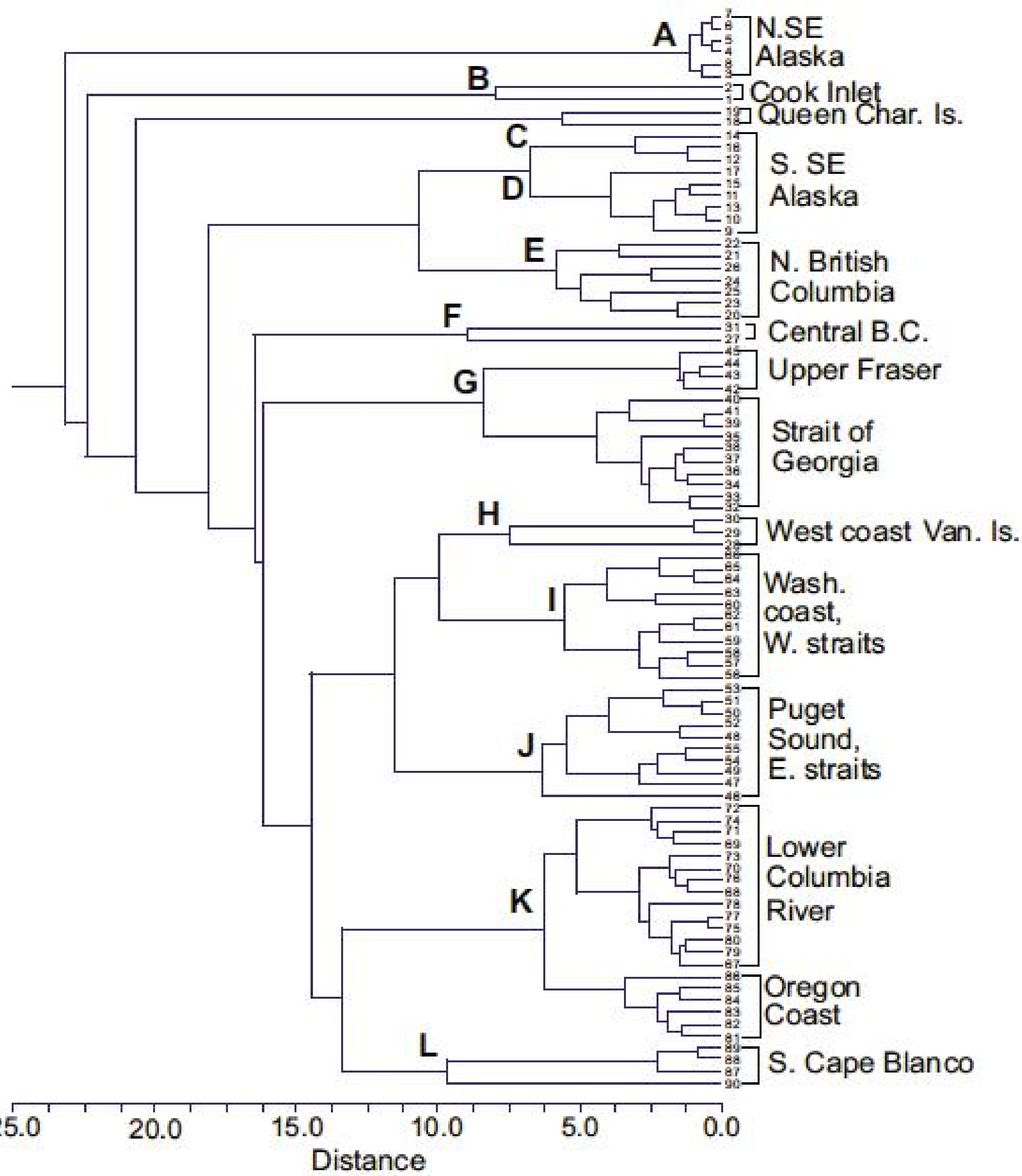

Figure 4. Dendogram based on marine recovery patterns of 90 hatchery and 36 wild coho salmon populations. Names indicate the freshwater release region. (Reprinted with permission from Weitkamp and Neely 2002, copyright National Research Council Canada).

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).

Genetical characteristics

The DNA data set 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). That 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 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 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), 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).

Average F_{st} 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 F_{st} value was for east Vancouver Island (0.023), largely due to the divergence effect of the Goldstream Hatchery population. The second largest within-region F_{st} was the northern Washington coast group (0.021), primarily because of the natural and hatchery summer-run coho salmon populations in the Sol Duc River,

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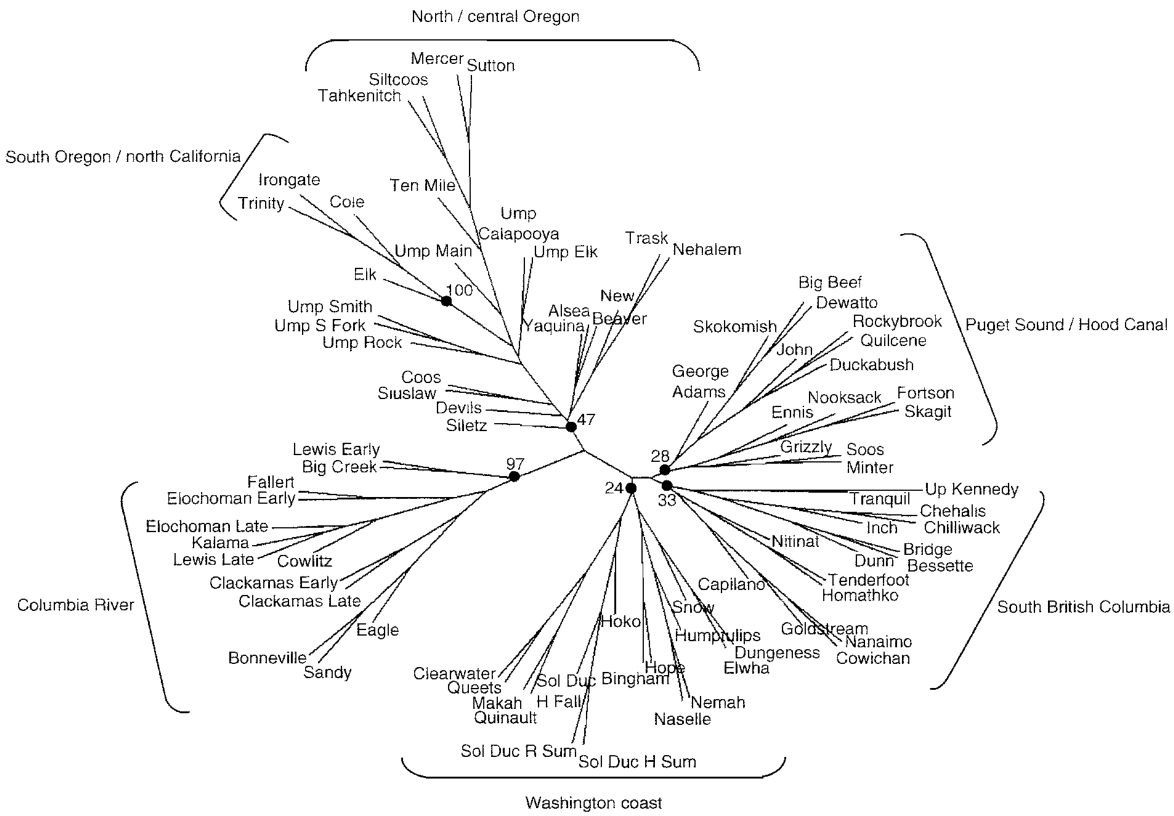

Figure 5. Neighbor-joining dendrogram generated from Cavalli-Sforza and Edwards' (1967) chord distances for 84 coho salmon samples collected within six regions of the Pacific coast. Bootstrap values (%) for the regions are shown. (Reprinted with permission from Van Doornik et al. 2007, copyright Taylor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

Table 4. Mean pairwise F_{st} 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. Data 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

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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 F_{st} 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 with which coho salmon interact. West Coast ESUs have been delineated for pink salmon (*Oncorhynchus gorbuscha*) (Hard et al. 1996), chum salmon (Johnson et al. 1997), sockeye salmon (Gustafson et al. 1997), 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, 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 northernmost 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, 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

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foundation of CUs 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 6 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. 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

This subsection 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 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.

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 the 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 DPSs or sharing some characteristics with either of the DPSs. 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. ODFW includes several small tributaries, Mosier, Mill, and Fifteenmile creeks in its Mid-Columbia Gene Conservation Group (Kostow 1995).

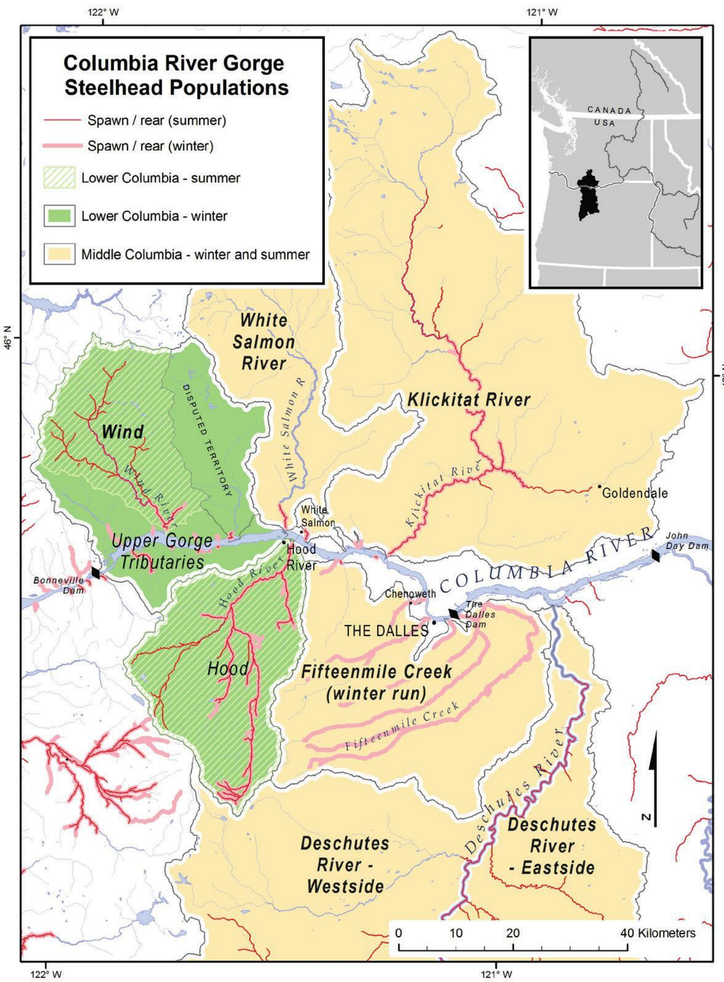

Figure 6. Current boundaries between the lower and middle Columbia River steelhead DPSs. The current boundary between the lower and middle Columbia River Chinook salmon ESUs runs between the White Salmon and the Klickitat rivers and the Hood and Deschutes rivers.

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. (1986) 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 River basin steelhead populations with an affinity to interior populations (Figure 7). Phelps et al. (1997) grouped adult and juvenile steelhead 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 steelhead from the Yakima and Klickitat rivers were distinct from each

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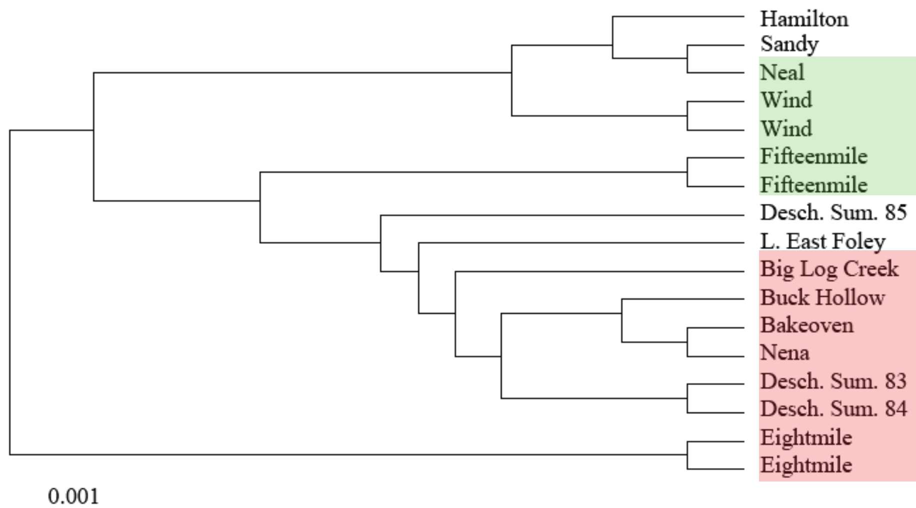

Figure 7. UPGMA (unweighted pair group method with arithmetic mean) dendrogram of lower Columbia and Deschutes river steelhead based on CSE chord distances. Data from Currens 1997, graph from McClure et al. 2003. Lower Columbia populations are in top block, interior Columbia populations are in bottom block. Eightmile Creek *O. mykiss* are thought to be resident rainbow trout (Currens 1997).

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 coastal steelhead 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.

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 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 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. (1986) 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.

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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 reentering freshwater. 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-ocean steelhead (Table 5). Busby et al. (1996) 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 with 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.

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) would 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 that 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.

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

Population	Run type	0	1	2	3	4	N
Cowlitz River	O	—	—	**0.64**	0.34	0.02	56
Kalama River	O	—	0.04	**0.76**	0.20	—	1,363
Kalama River	S	—	0.20	**0.74**	0.06	—	909
Washougal River	O	—	0.14	**0.71**	0.14	—	141
Wind River	S	—	0.05	**0.68**	0.26	—	19
Hood River	O	—	0.06	**0.73**	0.21	—	*
Hood River	S	—	0.08	**0.77**	0.15	—	*
Klickitat River	S	—	0.16	**0.79**	0.05	—	148
Deschutes River	S	—	**0.53**	0.47	—	—	100
John Day River	S	—	**0.51**	0.44	0.04	—	115

*Data from Kostow 2003, sample size not reported.

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The relationship between steelhead populations in the White Salmon, Klickitat, and Hood rivers and Fifteenmile Creek and coastal and inland lineages remained topical outside of the BRT discussions. Steelhead 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 areas 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 were not assessed.

Kostow (2003) indicated that Fifteenmile Creek was the easternmost 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 Eightmile and Fifteenmile 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).

Information Related to the Original Delineation of Chinook DPS Boundaries in the Columbia River

The coast-wide Chinook salmon BRT (Myers et al. 1998) initially reviewed biological and geographic information on Chinook populations in California, Idaho, Oregon, and Washington. In identifying 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-run and fall-run Chinook that existed in the Big White Salmon River

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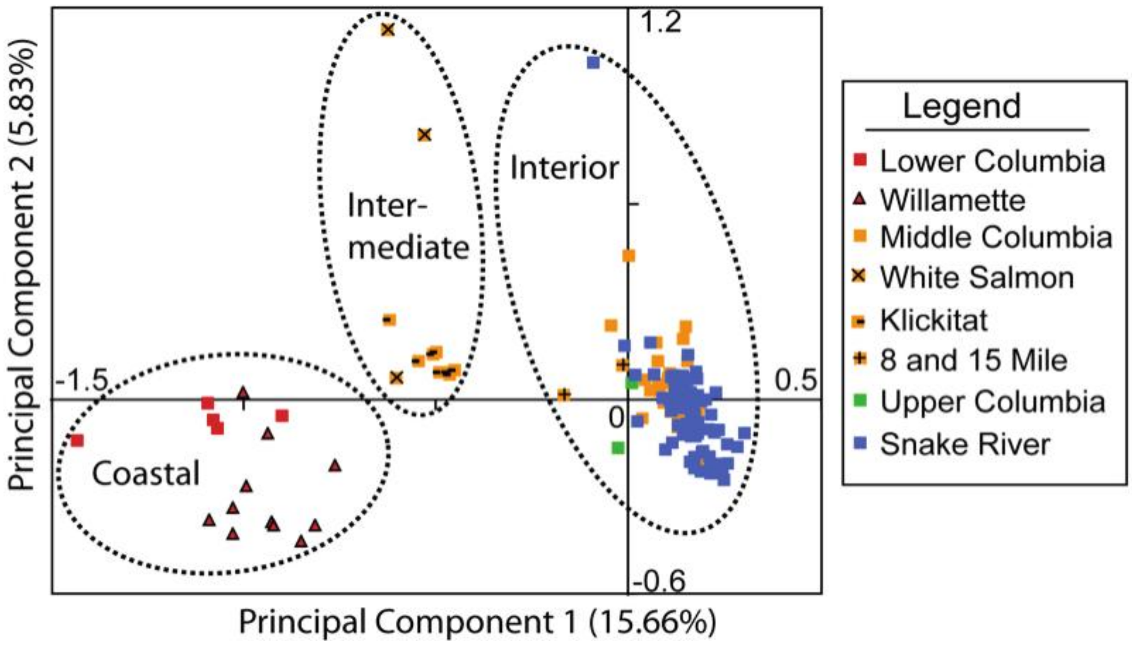

Figure 8. Principal components analysis of allele frequency data for steelhead populations in the Columbia River basin. The analysis is based on allele frequencies at 12 microsatellite loci. Each symbol represents a population sample, and the distance between symbols is proportional to the genetic differences between the respective populations. The four DPSs are the lower, middle, and upper Columbia River and the Snake River. (Reprinted from Hess et al. 2008.)

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 National Fish Hatchery (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 River 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 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 Chinook Salmon ESU), while the Klickitat River enters the Columbia River at RKM 289.

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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). WDF (1951) suggests that fall-run Chinook salmon may have spawned in a kilometer or two of the 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 1998 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 its Lower Columbia River MAL. Genetic analysis of Chinook salmon in the Columbia River, run as part of the coast-wide 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 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 North Fork Lewis River, Cowlitz River, and Kalama River spring-run Chinook salmon samples.

Based on 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 rivers) 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

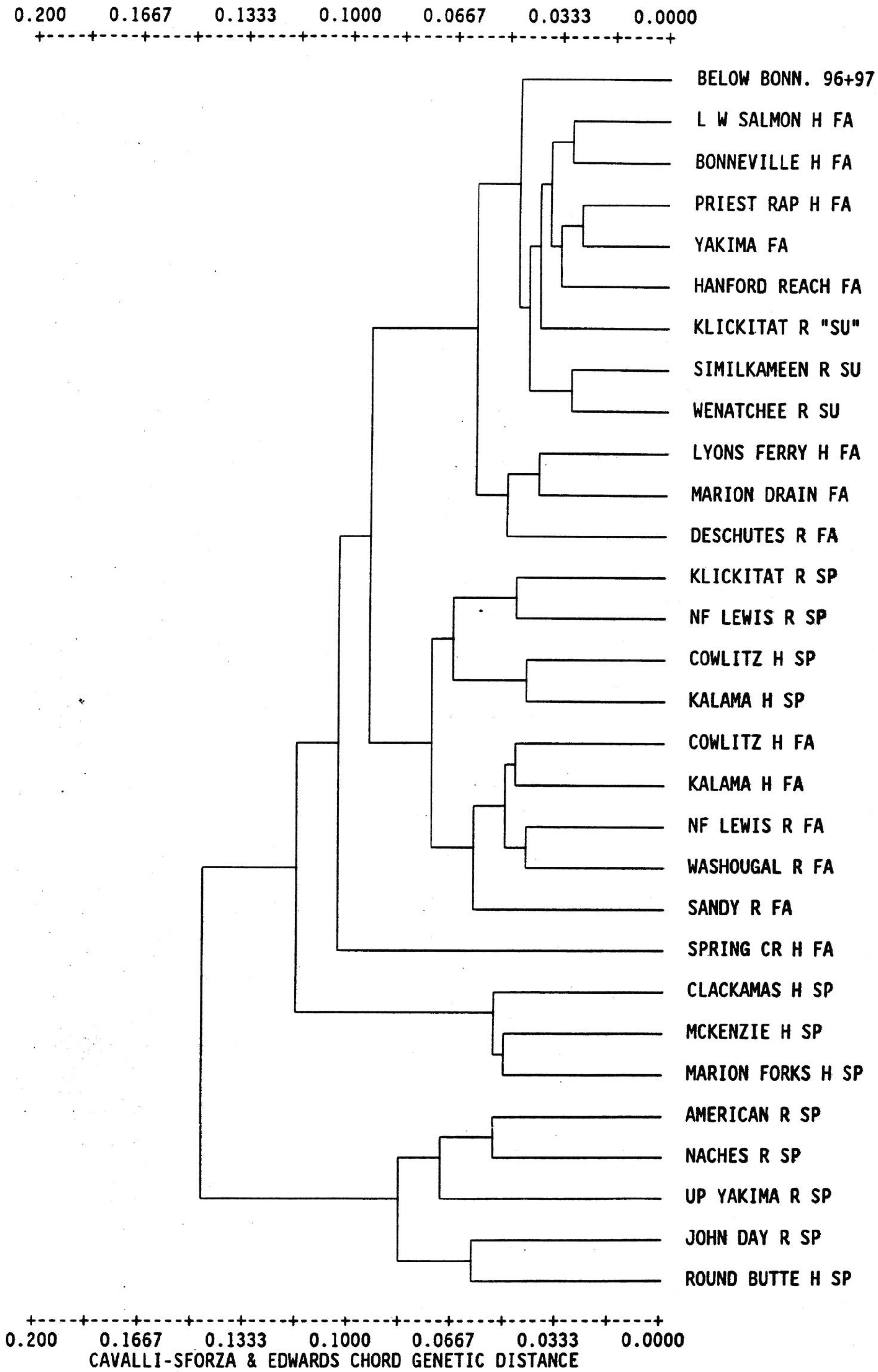

Figure 9. Dendrogram of lower Columbia River Chinook salmon populations. (Reprinted from Marshall 1998.)

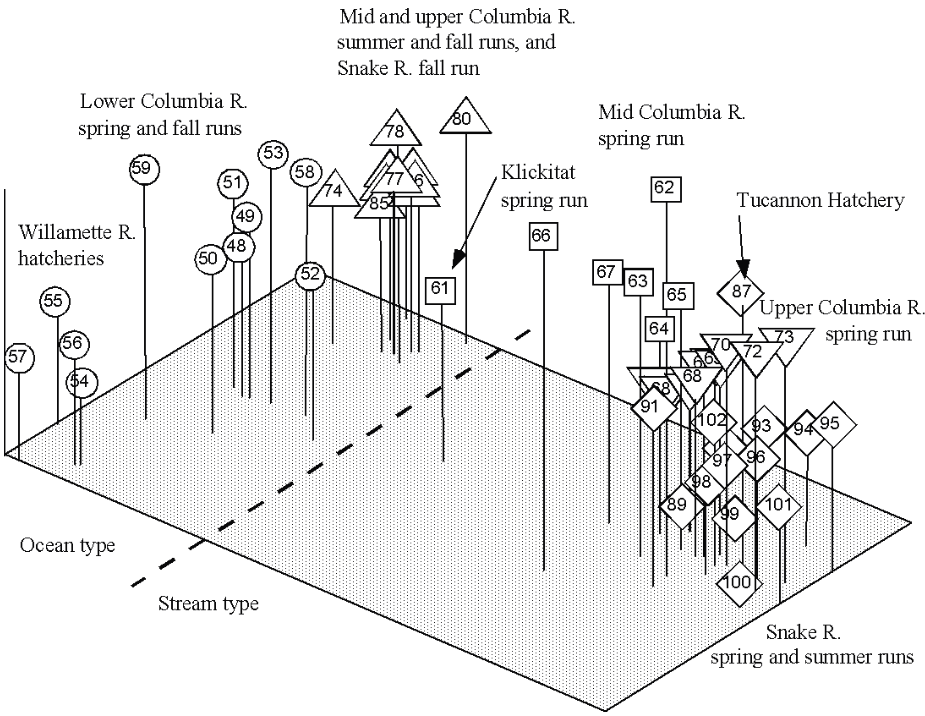

Figure 10. MDS (Multidimensional scaling) of Cavalli-Sforza and Edwards (1967) chord distances based on 31 allozyme loci between 55 composite samples of Chinook salmon from populations in the Columbia River drainage. The ocean/stream line was added subsequent to the decision to place the Klickitat spring run in the middle Columbia River spring-run ESU. (Reprinted from Myers et al. 1998.)

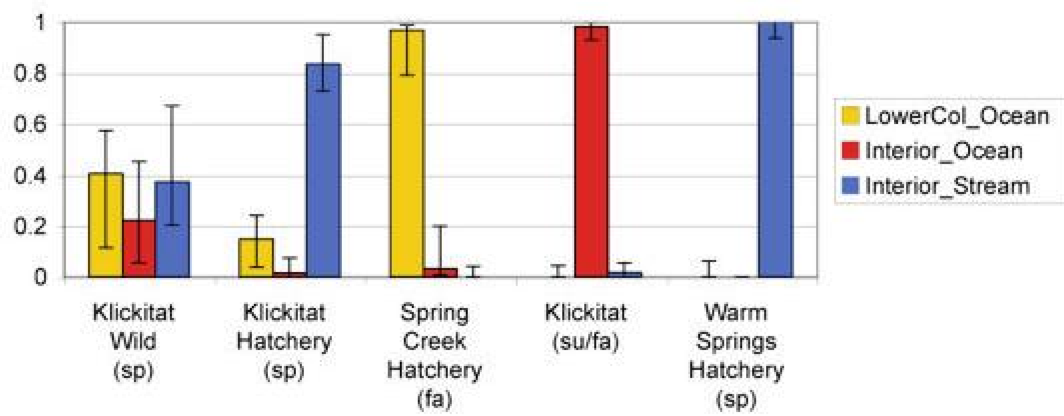

Figure 11. Proportion of sample assigned to three major Columbia River Chinook salmon lineages. (Reprinted from Hess et al. 2010.)

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.

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 coast-wide 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 Hood River steelhead are associated with lower Columbia River populations (based on previous and current studies). 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 suggesting 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 Fifteenmile Creek population, however, appears to be clearly associated with the interior Columbia River 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 River regions have been largely extirpated, genetic analyses have not been conducted of coho in this region. The original Lower Columbia River Coho Salmon 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 River Coho Salmon ESU. This would establish a common boundary for Chinook salmon, coho salmon, chum salmon, and steelhead at the Celilo Falls (Dalles Dam).

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Interior Columbia River Domain Status Summaries

Upper Columbia River Spring-run Chinook Salmon ESU

The Upper Columbia Spring-run Chinook Salmon ESU includes naturally spawning 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 River spring Chinook populations had "rebounded somewhat from the critically low levels" observed in the 1998 review. Although the BRT considered this an encouraging sign, it noted that the increase was largely driven by returns in the two most recent spawning years available at the time of the review. 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 (ICTRT) has identified three extant populations within this ESU (ICTRT 2003). Populations were identified based on genetic analysis and the distribution of spawning reaches versus 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, Entiat, and Methow rivers. 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. ICTRT classified the extant populations as a single major population group (MPG), 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

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

TRT and Recovery Plan Criteria

NMFS adopted a recovery plan for upper Columbia spring Chinook salmon and steelhead in 2007 (Federal Register Vol. 72 No. 194, p. 57303−57307). The plan was developed by the Upper Columbia Salmon Recovery Board (UCSRB) and is available through its Web site (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. The plan includes three specific quantitative reclassification criteria expressed relative to population viability curves (ICTRT 2007). Abundance and productivity of naturally produced spring Chinook salmon 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 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. The plan also established minimum productivity thresholds. 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. 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 UCSRB plan adopted an alternative approach for

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addressing 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 by an earlier working group (Ford et al. 2001). The plan incorporates spatial structure criteria specific to each spring Chinook population in Subsection 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 1950s. Multiple pass surveys in index areas complemented by supplemental surveys covering the majority of spawning reaches have been conducted since the mid 1980s. 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 salmon 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 River spring Chinook salmon based on data covering up to the 2003 return year (ICTRT 2008). 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.

Standard abundance and trends

Recent year geometric mean spawning abundance estimates for each of the three extant upper Columbia River spring Chinook salmon populations are summarized in Table 6. Total spawning abundance, including natural-origin and hatchery fish, has increased relative to the levels reported in the previous BRT review. The geometric mean abundances of 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

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Table 6. Estimated spawning abundance in natural spawning areas for upper Columbia River spring-run Chinook salmon populations.

	Total spawners (5-year geometric mean, range)			**Natural origin (5-year geometric mean)**			**Percent natural origin (5-year average)**		
Population	**Listing (1991–1996)**	**Prior (1997–2001)**	**Current (2004–2008)**	**Listing (1991–1996)**	**Prior (1997–2001)**	**Current (2004–2008)**	**Listing (1991–1996)**	**Prior (1997–2001)**	**Current (2004–2008)**
Wenatchee River	167	463 (133–2,957)	1,336 (595–2,104)	NA	274	489	69	60	31
Entiat River	89	111 (53–444)	261 (224–325)	NA	61	112	82	62	46
Methow River	325	465 (443–11,144)	1,343 (1,002–1,801)	NA	248	402	78	45	29

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Entiat River system are predominately strays from Entiat NFH releases. The Entiat NFH spring Chinook release program was discontinued in 2007. Given the 3 to 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.

Annual spawning escapements for all three 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 1990−1994 broodyears (Figure 13). Prior to the early 1980s, broodyear return-per-spawner estimates were generally above replacement at low to moderate parent escapement levels. Broodyear 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.

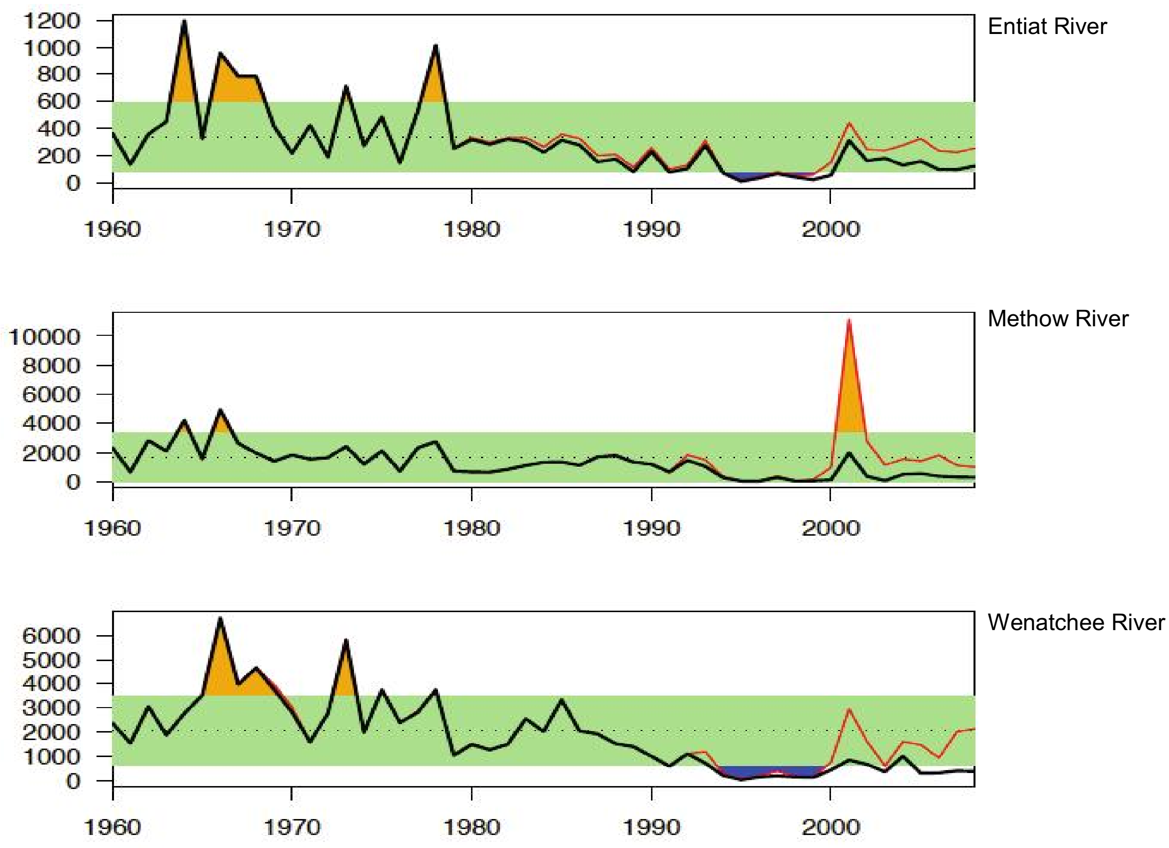

Figure 12. Updated spawning abundance by year for upper Columbia River spring-run Chinook salmon populations. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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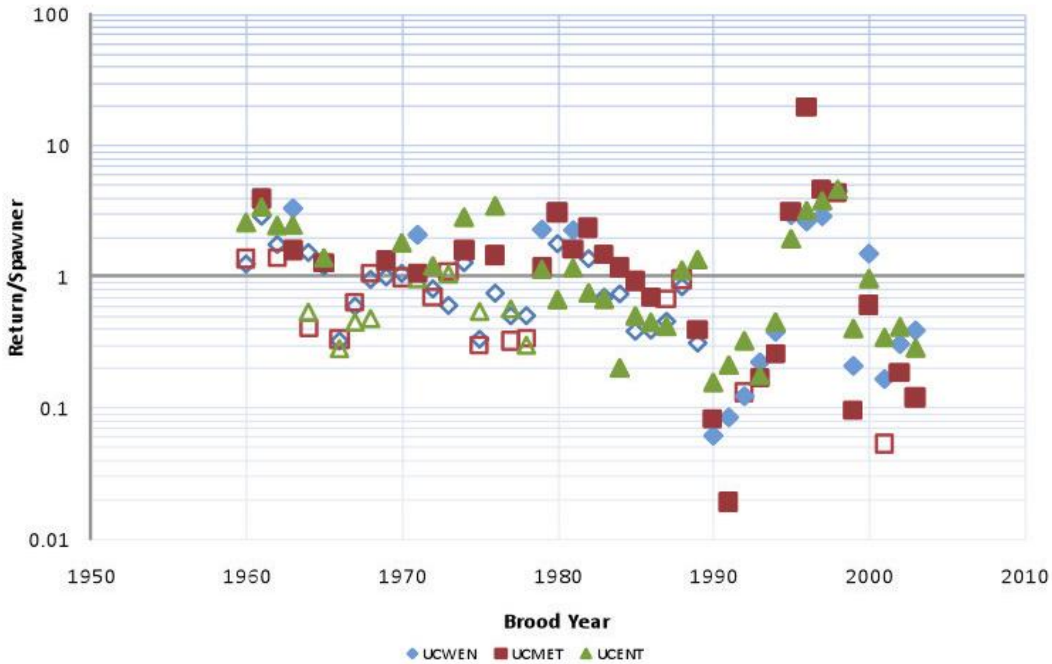

Figure 13. Trend of broodyear spawner-to-spawner return rate estimates for Upper Columbia River Spring-run Chinook Salmon ESU populations. Filled markers: parent spawner estimate below 75% of minimum abundance threshold. Open markers: parent escapement greater than 75% of minimum abundance threshold.

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).

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.

Current abundance estimates for all three upper Columbia River spring Chinook salmon 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.

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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, $P > 1.0$).

Population		Short-term trend 1998 BRT (1987–97)	Previous (1990–2001)	Current (1995–2008)
Wenatchee River	Estimate	0.88	0.99	1.16
	CI		0.82–1.18	1.04–1.30
	$P > 1.0$		0.43	0.994
Entiat River	Estimate	0.801	1.01	1.16
	CI		0.87–1.16	1.05–1.28
	$P > 1.0$		0.53	0.996
Methow River	Estimate	0.85	1.2	1.2
	CI		0.62–1.28	1.03–1.40
	$P > 1.0$		0.25	0.988

Table 8. Short-term population growth rate estimates for upper Columbia River spring-run Chinook salmon populations.

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

Table 9. Long-term trend metrics for upper Columbia River spring-run Chinook salmon populations.

		Trend in total spawners	Lambda (HF = 0)		Lambda (HF = 1)	
Population	Years	Estimate (CI)	Estimate (CI)	$P > 1$	Estimate (CI)	$P > 1$
Wenatchee River	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 River	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 River	1960–2008	0.94 (0.92–0.96)	0.96 (0.82–1.13)	0.31	0.90 (0.76–1.06)	0.08

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Other data

The ICTRT current productivity metric incorporates a relative adjustment for annual smolt to adult return ratio (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 broodyear (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 broodyears, but well above the extremely low survivals observed for the 1990 and 1991 broods.

Natural production of spring Chinook salmon 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. 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.

TRT metrics

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

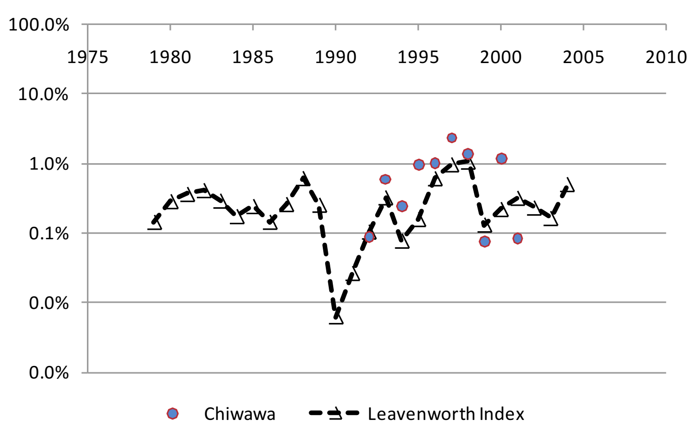

Figure 14. Chiwawa River natural production SAR estimates, broodyear adult returns to the Wenatchee River divided by estimated smolts produced. Leavenworth Hatchery spring-run Chinook SAR estimates, broodyear adult returns divided by smolt release.

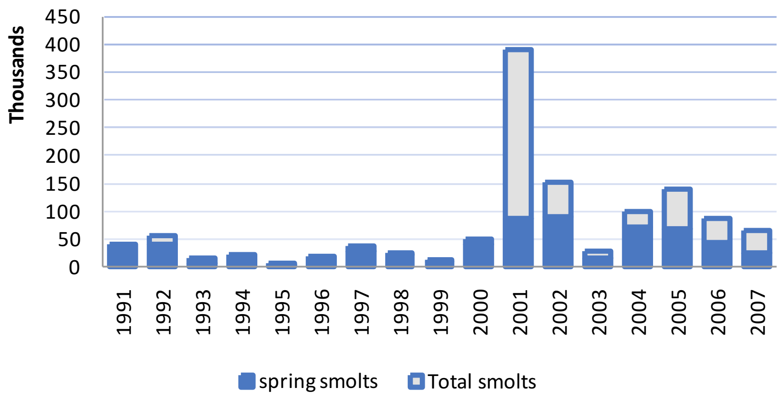

Figure 15. Estimated number of natural-origin smolts produced from spawning in the Chiwawa River tributary within the Wenatchee River spring-run Chinook salmon population by year. Data from Table 5-15 in Hillman et al. 2010.

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 10). The spatial processes component of the SS/D risk is low for the Wenatchee 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 A/P and SS/D, all three of the extant populations of upper Columbia spring Chinook salmon remain rated at high overall risk (Figure 16).

Harvest

Spring Chinook salmon from the upper Columbia River 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 nontribal 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 salmon to the Columbia River basin.

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Table 10. Viability assessments for upper Columbia River spring-run Chinook salmon populations in the North Cascades MPG. Spatial structure and diversity risk ratings from ICTRT 2008. NA = not applicable.

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Wenatchee River	2,000			High	Low	High	High	High risk
1999–2008		449 (119–1,050)	0.61 (0.40–0.95)					
1994–2003		216 (22–935)	0.75 (0.48–1.18)					
Entiat River	500			High	Moderate	High	High	High risk
1999–2008		105 (27–291)	1.08 (0.75–1.55)					
1994–2003		59 (10–291)	1.04 (0.72–1.50)					
Methow River	2,000			High	Low	High	High	High risk
1999–2008		307 (79–1,979)	0.45 (0.26–0.8)					
1994–2003		180 (20–1,979)	0.76 (0.47–1.24)					
Okanogan River	750 (U.S. portion)	NA	NA	NA	NA	NA	NA	Extirpated

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		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-run Chinook Salmon MPG population risk ratings integrated across the four viable salmonid population (VSP) metrics. Viability key: HV = highly viable, V = viable, M = maintained, and HR = high risk (does not meet viability criteria).

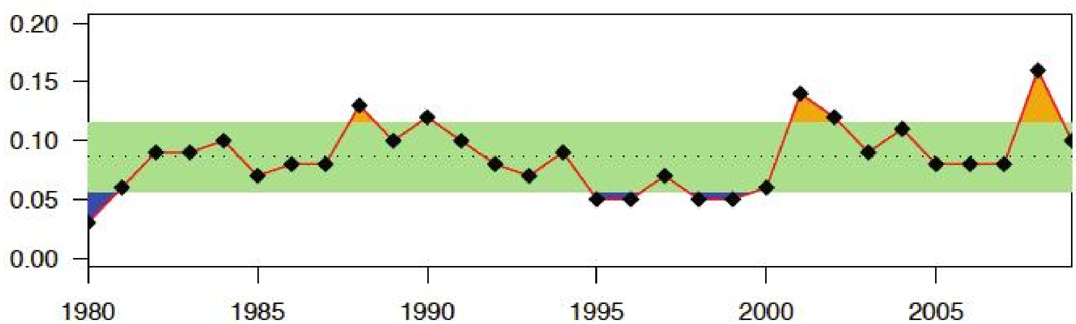

Figure 17. Total exploitation rate by year for upper Columbia River spring-run Chinook salmon. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from TAC 2010.

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.

Upper Columbia Spring Chinook: Updated Risk Summary

The Upper Columbia Spring-run Chinook Salmon ESU is not currently meeting viability criteria (adapted from the ICTRT) in the Upper Columbia Salmon 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

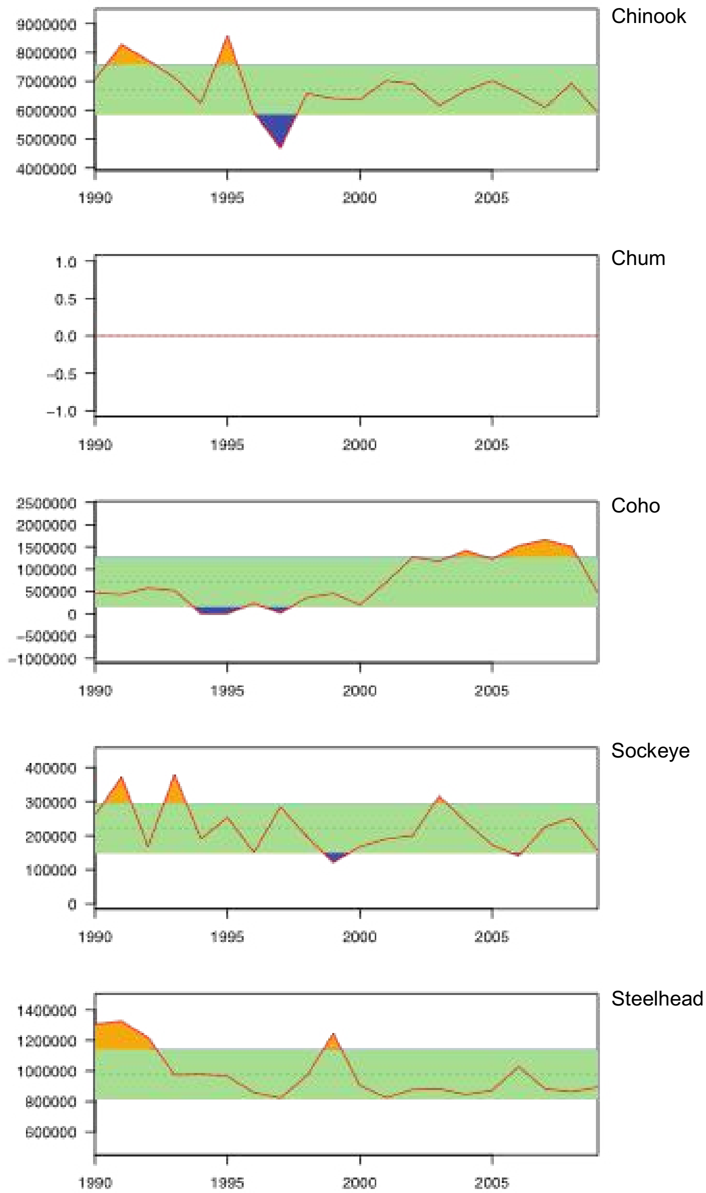

Figure 18. Trends in hatchery releases by year within the spawning and rearing area of the Upper Columbia River Spring-run Chinook Salmon ESU. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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 Salmon 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 Upper Columbia Recovery Plan, improvements in survival due to changes in habitat conditions are expected to accrue over a 10−50 year period. Overall, the viability of the Upper Columbia Spring-run 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.

Upper Columbia River Steelhead ESU

The Upper Columbia River Steelhead DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams in the Columbia River basin upstream from the Yakima River, Washington, to the U.S.-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 River Steelhead DPS was originally listed under the ESA in 1997; it is currently designated as threatened by NMFS.

NMFS 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 on evaluating information on the abundance, productivity, spatial structure, and diversity of the anadromous component of this species (Good et al. 2005, 70 FR 67130). Many steelhead populations along the U.S. West Coast 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 versus 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 levels reported in the 1998 status review. As with the mid-Columbia and Snake River DPS reviews, the 2005 BRT recognized that resident rainbow trout 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 of Recovery Planning

The ICTRT identified four extant populations of anadromous steelhead 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

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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. Grand 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.

TRT and Recovery Plan Criteria

NMFS adopted a recovery plan for upper Columbia River spring Chinook salmon and steelhead in 2007 (FR 72 #194, 57303−57307). The plan was developed by the Upper Columbia Salmon Recovery Board (UCSRB) and is online 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 UC Recovery Plan includes three specific quantitative reclassification criteria expressed relative to population viability curves (ICTRT 2007). A/P of naturally produced steelhead within each of the extant upper Columbia River 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 abundance, productivity, spatial structure, and diversity is the longer term goal of the UC Recovery Plan. It 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 River 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 and Okanogan river populations. The plan also established minimum productivity thresholds. 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 and Methow rivers), 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 Recovery 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 UC 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 UC Recovery 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 Subsection 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 broodyear (2002 run year). Estimates of spawning escapements in upper Columbia River 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.

The most recent estimates (5-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 5-year series were all above the population specific ranges in returns for the 5-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 5-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 rivers remained at extremely low levels.

The short-term trend metrics for each of the upper Columbia River steelhead populations are also above the levels associated with the prior review. Natural-origin spawners increased at

Table 11. Recent abundance and proportion natural origin in natural spawning areas compared to estimates at the time of listing and in the previous BRT review. Abundance estimates (5-year geometric mean with range in parentheses) correspond to the time of listing and the 2005 BRT.

Populaton North Cascades MPG	Total spawners (5-year geometric mean, range)			Natural origin (5-year geometric mean)			Percent 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 (931–3,608)	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 (1,417–3,325)	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

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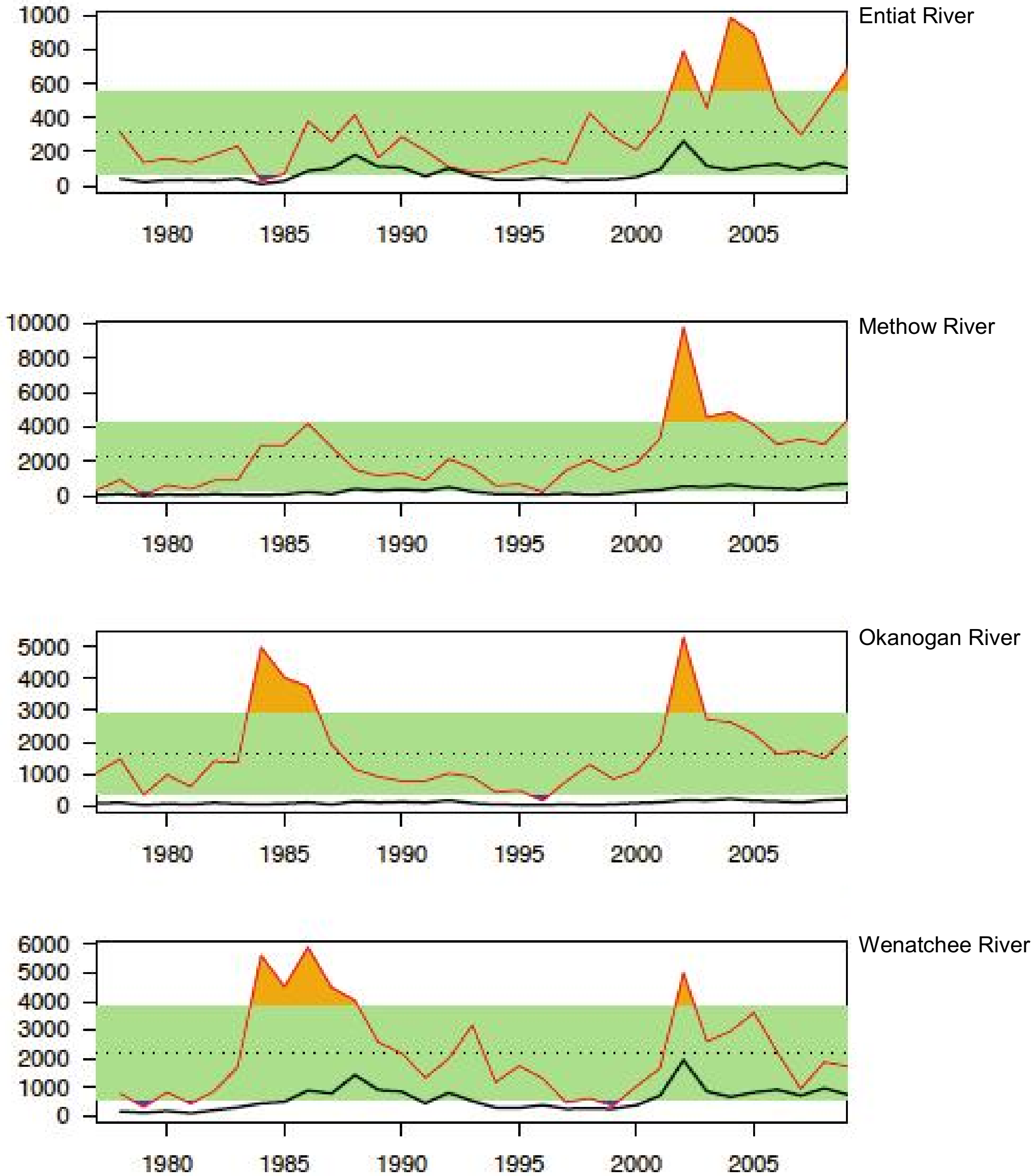

Figure 19. Annual spawning abundance by year for upper Columbia River steelhead populations. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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).

Annual spawning escapement estimates for upper Columbia steelhead populations are available going back to the late 1970s (Figure 19). All four populations show similar overall

Table 12. Comparison of current trends to prior reviews of short-term trend in natural-origin spawners, upper Columbia River spring-run Chinook salmon.

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

Table 13. Current short-term (since 1995) population growth rate (lambda) estimates versus 2005 BRT short-term time series.

Population		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
	P > 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
	P > 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
	P > 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
	P > 1.0	0.36	0.80	0.05	0.05

annual patterns in total and natural origin spawners, respectively. Spawning escapements in all four populations include substantial numbers of hatchery origin fish. Temporal patterns in brood year return per spawner estimates are similar among the populations as well (Figure 20). The relative effectiveness of hatchery versus natural origin parent spawners is not known for upper Columbia steelhead populations. Return per spawner estimates from parent escapements below the minimum abundance thresholds are generally well below replacement under the assumption that hatchery fish and natural origin parent spawners are contributing at the same rate to natural production. Return per spawner estimates under an alternative assumption, that hatchery parent

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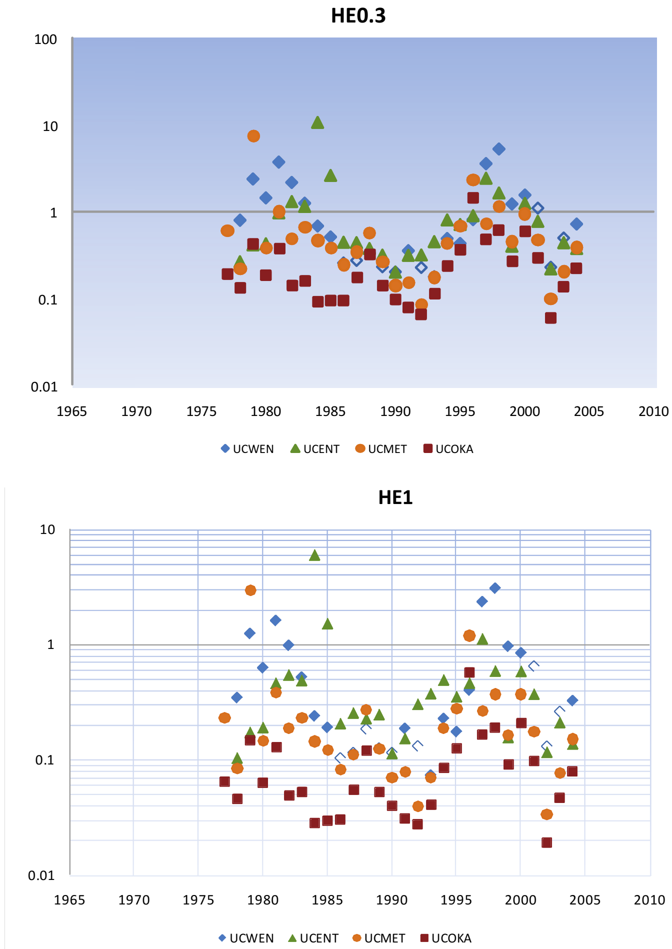

Figure 20. Return per spawner estimates by year for upper Columbia River steelhead populations. Upper panel hatchery effectiveness = 0.3. Lower panel hatchery effectiveness = 1.0. Filled markers are parent spawner estimate below 75% of minimum abundance threshold. Open markers are parent escapement greater than 75% of minimum abundance threshold.

spawners are contributing at 0.30 relative to natural origin, are still relatively low but generally vary around replacement. Figure 20 also illustrates the difficulty in assessing population average return per spawner estimates when hatchery contributions result in total parent escapements well in excess of levels where density dependent effects may be strong (open symbols). The relative effectiveness of hatchery origin spawners and the long term impact on productivity of high levels of hatchery contributions to natural spawning are key uncertainties for these populations.

The long-term trends in natural-origin spawners are positive, ranging from an annualized average of 3% per year for the Okanogan River 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 broodyear natural production at the same rate as natural-origin parent

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Table 14. Long-term trends in natural-origin spawning abundance for upper Columbia River steelhead populations.

Population	Years	Trend in total spawners	Lambda (HF = 0)		Lambda (HF = 1)	
		Estimate (CI)	Estimate (CI)	*P* > 1	Estimate (CI)	*P* > 1
Wenatchee River	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 River	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 River	1977–2009	1.08 (1.05–1.12)	1.08 (0.89–1.32)	0.82	0.67 (0.59–0.77)	0.000 3
Okanogan River	1977–2009	1.03 (1.01–1.05)	1.03 (0.86–1.23)	0.66	0.56 (0.49–0.65)	00.00 01

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 broodyear natural production. Population-level estimates under this assumption are positive for all populations and are similar to trends in natural spawners.

Current Status: Recovery Plan and ICTRT Viability Criteria

All four populations of upper Columbia River steelhead remain rated at high risk after incorporating 6 additional years of status information into the assessment against ICTRT viability criteria (Table 15 and Figure 21). 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 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 A/P estimates are the highest for the Wenatchee River, the population with the lowest relative proportion of hatchery spawners.

With the exception of the Okanogan population, the upper Columbia River 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.

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Table 15. Viability assessments for upper Columbia River steelhead populations, updated to reflect return years through 2009. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Wenatchee River	1,000			High	Low	High	High	High risk
2000–2009		795 (365–1,947)	0.87 (0.44–1.74)					
1994–2003		559 (241–1,947)	0.84 (0.68–1.39)					
Entiat River	500			High	Moderate	High	High	High risk
2000–2009		112 (52–263)	0.55 (0.35–0.88)					
1994–2003		79 (31–263)	0.48 (0.30–0.66)					
Methow River	1,000			High	Low	High	High	High risk
2000–2009		468 (256–703)	0.32 (0.14–0.72)					
1994–2003		289 (68–554)	0.28 (0.12–0.81)					
Okanogan River	750			High	High	High	High	High risk
2000–2009		147 (84–212)	0.15 (0.06–0.35					
1994–2003		95 (22–181)	0.12 (0.07–0.21)					

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		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.

Figure 21. North Cascades MPG steelhead population risk ratings integrated across the four VSP metrics. Viability key: HV = highly viable, V = viable, M = maintained, and HR = high risk (does not meet viability criteria).

Harvest

Summer-run steelhead from the interior Columbia River basin are divided into two runs by managers: A-run and 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 Basin Steelhead ESU, in the Clearwater, Middle Fork Salmon, and South Fork Salmon rivers.

Steelhead were historically taken in tribal and nontribal gill net fisheries and in recreational fisheries in the mainstem Columbia River and in tributaries. In the 1970s retention of steelhead in nontribal 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 recreational fisheries. The majority of impacts on the summer run occur in tribal gill net and dip net fisheries targeting Chinook salmon. Because of their larger size, B-run fish are more vulnerable to gill net gear. Consequently, this component of the summer run experiences higher fishing mortality than the A-run component (Figure 22). 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 ranged 15−20%.

Hatchery releases

Hatchery releases of upper Columbia River steelhead have generally fluctuated between 800,000 and 900,000 yearling smolts since the mid-1990s (Figure 23). Releases in the Wenatchee River basin have decreased while releases into the Methow and Okanogan river drainages have increased over the same period.

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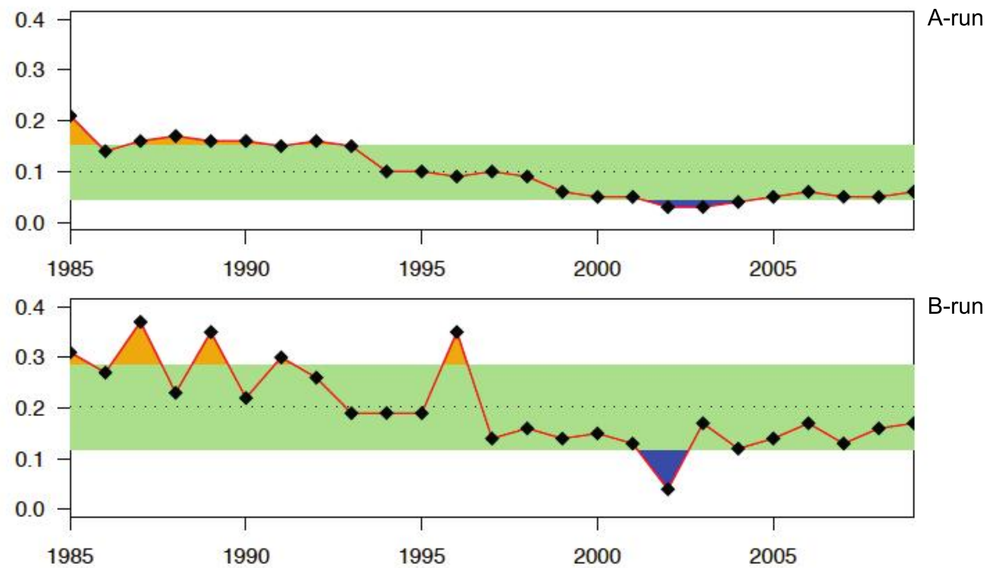

Figure 22. Total exploitation rate by year on natural summer steelhead above Bonneville Dam. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data for 1985−1998 from NMFS biological opinion[4] and for 1999−2008 from TAC run reconstruction.[5]

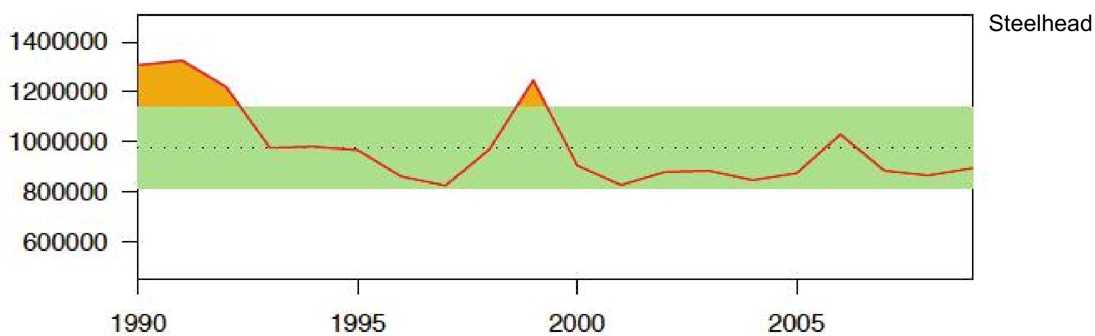

Figure 23. Trend in hatchery releases of upper Columbia River steelhead by year. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

Upper Columbia Steelhead DPS: Updated Risk Summary

Upper Columbia River 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 Salmon Recovery

[4] P. Dygert, NMFS, Seattle, WA. Pers. commun., 8 July 2010.
[5] C. LeFleur, WDFW, Vancouver, WA. Pers. commun., 7 July 2010.

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.

Middle Columbia River Steelhead DPS

The Middle Columbia River Steelhead DPS includes all naturally spawning populations of steelhead 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 NMFS in 1999, with that designation reaffirmed in 2006. NMFS 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 on evaluating information on the A/P, spatial structure, and diversity of the anadromous component of this species (Good et al. 2005; 70 FR 67130). Many steelhead populations along the U.S. West Coast 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 of Recovery Planning

The 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 (three extant and one extirpated populations), the John Day River drainage (five extant populations), and the Eastern Cascades group (five extant and two extirpated populations).

NMFS recently adopted a recovery plan for the Middle Columbia Steelhead DPS. The Mid-Columbia Sub-domain ESA Steelhead Recovery Plan (www.nwr.noaa.gov/Salmon

-Recovery-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 River 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 online 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: A/P, spatial structure, and diversity (McElhany 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.

Recovery Plan MPG Recovery Scenarios

The Mid-Columbia Sub-domain ESA Steelhead Recovery Plan identifies a set of most likely scenarios to meet the ICTRT recommendations for low risk populations at the MPG level. In addition, the management unit plans generally call for achieving moderate risk ratings (maintained status) across the remaining extant populations in each MPG.

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Cascades eastern slopes tributaries MPG

The Klickitat, Fifteenmile, and both the Deschutes east side and west side 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 further bolstered if reintroduction of steelhead into the Crooked River succeeds and if the White Salmon population successfully recolonizes its historical habitat following the removal of Condit Dam.

John Day River MPG

The 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 River or Touchet River needs to be viable.

New Data and Updated Analyses

The 2005 BRT status assessment of the Middle Columbia River Steelhead 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 estimates of the annual number of total spawners in a population (e.g., Fifteenmile 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 and Yakima rivers). 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

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year with some series including an additional year, the 2008/2008 return (Figure 24 through Figure 31).

Abundance data series are available for three of the five extant populations in the north Cascades MPG (Table 16). Total spawning abundance estimates for the most recent 5-year series (2005−2009) are below the levels reported in the 2005 BRT analysis for all three population series. Estimates of the proportion natural-origin spawners were higher for each of the populations in the most recent brood cycle. Natural-origin spawner abundance has increased relative to the previous BRT analysis for all three series. Two years of abundance estimates have been generated for a fourth population, the Klickitat River. Based on mark-recapture analysis, 1,577 natural and hatchery steelhead passed upstream of the falls and into spawning reaches during 2006−2007 in the Klickitat River.

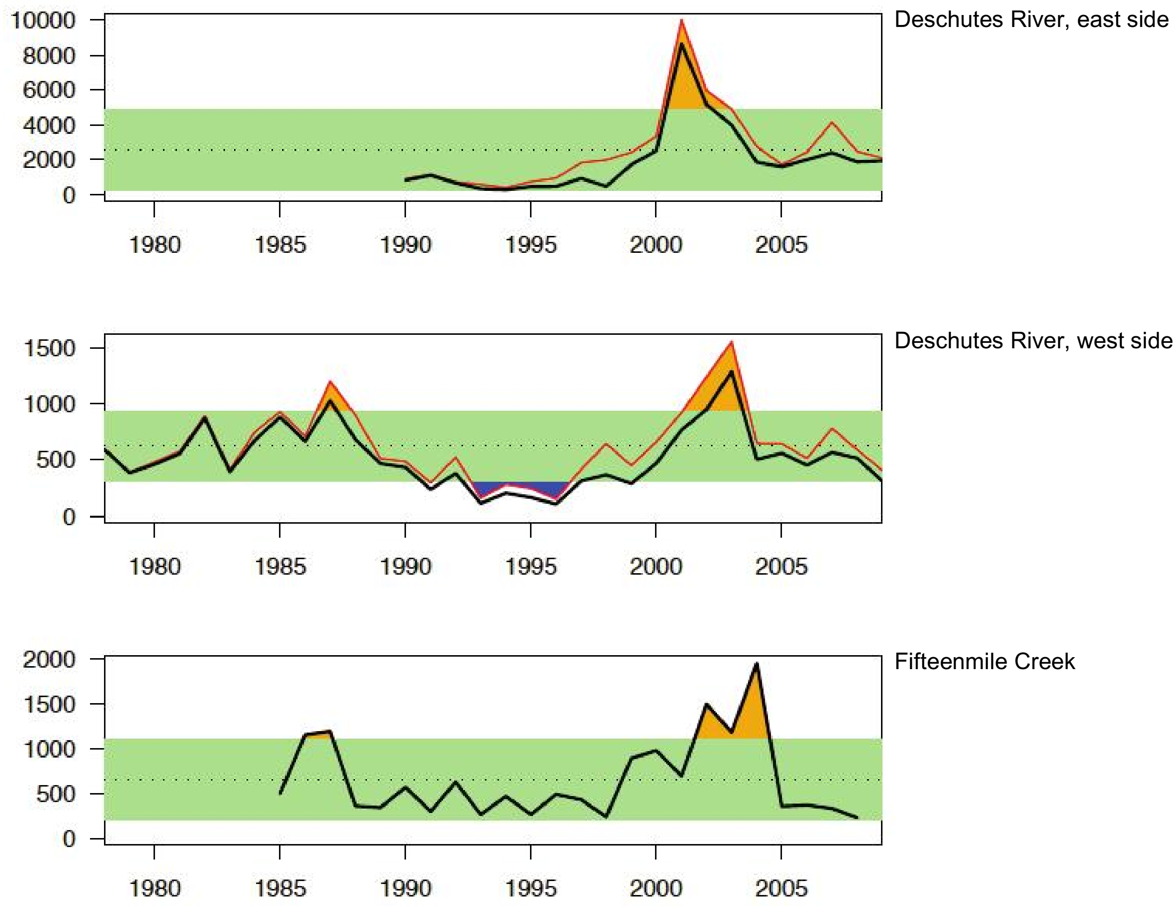

Figure 24. Spawning abundance by year for the east Cascades MPG in the Middle Columbia River Steelhead DPS. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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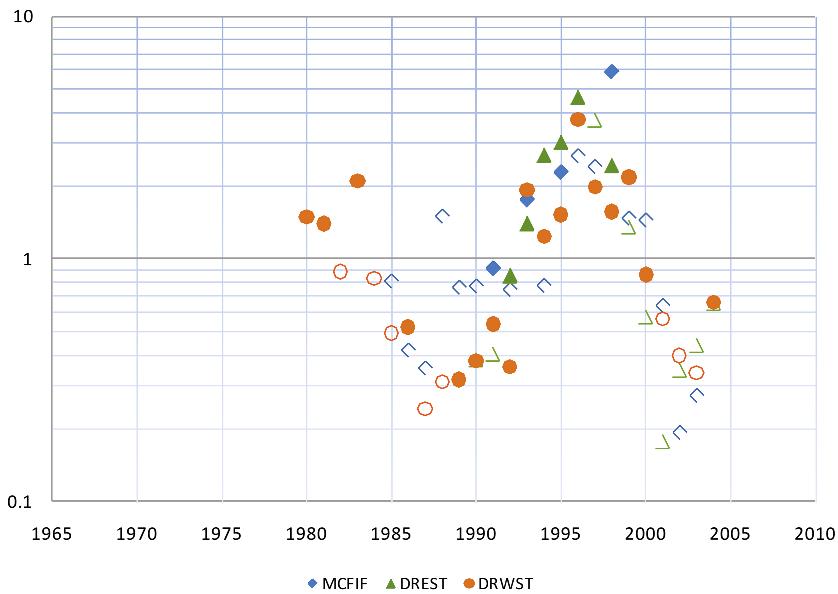

Figure 25. Productivity of the east Cascades MPG in the Middle Columbia River Steelhead DPS. Filled markers are parent spawner estimates below 75% of minimum abundance threshold. Open markers are parent escapement greater than 75% of minimum abundance threshold.

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. 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 16).

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 16, 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 of 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/Walla Walla MPG (Table 16). Natural-origin escapements are higher for two populations (Umatilla and Walla Walla rivers) 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 (5-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 four populations.

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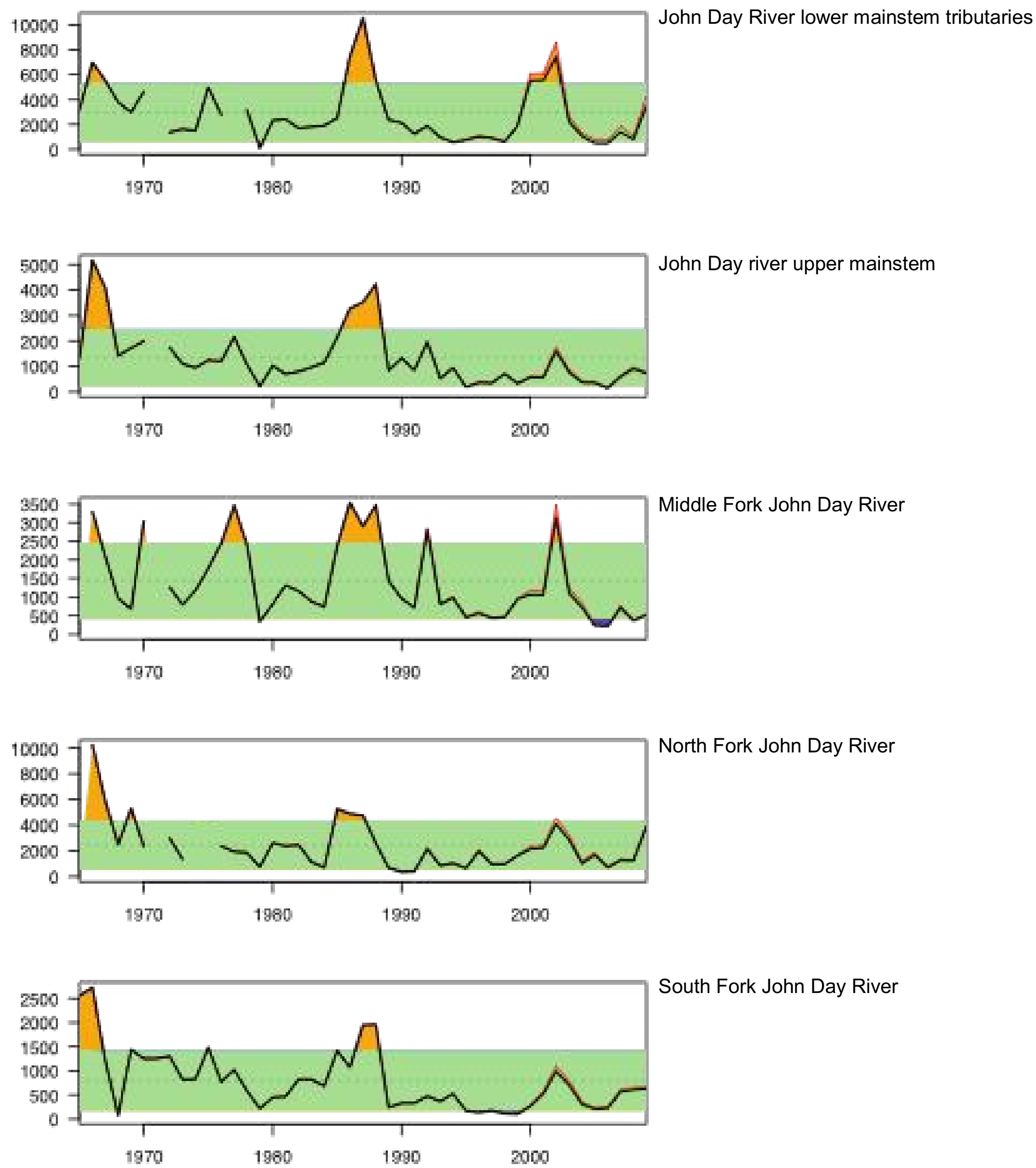

Figure 26. Spawning abundance by year for the John Day MPG in the Middle Columbia River Steelhead DPS. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

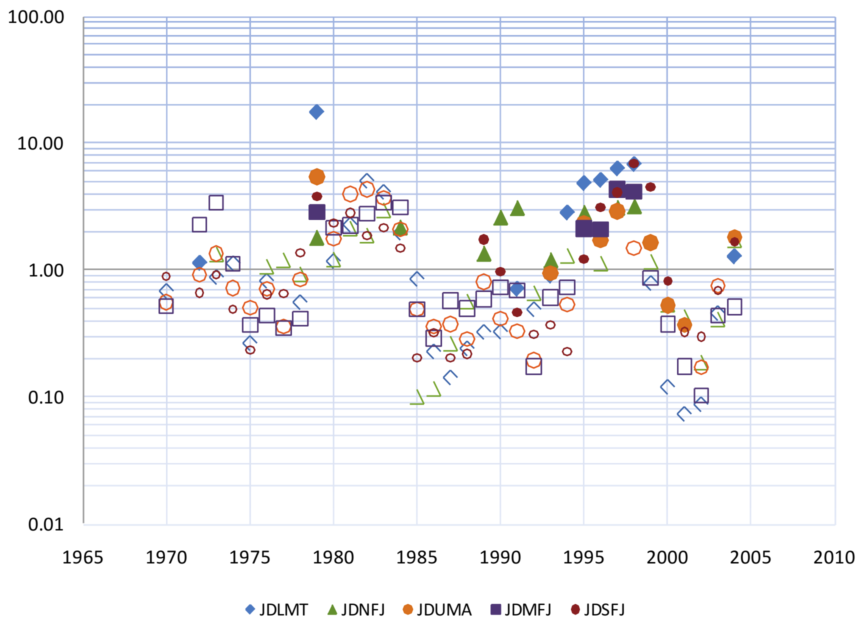

Figure 27. Productivity of the John Day MPG in the Middle Columbia River Steelhead DPS. Filled markers are parent spawner estimates below 75% of minimum abundance threshold. Open markers are parent escapement greater than 75% of minimum abundance threshold.

Populations in all four of the mid-Columbia steelhead MPGs exhibited similar temporal patterns in returns per spawner (Figure 25, Figure 27, Figure 28, Figure 31, and Figure 32). Return rates for broodyears 1995−1999 generally exceeded replacement (1:1). Spawner-to-spawner ratios for broodyears 2001−2003 were generally well below replacement for many populations. Broodyear productivity estimates returned levels at or above 1:1 for the most recent 1−2 broodyears for populations in the Yakima and John Day river MPGs, but remained below replacement for the eastern Cascades and Umatilla/Walla Walla populations. Broodyear return rates reflect the combined impacts of year to year patterns in marine life history stages, upstream and downstream passage survivals, and density dependent effects resulting from capacity or survival limitations on tributary spawning or juvenile rearing habitats.

Short-term trends for all populations in the Yakima River MPGs were strongly positive over the period 1995−2009 (Figure 28). Trends for east Cascades, John Day, and Umatilla/Walla Walla populations were generally positive with three exceptions. The geometric mean trend estimates for Fifteenmile 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.

Current Status: Recovery Plan Viability Criteria

Two of the five populations in the Cascades Eastern Slope MPG—Fifteenmile Creek and the Deschutes River (east side)—are currently rated as viable using the ICTRT criteria incorporated into the Mid-Columbia Steelhead Recovery Plan (Table 17). The Deschutes (west side) population remains rated at high risk driven by relatively low estimates for current productivity and natural-origin abundance versus the DPS-specific viability curve for

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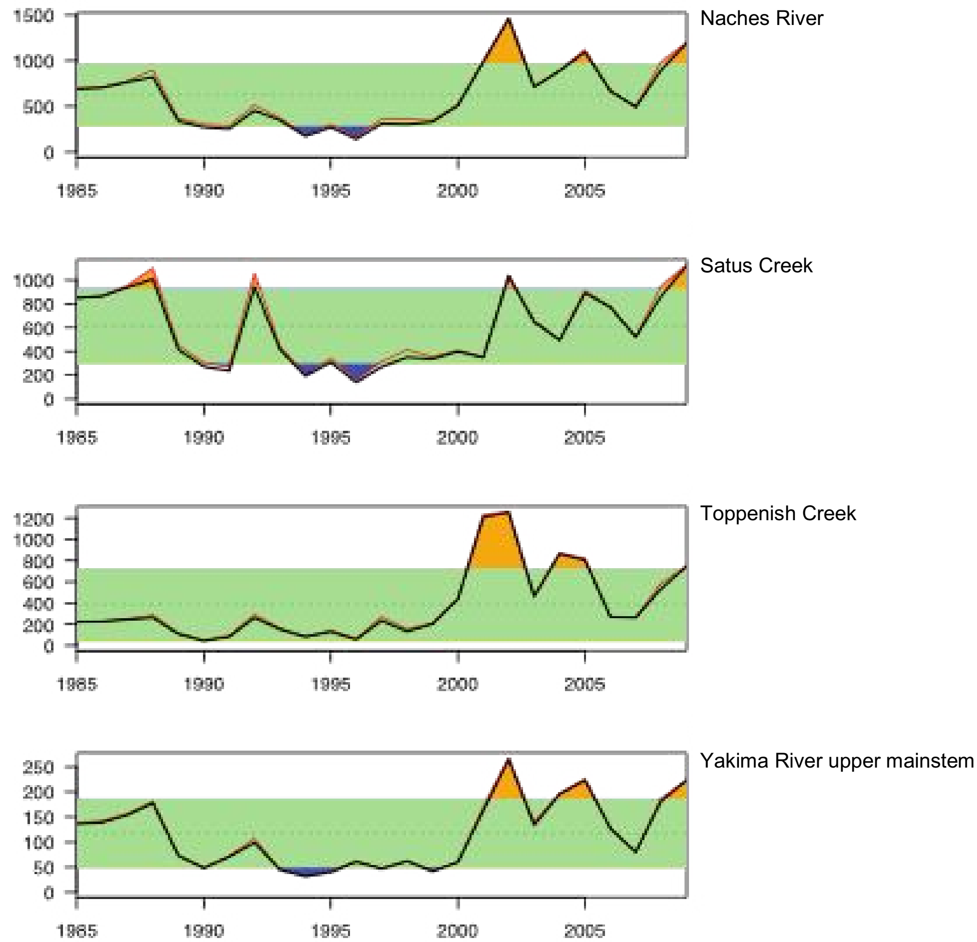

Figure 28. Spawning abundance by year for the Yakima MPG in the Middle Columbia River Steelhead DPS. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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 assessments performed for the 2008 ICTRT status assessments.

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 (Table 18). The remaining four populations in the John Day River MPG remain rated as maintained. Natural-origin abundance estimates (10-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 broodyear spawner/spawner at low to moderate

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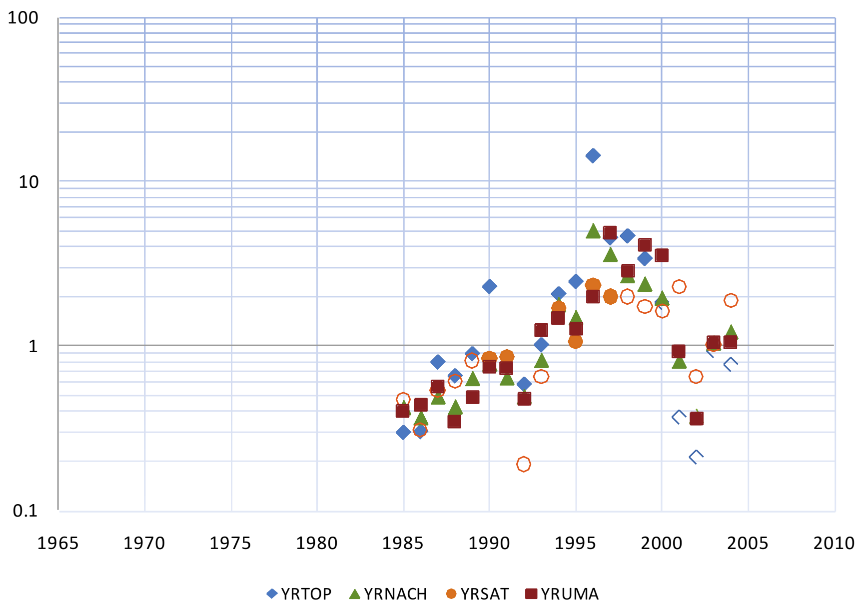

Figure 29. Productivity of the Yakima MPG in the Middle Columbia River Steelhead DPS. Filled markers are parent spawner estimates below 75% of minimum abundance threshold. Open markers are parent escapement greater than 75% of minimum abundance threshold.

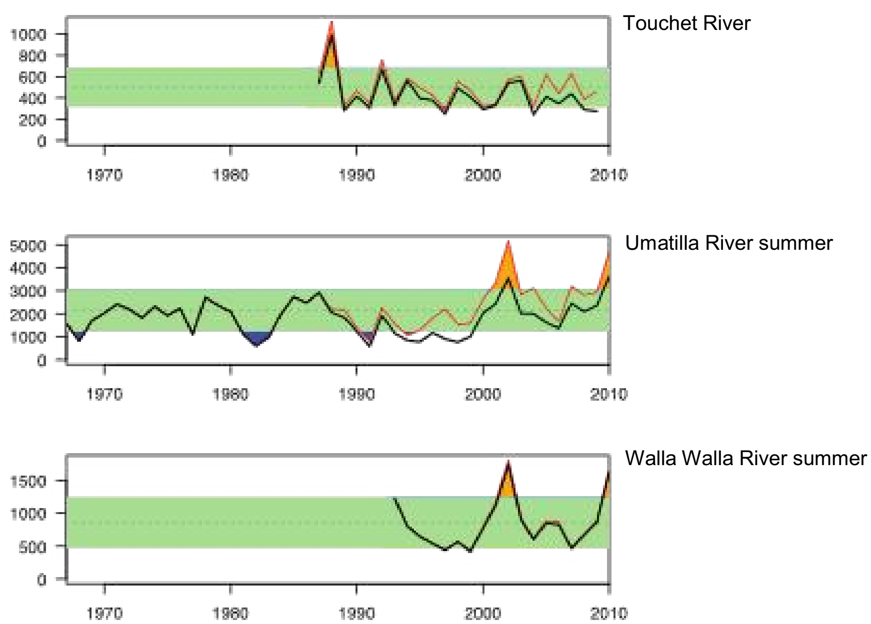

Figure 30. Spawning abundance by year for the Umatilla/Walla Walla MPG in the Middle Columbia River Steelhead DPS. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

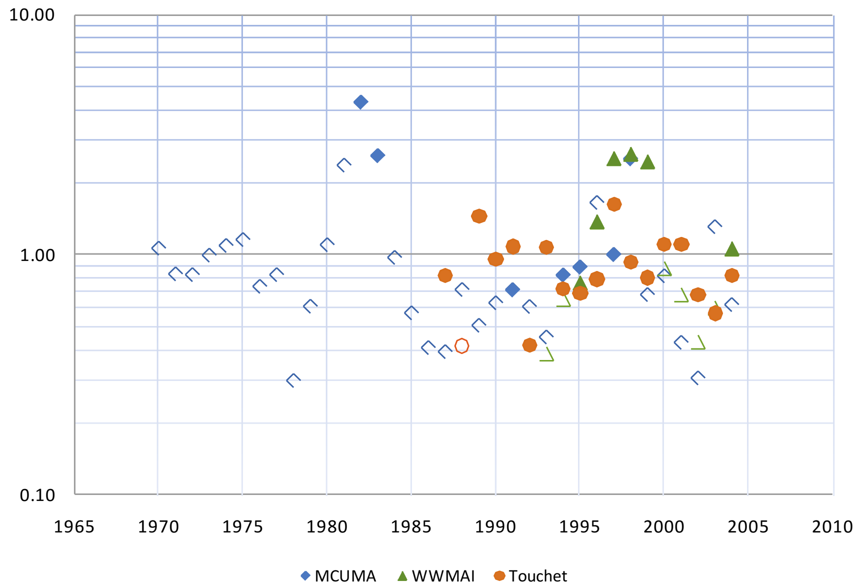

Figure 31. Productivity of the Umatilla/Walla Walla MPG in the Middle Columbia River Steelhead DPS. Filled markers are parent spawner estimates below 75% of minimum abundance threshold. Open markers are parent escapement greater than 75% of minimum abundance threshold.

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.

Overall status ratings for the Umatilla and Walla Walla river populations remained at maintained after incorporation of the updated A/P data (Table 19). 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 and 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.

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 aggregate counts (Table 20). The overall viability ratings have increased from maintained to viable for the Satus Creek population, remain at maintained for the Naches and Toppenish river populations. The overall rating remains at high risk for the upper Yakima River population (Table 21). The change in ratings for Satus Creek 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.

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Harvest

Summer-run steelhead from the upper basin are divided into two runs by managers, A-run and 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 Basin Steelhead ESU in the Clearwater, Middle Fork Salmon, and South Fork Salmon rivers.

Steelhead were historically taken in tribal and nontribal gill net fisheries, and in recreational fisheries in the mainstem Columbia River and tributaries. In the 1970s, retention of steelhead in nontribal 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 gill net and dip net fisheries targeting Chinook salmon. Because of their larger size, B-run fish are more vulnerable to gill net gear. Consequently, this component of the summer run experiences higher fishing mortality than the A-run component (Figure 33). 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%.

Hatchery Releases

Total hatchery releases of steelhead, Chinook, and coho salmon have remained similar since 2005. Releases for coho and steelhead fell substantially from their levels in the mid-1990s (Figure 34).

Middle Columbia Steelhead: Updated Risk Summary

There have been improvements in the viability ratings for some of the component populations, but the Middle Columbia River 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.

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Table 16. Summary of abundance and hatchery proportions in natural spawning areas for mid-Columbia steelhead populations organized by MPG. Estimates for brood cycle prior listing (1992−1996) and the 2005 BFT review included for comparison. Estimates for all series calculated using current data sets.

Population (organized by MPG)	Total spawners (5-year geometric mean, range)			Natural origin (5-year geometric mean)			Percent 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 Cascades MPG									
Fifteenmile Cr.	396	571 (234–974)	452 (225–1,956)	396	571 (234–974)	452 (225–1,956)	100	100	100
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	415 (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 (1,021–4,539)	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 (105–1,094)	434 (232–662)	290	273 (103–984)	398 (207–6,302)	96	93	92
Lower mainstem	1,001	2,139 (625–6,096)	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 (524–1,129)	317	337 (269–398)	809 (519–1,121)	91	92	97
Toppenish Creek	131	345 (156–1,229)	482 (265–820)	119	318 (132–1,208)	469 (262–802)	91	92	97
Naches River	278	471 (346–1,000)	848 (496–1,199)	254	435 (304–983)	825 (491–1,190)	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	2,163 (1,527–3,360)	2,893 (1,654–4,667)	1,118	1,288 (769–2,451)	2,273 (1,373–3,625)	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 (421–1,172)	838 (472–1,658)	765	618 (419–1,118)	815 (464–1,623)	99	98	97

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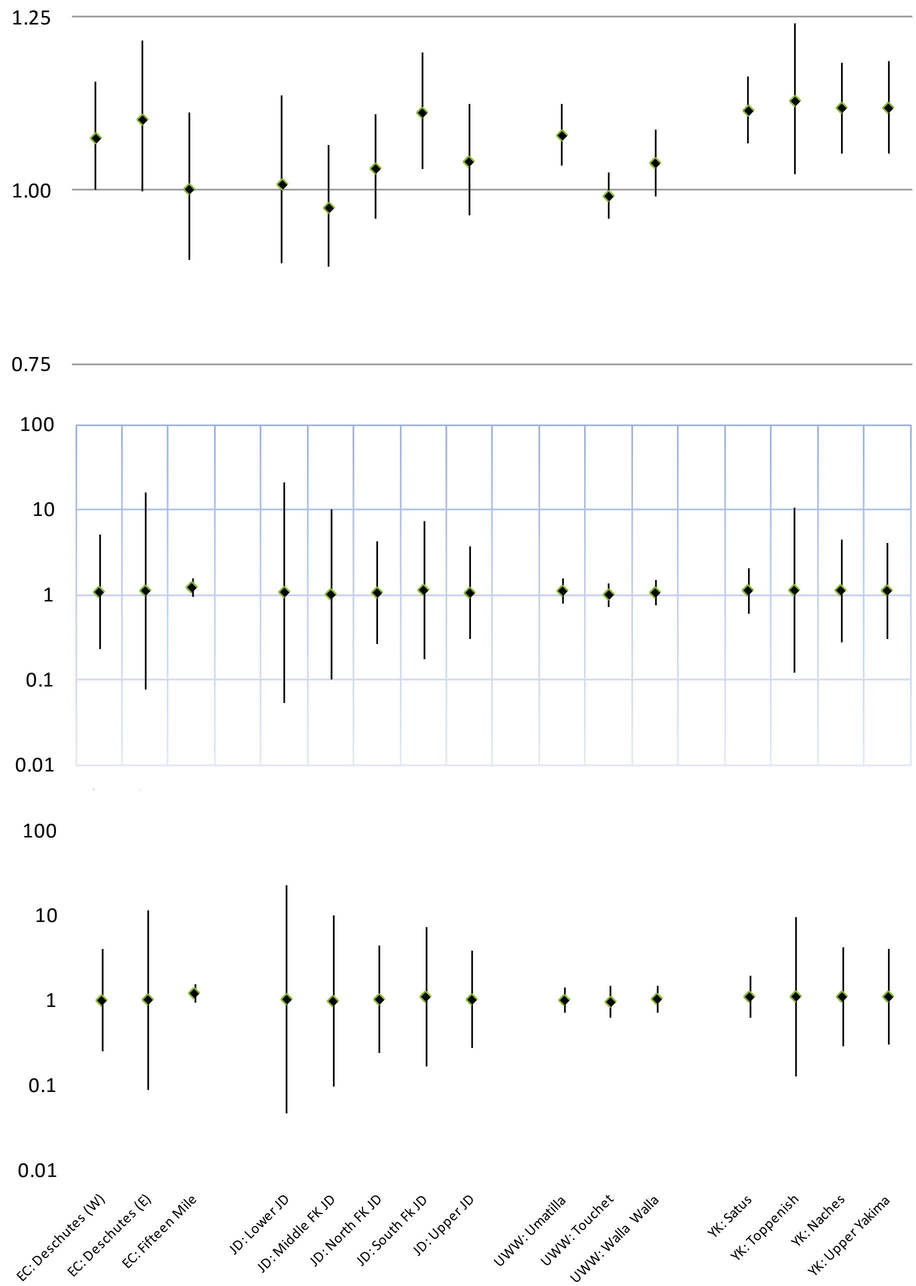

Figure 32. The top panel illustrates the short-term (1995−2009) trends in natural-origin spawners. Estimated as slope of ln(natural-origin abundance) versus year. Population estimates organized by MPG: eastern Cascades, EC; John Day River, JD; Umatilla/Walla Walla, UWW; and Yakima River, YK. Lines are 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 is 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 is set to 1.0. Solid diamond/bar is point estimate and 95% cf for 1995−2009.

AR054499

Table 17. Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the Cascades Eastern Slope MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Fifteenmile	500			Low	Very low	Low	Low	Viable
1999–2008		675 (225–1,946)	1.83 (0.95–3.54)					
1995–2004		695 (236–1,946)	1.83 (0.95–3.54)					
Klickitat	1,000	Insufficient data	Insufficient data	Moderate[a]	Low	Moderate	Moderate	Maintained?[b]
East side Deschutes	1,000			Low	Low	Moderate	Moderate	Viable
2000–2009		2,730 (1,600–8,637)	2.31 (1.49–3.60)					
1995–2004		1,633 (462–8,637)	2.31 (1.49–3.60)					
West side Deschutes	1,000			High	Low	Moderate	Moderate	High risk
2000–2009		591 (314–1,284)	1.11 (0.68–1.37)					
1995–2004		410 (108–1,284)	1.08 (0.82–1.42)					
Rock Creek	500	Insufficient data	Insufficient data	High[c]	Moderate	Moderate	Moderate	High risk?[b]
White Salmon Riv.	500	NA[d]	NA	Extinct[e]	NA	NA	NA	Extirpated
Crooked River	2,250	NA	NA	Extinct	NA	NA	NA	Extirpated

[a]Moderate A/P rating (provisional) for Klickitat River population based on limited abundance series (estimates for two recent years).
[b]Uncertain due to lack of data, only a few years of data, or large gaps in the data series.
[c]Annual surveys not conducted; therefore, we assumed a provisional A/P rating of High.
[d]NA = not applicable.
[e]Assumed to be functionally extinct (upstream habitat cut off by Condit Dam).

AR054500

Table 18. Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the John Day River MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Upper mainstem	1,000			Moderate	Very low	Moderate	Moderate	Maintained
2000–2009		558 (149–1,593)	1.25 (1.01–1.56)					
1995–2004		487 (185–1,593)	11.56 (1.04–2.31)					
North Fork	1,500			Very low	Very low	Low	Low	Highly viable
2000–2009		1,826 (707–4,083)	2.53 (1.57–4.08)					
1995–2004		1,601 (640–4,083)	2.37 (1.54–3.63)					
Middle Fork	1,000			Moderate	Low	Moderate	Moderate	Maintained
2000–2009		672 (213–3,129)	2.28 (1.79–2.90					
1995–2004		818 (463–3,129)	2.23 (1.84–2.71)					
South Fork	500			Moderate	Very low	Moderate	Moderate	Maintained
2000–2009		443 (207–984)	1.81 (1.00–2.30					
1995–2004		259 (103–984)	1.87 (1.23–2.80)					
Lower mainstem	2,250			Moderate	Very low	Moderate	Moderate	Maintained
2000–2009		1,881 (508–7,419)	2.98 (1.51–4.32					
1995–2004		1,800 (625–7,419)	3.09 (1.96–4.88)					

AR054501

Table 19. Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the Umatilla/Walla Walla MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				**Spatial structure and diversity metrics**			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Willow Creek	NA[a]	NA	NA	Extinct	NA	NA	NA	Extirpated
Umatilla River	1,500			Moderate	Moderate	Moderate	Moderate	Maintained
2000–2009		2,257 (1,654–5,176)	1.21 (0.48–3.07)					
1995–2004		1,200 (769–2,451)	1.45 (1.10–1.91)					
Touchet River	1,000				Low	Moderate	Moderate	Maintained?
2000–2009		360 (245–563)	1.46 (0.93–2.30	High				
1995–2004		375 (245–563)	1.54 (1.08–2.20)	Moderate?[b]				
Walla Walla River	1,000			Moderate	Very low	Moderate	Moderate	Maintained
2000–2009		894 (464–1,811)	1.42 (0.69–1.92)					
1995–2004		705 (419–1,746)	1.34 (1.05–1.68)					

[a]NA = not applicable

[b]Annual abundance data series for the Touchet River steelhead population is relatively short and has several missing years. A/P estimates for this population are provisional and should be interpreted with caution.

Table 20. Summary of current status of populations using viability criteria incorporated into the Mid-Columbia Steelhead Recovery Plan for the Yakima MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Satus Creek	500			Moderate	Low	Moderate	Moderate	Viable (maintained)
2000–2009		660 (347–1,121)	1.84 (1.42–2.26)					
1995–2004		379 (138–1,032)	1.70 (1.33–2.25)					
Toppenish Creek	500				Low	Moderate	Moderate	Maintained
2000–2009		599 (262–1,252)	1.59 (1.81–4.45)	Moderate*				
1995–2004		322 (57–1,252)	1.60 (0.94–2.71)	Moderate				
Naches River	1,500				Low	Moderate	Moderate	Maintained
2000–2009		840 (491–1,454)	1.25 (1.25–2.01	Moderate				
1995–2004		472 (142–1,454)	1.12 (0.75–1.65)	High				
Upper Yakima	1,500			High	Moderate	High	High	High risk
2000–2009		1,51 (60–265)	1.28 (1.17–1.98					
1995–2004		85 (40–265)	1.12 (0.76–1.64)					

*Moderate rating for Toppenish Creek based on high uncertainty in productivity estimates.

AR054503

Table 21. Recent (5-year geometric mean) estimates of total and natural-origin spawning escapement in natural spawning areas for Snake River spring/summer-run Chinook salmon 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 MPG)	Total spawners (5-year geometric mean, range)			Natural origin (5-year geometric mean)			Percent 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 (161–1,676)	66	68 (5–672)	276 (116–682)	56	40	53
Grand 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 (443–1,778)	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 (387–2,282)	1,094 (727–1,996)	225	347 (158–1,119)	196 (127–281)	50	46	25
South Fork									
Secesh	171	341 (101–1,395)	428 (191–956)	166	308 (86–1,228)	362 (162–811)	97	96	93
EF/Johnson Creek	87	186 (55–1,257)	266 (141–589)	84	146 (45–1,018)	113 (63–244)	97	93	46
SF mainstem	689	1,399 (926–2,529)	1,046 (901–1,231)	392	712 (453–1,644)	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

Table 21 continued. Recent (5-year geometric mean) estimates of total and natural-origin spawning escapement in natural spawning areas for Snake River spring/summer-run Chinook salmon 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 MPG)	Total spawners (5-year geometric mean, range)			Natural origin (5-year geometric mean)			Percent 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)**
Middle Fork (cont.)									
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 Creek	150	184 (23–1,329)	471 (360–558)	150	179 (23–1,308)	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 (83–1,108)	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

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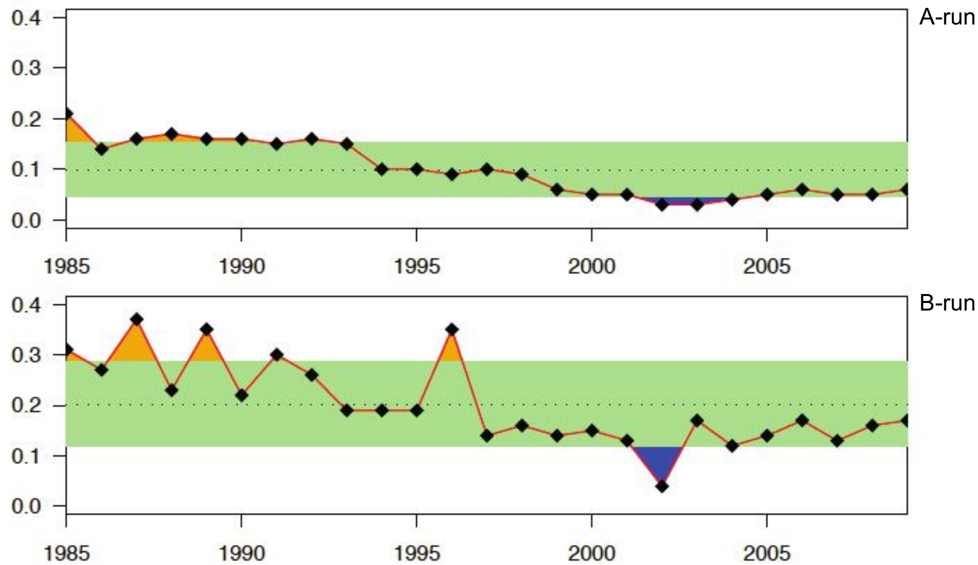

Figure 33. Total exploitation rate on natural summer steelhead above Bonneville Dam by year. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data for 1985−1998 from NMFS biological opinion[6] and for 1999−2008 from TAC run reconstruction.[7]

Snake River Spring/Summer-run Chinook Salmon ESU

The Snake River Spring/Summer-run Chinook Salmon ESU includes all naturally spawned populations of spring/summer-run Chinook salmon in the mainstem Snake River and the Tucannon, Grande Ronde, Imnaha, and Salmon river subbasins, as well as 15 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-run 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, 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

[6] See footnote 4.
[7] See footnote 5.

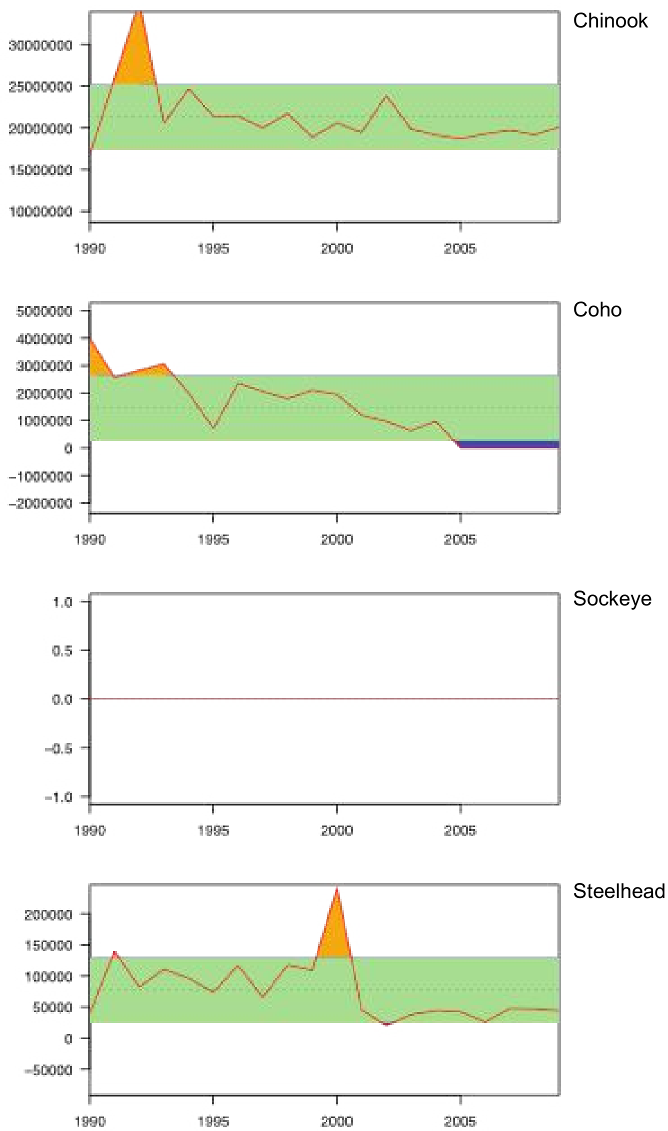

Figure 34. Summary of hatchery releases by year for species within the spawning and rearing boundaries of the Middle Columbia River Steelhead ESU. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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 nonnative Rapid River–origin hatchery program in the Grande Ronde basin was viewed as a positive action.

Brief Review of Recovery Planning

The ICTRT identified 27 extant and 4 extirpated populations of Snake River spring/summer-run Chinook salmon that historically used the accessible tributary and upper mainstem habitats within the Snake River drainages (ICTRT 2003). The populations are aggregated into five extant 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.

NMFS 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 (LSRB) and was accepted by NMFS in 2005. The LSRB Plan provides recovery criteria, targets, and tributary habitat action plans for the two populations of spring/summer-run Chinook salmon in the Lower Snake MPG in addition to the Touchet River (Middle Columbia River 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 NMFS 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 online 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 VSP elements: abundance, productivity, spatial structure, and diversity (McElhany 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 Spring/Summer-run Chinook: 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 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

This MPG contains eight historical populations (two currently considered functionally extirpated). The basic ICTRT criteria call for a minimum of four 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 or Wenaha rivers.

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 or Camas creeks.

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 1960s 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 Snake River Spring/Summer-run Chinook Salmon ESU (Figure 35 through Figure 41).

Estimates of natural-origin abundance for the most recent 5-year brood cycle are available for 24 populations in this ESU (Table 21). 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 natural spawner abundance were generally positive over the period 1995 to 2008, with some differences in magnitude for populations within different MPGs (Figure 42 through Figure 44). Trends for most populations in the Middle Fork and Upper Salmon MPGS are strongly positive. Two populations in the Middle Fork MPG (Marsh and Loon creeks) along with one (Lemhi River) in the Upper Salmon MPG had relatively flat trends in natural spawner abundance since 1995. Short-term trends in natural spawner 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 37). In the Grande Ronde MPG, three of the populations exhibited moderately positive trends, the remaining three have 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 broodyears (Figure 42). The series also include relatively high abundance estimates in 2001−2003, reflecting above average survivals for production from spawning in the late 1990s (Figure 42). 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-run Chinook salmon populations. 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.

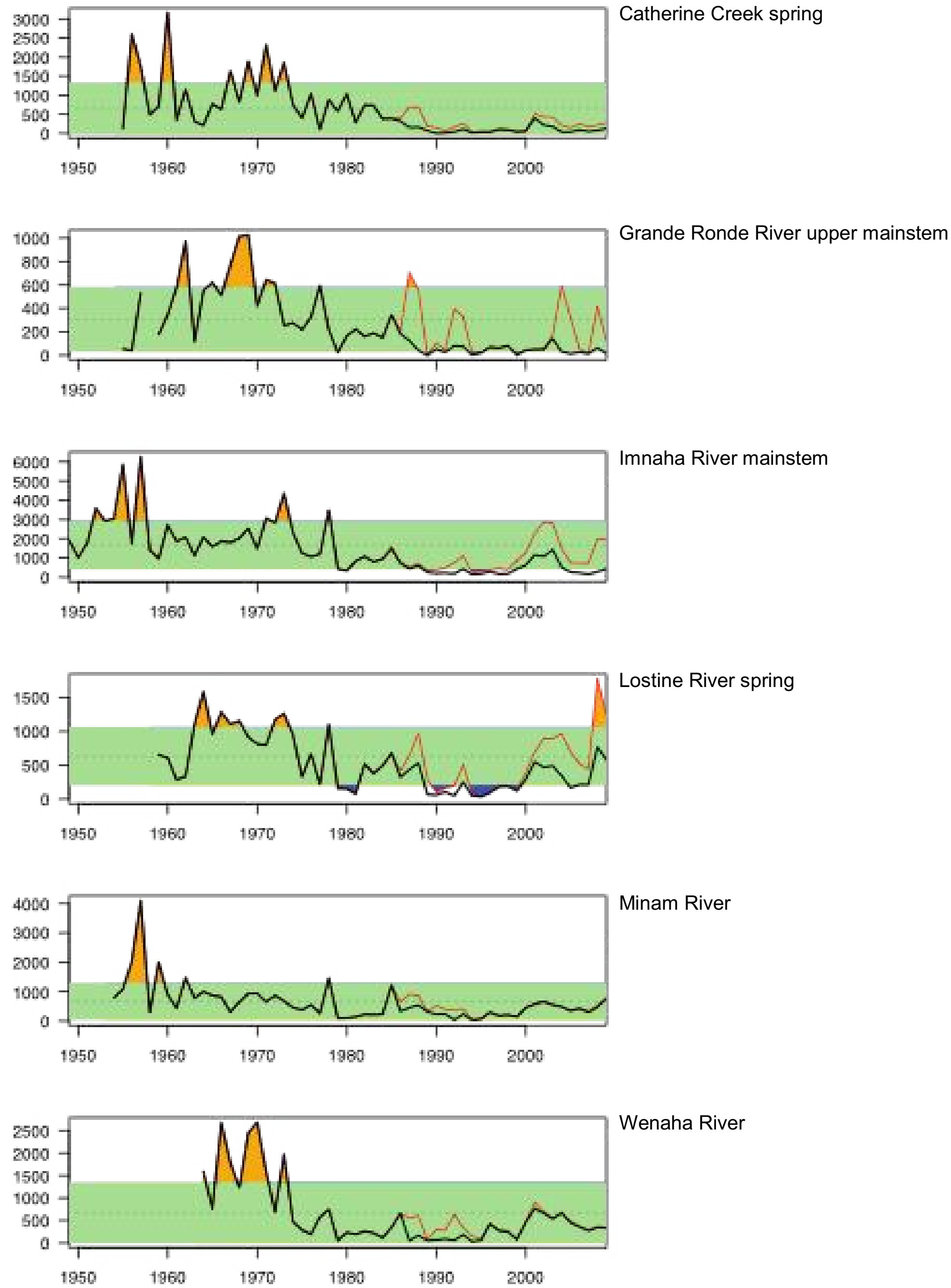

Figure 35. Spawning abundance by year for the Grande Ronde/Imnaha MPG in the Snake River Spring/Summer-run Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

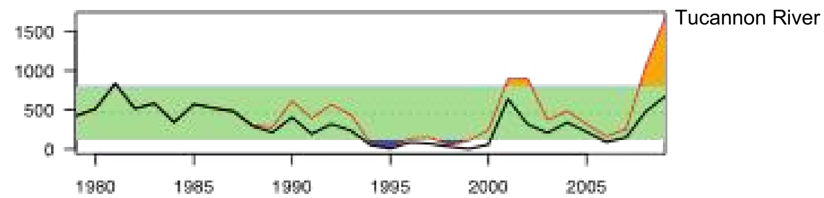

Figure 36. Spawning abundance by year for the Lower Snake MPG in the Snake River Spring/Summer-run Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

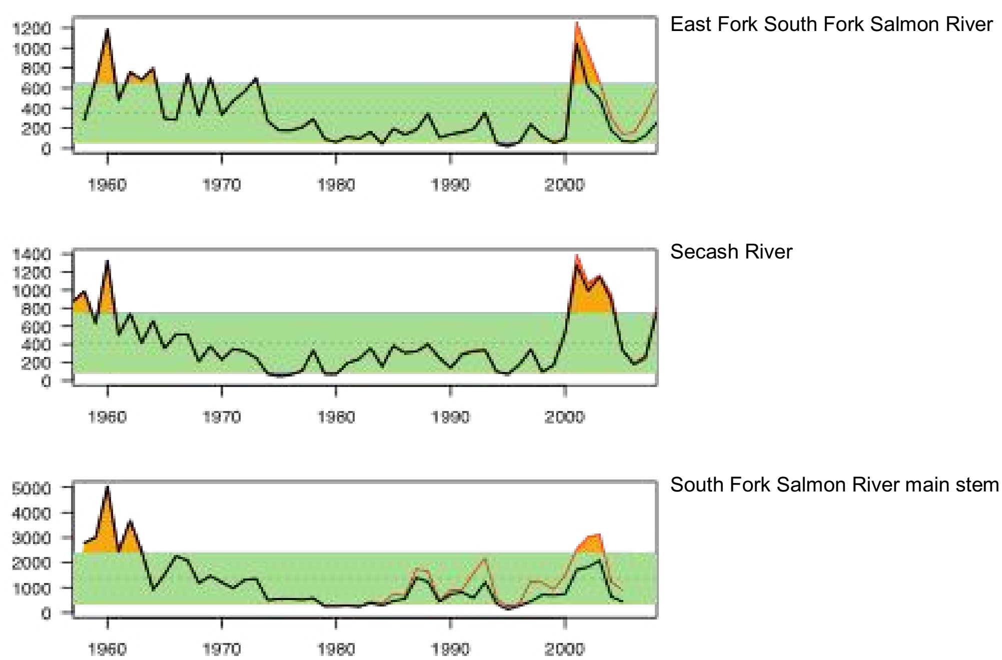

Figure 37. Spawning abundance by year for the South Fork Salmon MPG in the Snake River Spring/Summer-run Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the green shaded area indicates ±1 SD around the mean.

Current Status: ICTRT Viability Criteria

The overall viability ratings for all populations in the Snake River Spring/Summer-run Chinook Salmon 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.

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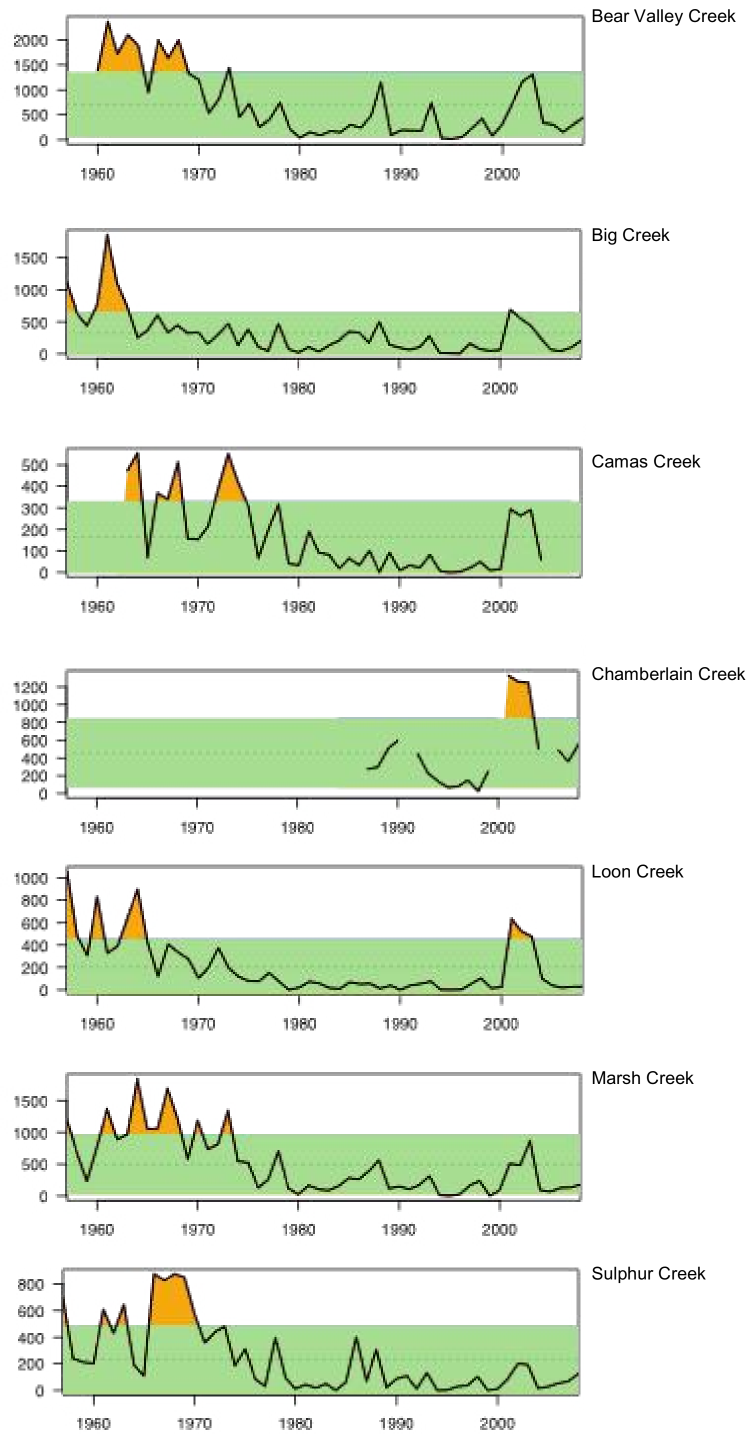

Figure 38. Spawning abundance by year for the Middle Fork Salmon River MPG in the Snake River Spring/Summer-run Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

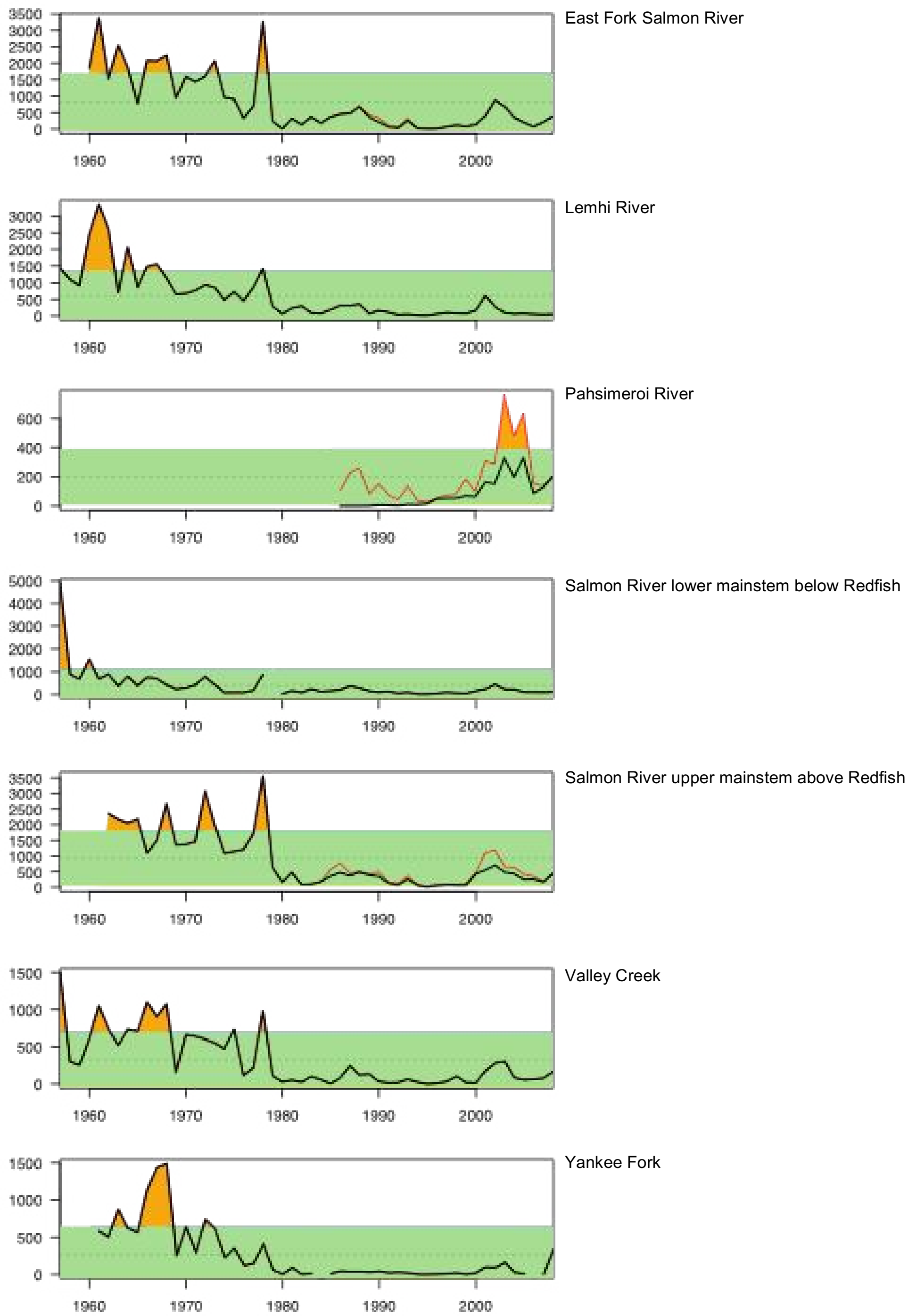

Figure 39. Spawning abundance by year for the Upper Salmon River MPG in the Snake River Spring/Summer-run Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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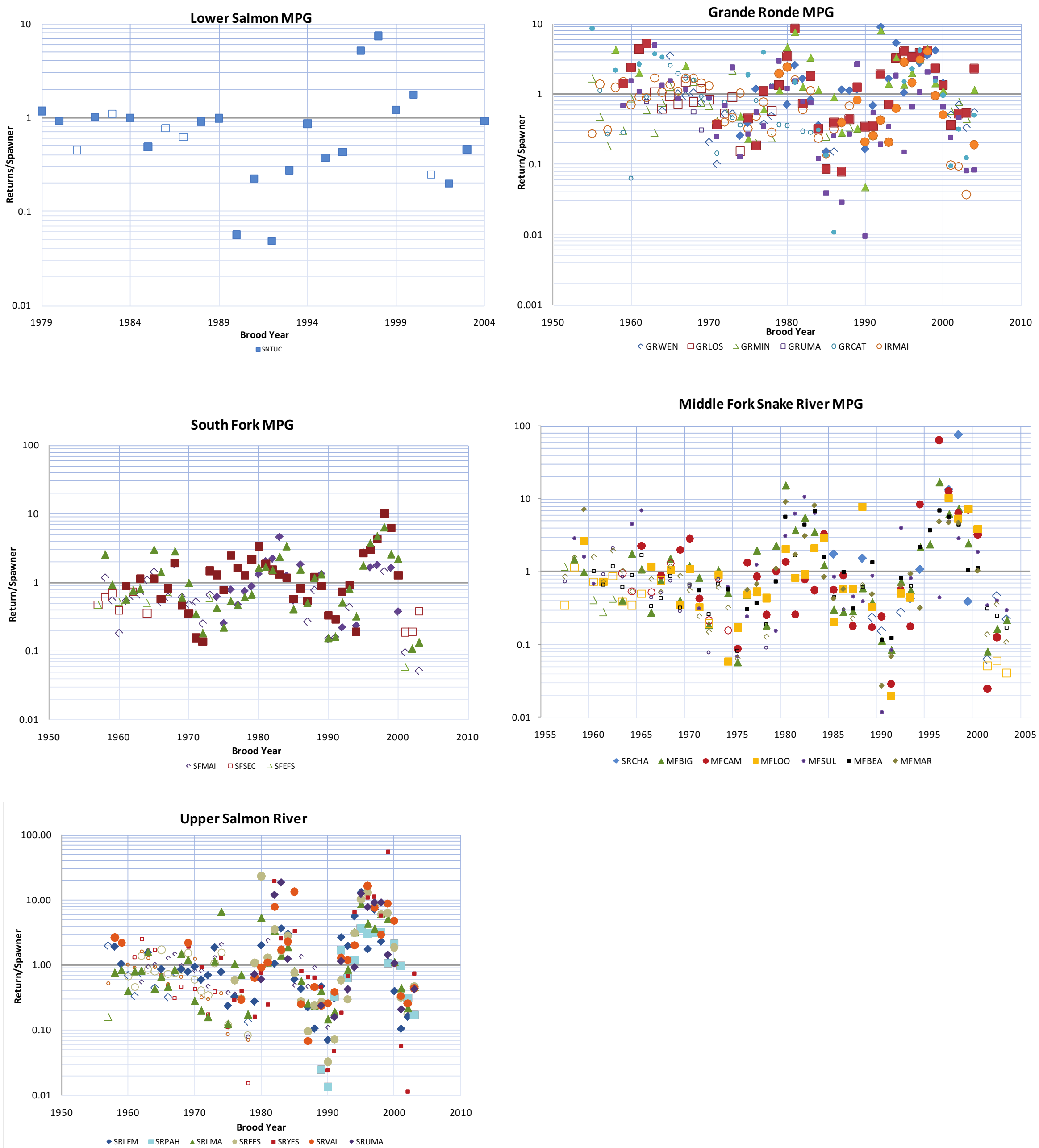

Figure 40. Snake River Spring/Summer-run Chinook salmon. Population recruit per spawner estimates organized by MPG. Recruits expressed as returns to tributary spawning areas. Filled markers are parent spawner estimates below 75% of minimum abundance threshold. Open markers are parent escapement greater than 75% of minimum abundance threshold.

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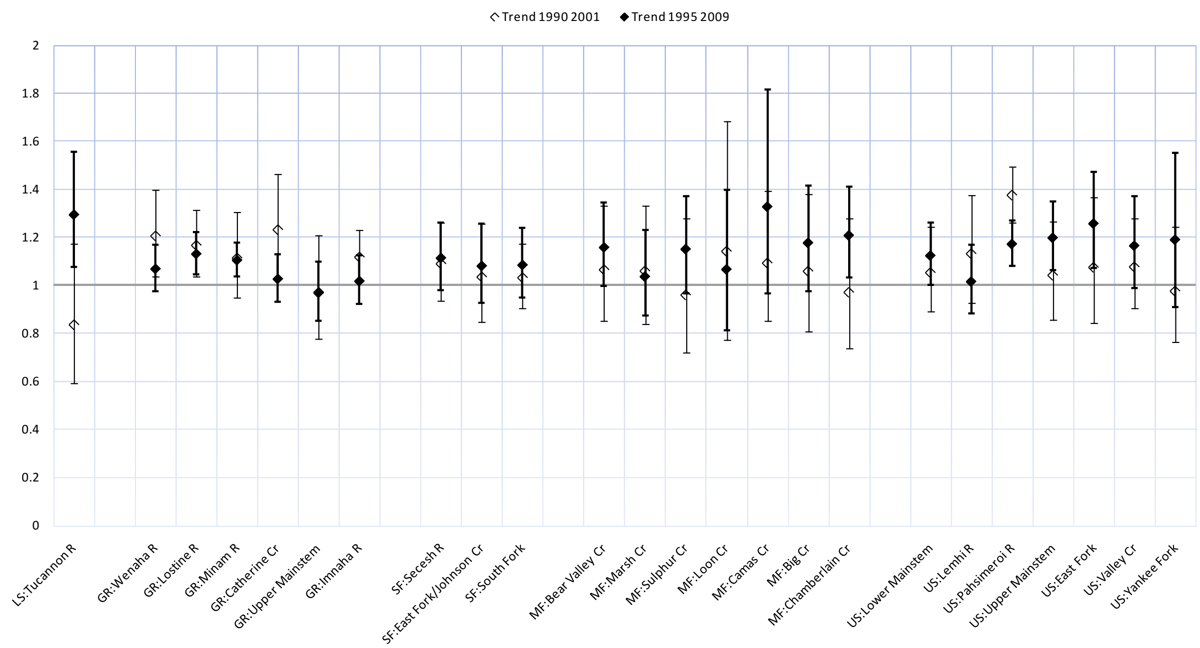

Figure 41. Short-term trend in natural-origin spawning abundance exp (slope of ln(natural-origin spawners) vs. year) for Snake River Spring/Summer-run Chinook salmon populations. Solid diamond/bar is point estimate and 95% cf for 1995−2009. Open diamond/bar is equivalent statistics for prior review.

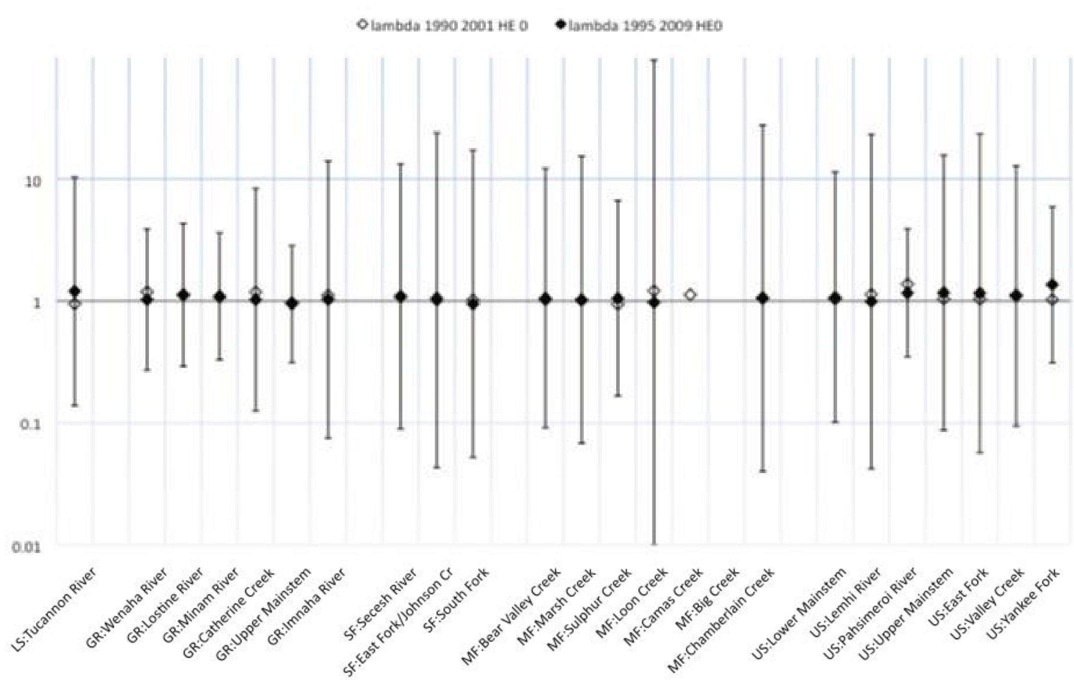

Figure 42. Short-term population growth rate (lambda) estimates for Snake River Spring/Summer-run Chinook salmon populations. Relative hatchery effectiveness set to 0.0. Solid diamond/bar is point estimate and 95% cf for 1995−2009. Open diamond/bar is equivalent statistics for prior review.

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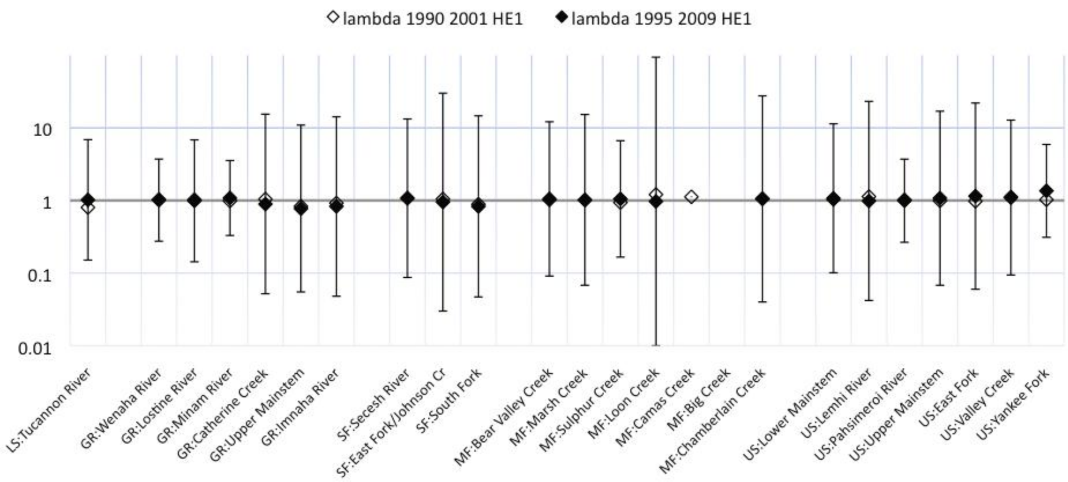

Figure 43. Short-term population growth rate (lambda) estimates for Snake River Spring/Summer-run Chinook salmon populations. Relative hatchery effectiveness set to 1.0. Solid diamond /bar is point estimate and 95% cf for 1995−2009. Open diamond/bar is equivalent statistics for prior review.

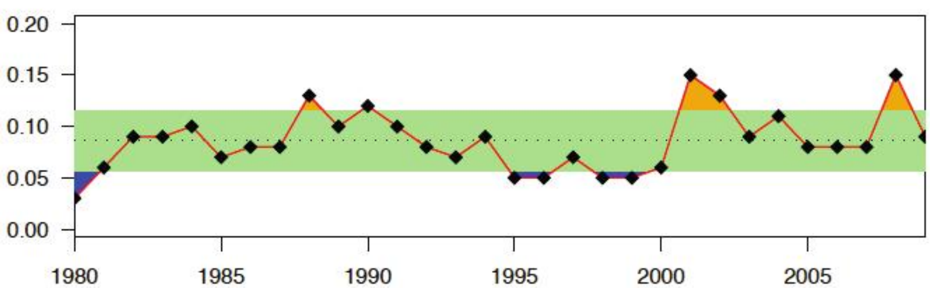

Figure 44. Total exploitation rates by year for Snake River spring/summer-run Chinook salmon. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from TAC 2010.

Lower Snake River MPG

Abundance and productivity remain the major concern for the Tucannon River population (Table 22). 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

The Wenaha, Lostine/Wallowa 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 (Table 23). Geometric mean productivity estimates remain relatively low for all populations in the MPG. The Upper Grande

AR054517

Ronde population is rated at high risk for spatial structure and diversity while the remaining populations are rated at moderate.

South Fork MPG

Natural spawning abundance (10-year geometric mean) estimates increased for the three populations with available data series (Table 24). 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 for two of the three populations in this MPG, although for the Secesh River the gap relative to the moderate risk viability curves is small. The updated geometric mean abundance and productivity estimates for the South Fork mainstem population increased sufficiently to just exceed the minimum requirements for a moderate risk rating. Spatial structure and 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

Natural-origin A/P remains extremely low for populations within this MPG (Table 25). As in the previous ICTRT assessment, A/P estimates for Bear Valley Creek and Chamberlain Creek (limited data series) are the closest to meeting viability minimums among populations in the MPG. SS/D 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

A/P estimates for most populations within this MPG remain at very low levels relative to viability objectives (Table 26). The Upper Salmon mainstem has the highest relative abundance and productivity combination of populations within the MPG. SS/D ratings vary considerably across the MPG. Four of the eight populations are rated at low or moderate risk for overall SS/D and could achieve viable status with improvements in average A/P. The high SS/D risk rating for the Lemhi population is driven by a substantial loss of access to tributary spawning and 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 22. Summary of current population status versus ICTRT viability criteria for the Lower Snake River MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Tucannon	750			High	Low	Moderate	Moderate	High risk
2000–2009		269 (58–682)	0.74 (0.52–1.06)					
1995–2004		182 (11–897)	0.69 (0.48–0.98)					

Table 23. Summary current population status versus ICTRT viability criteria for the Grande Ronde/Imnaha MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Wenaha	750			High	Low	Moderate	Moderate	High risk
2000–2009		441 (270–756)	0.72 (0.50–1.06)					
1995–2004		306 (51–756)	0.68 (0.50–0.94)					
Lostine/Wallowa	1,000			High	Low	Moderate	Moderate	High risk
2000–2009		320 (120–668)	0.77 (0.52–1.14)					
1995–2004		198 (33–541)	0.85 (0.58–1.26)					

AR054519

Table 23 continued. Summary current population status versus ICTRT viability criteria for the Grande Ronde/Imnaha MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				**Spatial structure and diversity metrics**			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Minam	750			High	Low	Moderate	Moderate	High risk
2000–2009		467 (301–697)	0.86 (0.62–1.20)					
1995–2004		287 (62–651)	1.07 (0.74–1.55)					
Catherine Creek	750			High	Moderate	Moderate	Moderate	High risk
2000–2009		107 (42–382)	0.71 (0.49–1.03					
1995–2004		87 (34–382)	0.73 (0.47–1.14)					
Up. Grande Ronde	1,000			High	High	Moderate	High	High risk
2000–2009		32 (13–140)	0.42 (0.26–0.68					
1995–2004		40 (4–140)	0.42 (0.27–0.68)					
Imhana River	750			High	Low	Moderate	Moderate	High risk
2000–2009		388 (127–1,342)	0.90 (0.74–1.13					
1995–2004		378 (74–1,342)	0.95 (0.77–1.16)					

AR054520

Table 24. Summary current population status versus ICTRT viability criteria for the South Fork Salmon River MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Secesh River	750			High	Low	Low	Low	High risk
2000–2009		472 (162–1,228)	1.25 (0.96–1.64)					
1995–2004		342 (59–1,228)	1.23 (0.97–1.55)					
EF/Johnson Creek	1,000			High	Low	Low	Low	High risk
2000–2009		162 (52–1,018)	1.15 (0.87–1.52)					
1995–2004		142 (20–1,018)	1.15 (0.91–1.46)					
South Fork Main	1,000			Moderate	Low	Moderate	Moderate	High risk
2000–2009		791 (374–1,873)	1.21 (0.67–2.20)					
1995–2004		630 (112–1,873)	1.25 (0.85–1.83)					
Little Salmon River		Insufficient data	Insufficient data	Insufficient data	Low	Low	Low	High risk

AR054521

Table 25. Summary current population status versus ICTRT viability criteria for the Middle Fork Salmon River MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Chamberlain Cr.	500			High*	Low	Low	Low	High risk
2000–2009		605 (239–1,308)	1.79 (0.38–8.44)					
1995–2004		249 (23–1,308)	1.77 (0.64–4.94)					
Big Creek	1,000			High	Very low	Moderate	Moderate	High risk
2000–2009		146 (42–662)	0.80 (0.57–1.12)					
1995–2004		93 (5–662)	1.17 (0.83–1.66)					
Low. Mid. Fk. Sal.	500	Insufficient data	Insufficient data	High	Moderate	Moderate	Moderate	High risk
2000–2009								
1995–2004								
Camas Creek	500			High	Low	Moderate	Moderate	High risk
2000–2009		57 (9–282)	0.70 (0.38–1.29					
1995–2004		30 (0–282)	0.74 (0.44–1.25)					
Loon Creek	500			High	Low	Moderate	High	High risk
2000–2009		67 (14–611)	1.19 (0.63–2.25					
1995–2004		49 (0–611)	1.01 (0.61–1.68)					
Up. Mid. Fk. Sal.	750	Insufficient data	Insufficient data	High	Low	Moderate	Moderate	High risk
2000–2009								
1995–2004								

AR054522

Table 25 continued. Summary current population status versus ICTRT viability criteria for the Middle Fork Salmon River MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Sulphur Creek	500			High	Low	Moderate	Moderate	High risk
2000–2009		37 (0–201)	0.76 (0.48–1.24					
1995–2004		26 (0–201)	1.10 (0.62–1.97)					
Bear Valley Creek	750			High	Very low	Low	Low	High risk
2000–2009		363 (73–1,282)	1.23 (0.90–1.68					
1995–2004		242 (16–1,282)	1.45 (1.08–1.94)					
Marsh Creek	500			High	Low	Low	Low	High risk
2000–2009		109 (0–861)	0.79 (0.53–1.19					
1995–2004		51 (0–861)	1.06 (0.70–1.62)					

*High risk rating retained for this population as a result of missing years; high uncertainty associated with recent abundance estimates.

AR054523

Table 26. Summary current population status versus ICTRT viability criteria for the Upper Salmon River MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Upper Salmon north fork	500			High	Low	Low	Low	High risk
2000–2009		Insufficient data	Insufficient data					
1995–2004								
Lemhi River	2,000			High	High	High	High	High risk
2000–2009		96 (38–582)	0.94 (0.59–1.52)					
1995–2004		92 (10–582)	1.13 (0.74–1.73)					
Pahsimeroi River	1,000			High	Moderate	High	High	High risk
2000–2009		154 (80–316)	0.58 (0.33–1.04					
1995–2004		91 (11–298)	0.48 (0.25–0.96)					
Upper Salmon lower mainstem	2,000			High	Low	Low	Low	High risk
2000–2009		120 (37–378)	1.16 (0.83–1.61					
1995–2004		83 (9–378)	1.28 (0.93–1.76)					
Upper Salmon east fork	1,000			High	Low	High	High	High risk
2000–2009		225 (68–784)	1.10 (0.68–1.78					
1995–2004		104 (6–784)	1.29 (0.77–2.16)					

AR054524

Table 26 continued. Summary current population status versus ICTRT viability criteria for the Upper Salmon River MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Yankee Fork	500			High	Moderate	High	High	High risk
2000–2009		21 (2–324)	0.80 (0.38–1.68					
1995–2004		16 (0–153)	1.01 (0.51–2.01)					
Valley Creek	500			High	Low	Moderate	Moderate	High risk
2000–2009		78 (13–292)	1.21 (0.78–1.91					
1995–2004		38 (0–292)	1.21 (0.78–1.89)					
Upper Salmon mainstem	1,000			High	Very low	Moderate	Moderate	High risk
2000–2009		313 (98–743)	1.21 (0.87–1.71					
1995–2004		181 (9–743)	1.42 (0.95–2.13)					

AR054525

Harvest

Harvest impacts (Figure 45) 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 salmon 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 (Figure 44). 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).

Hatchery releases

Total hatchery releases of spring/summer-run Chinook salmon 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 45). Releases of hatchery steelhead have declined by approximately one-third from pre-1995 levels.

Snake River Spring/summer-run Chinook Salmon 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.

Snake River Fall-run Chinook Salmon ESU

The Snake River Fall-run 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, 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 (Dauble and Geist 2000).

AR054526

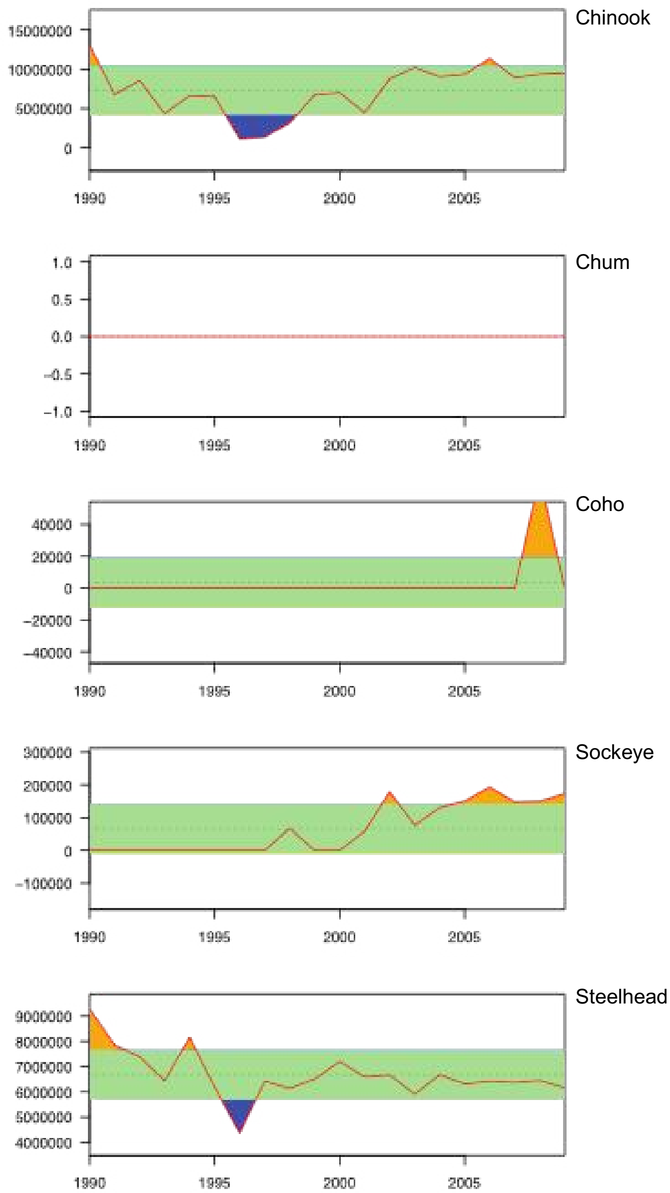

Figure 45. Trends in hatchery releases by year within the spawning and rearing areas of the Snake River Spring/Summer-run Chinook Salmon ESU. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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 contribution of native Lyons Ferry fish from supplementation programs was increasing, and 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-run 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-run Chinook and other Columbia River ESUs may have existed and that it has been compromised by hatchery straying.

Brief Review of Recovery Planning

NMFS 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 River basin will be based on an updated version of the Lower Snake River Salmon Recovery Plan provided to NMFS in 2005 by the State of Washington.

TRT and Recovery Plan Criteria

The ICTRT developed viability criteria for application to Snake River fall-run 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 and spring/summer ESUs and steelhead DPSs. At the population level, the ICTRT A/P criteria are expressed as viability curves. The lower mainstem population would be considered at low 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 2,000 spawners—75% of the minimum abundance threshold of 3,000) 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-run 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 and Salmon rivers were defined as minor spawning areas.

New Data and Updated Analyses

Annual estimates of spawning escapements for the extant population of Snake River fall-run Chinook salmon are based on counts and adult sampling at passage over Lower Granite Dam (Milks et al. 2009). 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 46).

The total spawning escapement into natural areas above Lower Granite Dam has remained relatively high since the rapid increase in the late 1990s. The current 5-year geometric mean total escapement is above 10,000, substantially greater than the 1997−2001 geometric mean reported in the previous BRT review (Table 27). A relatively high proportion of the estimated spawners are of hatchery origin (78% for the most recent 5-year cycle). However natural-origin returns have also increased substantially over the geometric mean estimates for the 2005 BRT review and the cycle just prior to the 1997 listing decision (Figure 47).

The most recent short-term trend in natural-origin spawners was strongly positive, increasing at an average rate of 16% per year (Table 28). 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 46). Although natural-origin returns have remained well above the levels estimated at the time of listing in the early 1990s, the most recent escapements have dropped from the peak in 2001−2003 and have fluctuated below the ICTRT minimum abundance threshold level. Recent annual spawning levels have been well above the ICTRT minimum abundance threshold for the population and the corresponding return per spawner levels have been well below replacement. The apparent leveling off of natural returns in spite of the increases in total broodyear spawners may indicate that density dependent habitat effects are influencing production or that high hatchery proportions may be influencing natural production rates.

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

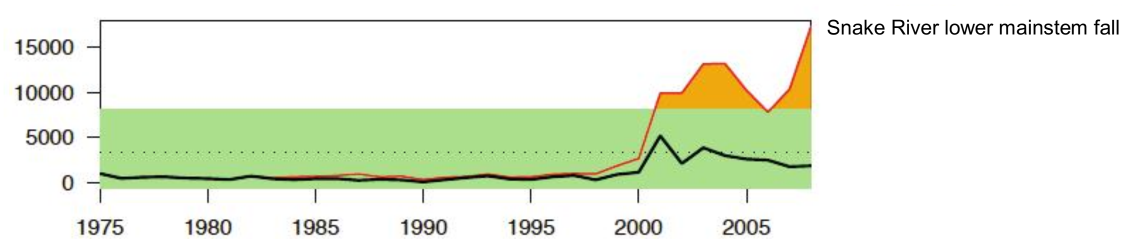

Figure 46. Estimated escapement by year for Snake River fall-run Chinook salmon above Lower Granite Dam. Adult run size to Lower Granite Dam minus fish trapped and transferred to hatchery programs. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

AR054529

Table 27. Recent abundance and proportion of natural origin Snake River fall-run Chinook salmon in natural spawning areas compared to estimates at the time of listing and the previous BRT review.

Total spawners (5-year geometric mean, range)		**Natural origin (5-year geometric mean)**		**Percent natural origin (5-year average)**	
Prior (1997–2001)	**Current (2003–2008)**	**Prior (1997–2001)**	**Current (2003–2008)**	**Prior (1997–2001)**	**Current (2003–2008)**
2,164 (962–9,875)	11,321 (7,784–17,266)	1,055 (306–5,163)	2,291 (1,762–2,983)	51	22

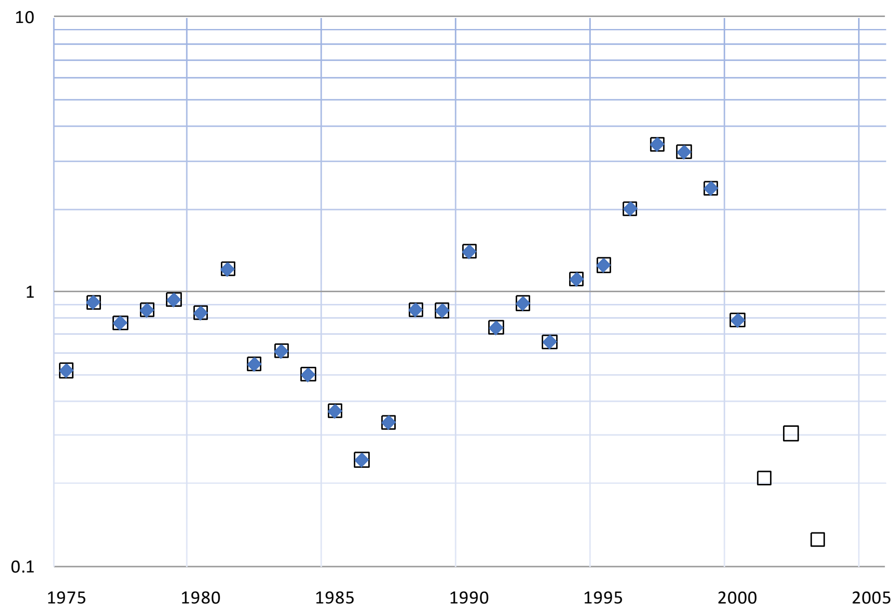

Figure 47. Snake River fall-run Chinook salmon broodyear spawner to spawner estimates. Filled diamonds are parent spawner estimate below 75% of minimum abundance threshold. Open squares are parent escapement greater than 75% of minimum abundance threshold.

Table 28. Short-term (since 1995) trends in natural-origin spawning abundance (slope of natural ln adult spawners) for the lower Snake River fall-run Chinook salmon population. Comparisons with time periods corresponding to prior BRT reviews included.

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

AR054530

trend in total spawners (Table 29 and Table 30). The population growth rate estimate under the assumption that hatchery-origin spawners have not contributed to production is an indicator of trends in total broodyear production across return years. That metric is positive, indicating that on average natural production has increased over broodyears 1975−2003.

The Snake River fall-run 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 (Table 31) (the average rate of increase of 6% per year), largely driven by recent increases.

TRT Viability Criteria Ratings

The ICTRT rated the current status of the Snake River fall-run Chinook salmon 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.

Abundance and productivity

The current estimate (1999−2008 10-year geometric mean) of natural-origin spawning abundance (10-year geometric mean) of Snake River fall-run Chinook salmon 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 broodyears. Previous ICTRT status reviews for Snake River fall Chinook included estimates based on a more recent time series to account for potential major, but unquantified changes in downstream

Table 29. Short-term lambda (since 1995) trends in spawning abundance (population growth rate) for the lower Snake River fall-run Chinook salmon population. Comparisons with time periods corresponding to prior BRT reviews included.

	Hatchery effectiveness = 0		**Hatchery effectiveness = 1.0**	
	2005 BRT (1990–2001)	**Current (1995–2008)**	**2005 BRT (1990–2001)**	**Current (1995–2008)**
Estimate	1.21	1.15	1.08	0.90
CI	0.46–3.17	0.18–7.37	0.49–2.35	0.08–10.23
P > 1.0	0.88	0.75	0.78	0.34

Table 30. Long-term trend estimates, years 1975–2008, for lower Snake River fall-run Chinook salmon population.

	Total spawners	**Lambda (HF = 0)**	**Lambda (HF = 1)**
Estimate	1.06	1.04	0.90
CI	(1.03–1.08)	(0.89–1.22)	(0.76–1.07)
P > 1.0		0.73	0.09

AR054531

Table 31. Viability assessments for lower Snake River fall-run Chinook salmon population using ICTRT criteria, updated to reflect return years through 2008 (i.e., abundance data updated through return year 2008 based on Chinook returns at age-2 through age-5, which allows reconstruction of returns through 2004). Two alternative scenarios were used in the assessment of this population: baseline (natural spawning abundance: most recent 10-year geometric mean [range]), and recent (using only brood years 1990–present). The recent period reflects improved transportation, flow and temperature patterns during rearing/migration period, increasing presence of reservoir form since 1991.

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Broodyears	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Recent	3,000			Moderate	Low	Moderate	Moderate	Maintained
1990–2004		2,208 (905–5,163)	1.28 (0.92–1.77)					
1990–2001		1,217 (306–5,163)	1.28 (0.92–1.77)					
Baseline	3,000				Low	Moderate	Moderate	Maintained
1985–2004		2,208 (905–5,163)	1.06 (0.83–1.36)	Moderate				
1985–2001		1,217 (306–5,163)	1.07 (0.88–1.31)	High				

AR054532

passage conditions (enhanced flows and transport regimes) initiated in 1990. Incorporating the most recent complete broodyear returns results in an updated productivity for the 1990-to-present series of 1.28. The estimate for the most recent 20-year series (1983−2003 broodyears) was 1.07 (Table 31). Combining the current natural spawning escapement estimate of 2,200 with either of the productivity estimates results in an A/P rating of moderate risk using the ICTRT viability curves for this population.

Spatial structure and diversity

The addition of 2 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, which states,

> 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 salmon 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 A/P and SS/D summarized above, the Lower Snake River fall-run Chinook salmon population would be rated as maintained (Figure 48). 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 Mainstem Snake	**HR**
	High (>25%)	**HR**	**HR**	**HR**	**HR**

Figure 48. Snake River lower mainstem fall-run Chinook salmon population risk ratings integrated across the four VSP metrics. Viability Key: HV = highly viable, V = viable, M = maintained, and HR = high risk. Shaded cells = does not meet viability criteria (darkest cells are at highest risk).

AR054533

Harvest

Snake River fall Chinook salmon 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 nontribal 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 ocean and river fisheries (Figure 49). The total exploitation rate has been relatively stable in the range of 40% to 50% since the mid-1990s.

Hatchery releases

Hatchery releases of Snake River fall Chinook salmon have generally been trending upward since the mid-1990s, as have releases of coho and sockeye salmon (Figure 50).

Snake River Fall-run Chinook Salmon: Updated Risk Summary

A/P estimates for the single remaining population of Snake River fall-run 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 one 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

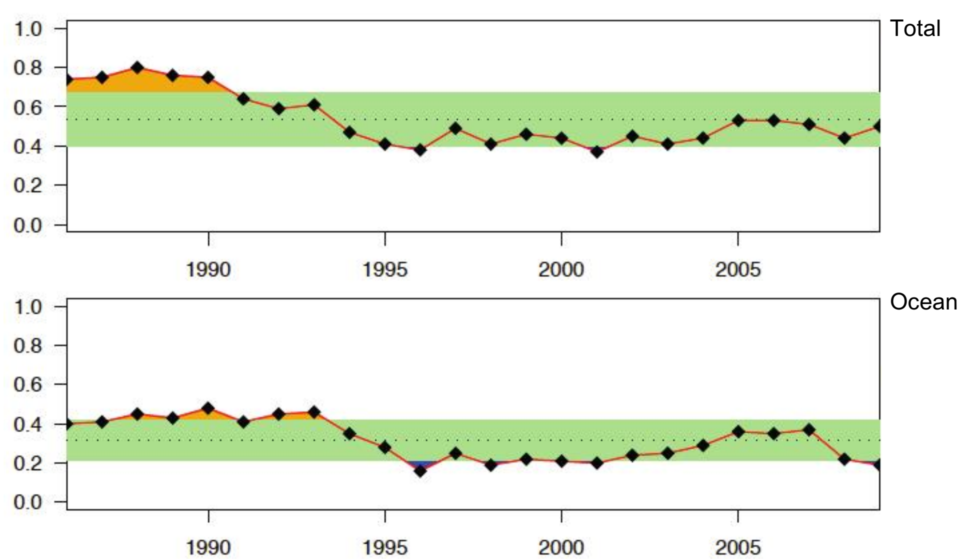

Figure 49. Exploitation rate by year for Snake River fall-run Chinook salmon. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data for marine exploitation rates from CTC in prep. and for in-river harvest rates from TAC 2009 and WDFW.[8]

[8] See footnote 5.

AR054534

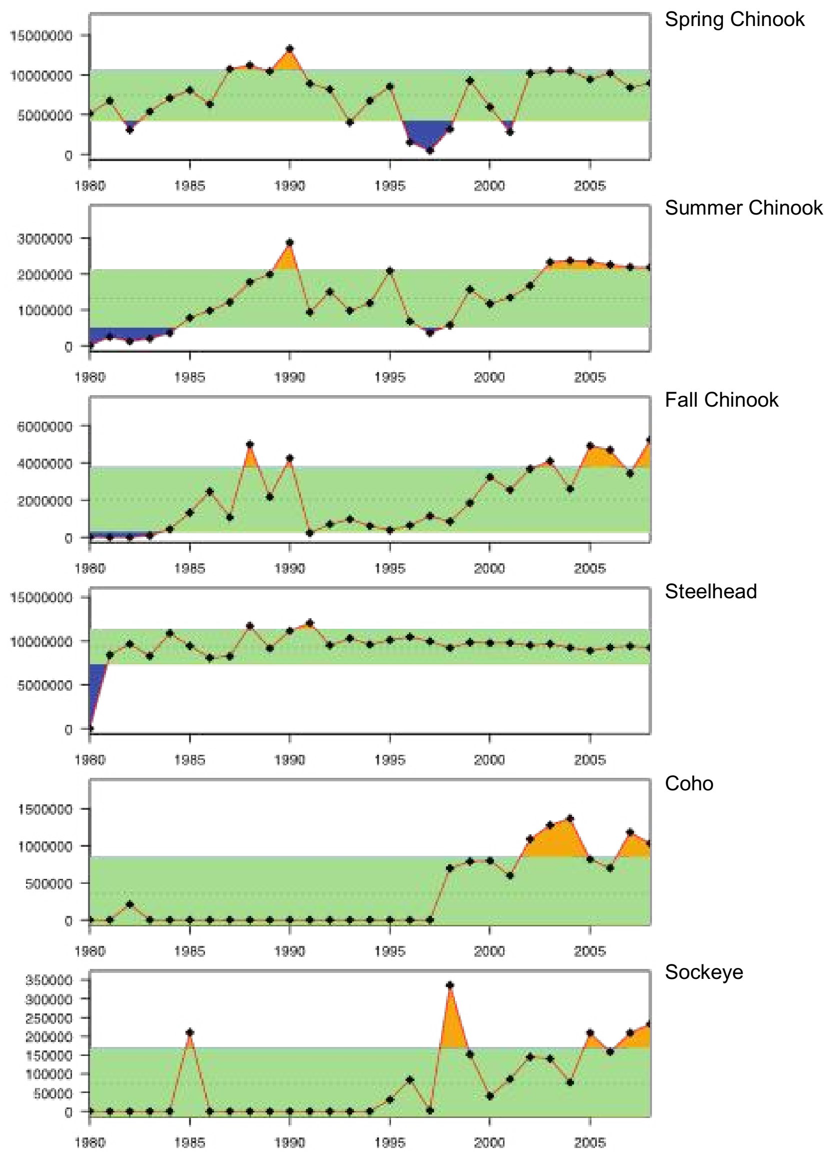

Figure 50. Snake River hatchery releases by year since 1980. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from Fish Passage Center, http://www.fpc .org/hatchery/misc_docs/SnakeHatcheryReleases.html.

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.

Snake River Sockeye Salmon ESU

This 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 and 37204).

Summary of Previous BRT Conclusions

The 2005 BRT assigned the Snake River Sockeye Salmon 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 of Recovery Planning

NMFS has initiated recovery planning for the Snake River drainage, including a component addressing the Snake River Sockeye Salmon ESU. 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 A/P criteria for application to Snake River sockeye salmon 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 and Alturas lakes 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 structure estimates from Redfish Lake sampling in the 1950s−1960s and year-to-year variations in broodyear 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.

AR054536

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 32). 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.

Increased returns in recent years have supported substantial increases in the number of adults released above the Redfish Lake Creek weir (Table 33). Annual adult releases since 2003 have ranged from 173 to 969, compared to the range for the 5-year period ending in 2002 (0 to 190 sockeye). The large increases in returning adults in recent years reflect improved downstream and ocean survivals as well as increases in juvenile production since the early 1990s (Table 33). Presmolt outplants into Redfish, Alturas, and Petit lakes were initiated in the mid-

Table 32. Adult sockeye salmon 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.

	Redfish Lake Creek			Sawtooth FH	Stanley Basin
Year	Below weir	Weir	Subtotal	weir count	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

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Table 33. Estimated annual numbers of salmon smolt outmigrants from the Stanley Basin. This includes hatchery smolt releases, known outmigrants originating from hatchery presmolt outplants, and estimates of unmarked juveniles migrating from Redfish, Alturas, and Stanley lakes combined.

Year	No. pre-smolts planted	Estimated outmigration from pre-smolt plants	No. smolts planted	No. pre-spawn adults planted	No. 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	85,005	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

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 more than 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 143,500−210,300 during the most recent 5-year period (2005−2008), compared to a range of 19,600−146,300 for 1998−2002, the period corresponding to the 2005 BRT review.

Ongoing studies of the limnological characteristics of the three Stanley Basin lakes and the current densities of sockeye 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

Increased production from the captive brood program has resulted in sufficient release and outplanting levels for initial evaluations of alternative supplementation strategies (Hebdon et al. 2004). Hatchery-reared presmolts have been outplanted into each of the three lakes since the mid-1990s (Table 34 and Table 35). Estimates of the proportion of those outplants emigrating

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Table 34. Release of Snake River sockeye salmon progeny from Redfish Lake captive brood program into Redfish Lake, Redfish Lake Creek, and the Salmon River at or above the Sawtooth Hatchery weir.

	Redfish Lake adult releases				Redfish Lake juv. releases		Sawtooth
Release year	Captive lake	Hatch (anad) lake	Total lake	Eggs lake	Presmolts lake	Smolts below weir	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

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 51).

Lakes to Lower Granite Dam juvenile migrant survivals

The increased numbers of juvenile migrants (primarily from hatchery releases) have also resulted in improved estimates of downstream passage mortality, including the generation of confidence limits 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 sockeye smolts sampled at Lower Granite Dam relative to the estimated outmigration from the Stanley Basin (Table 33). 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 52).

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Table 35. Release of Snake River sockeye salmon progeny from Redfish Lake captive brood program into Alturas and Petit lakes.

Release year	Adult releases Captive	Hatch (anad.)	Total	Eggs	Presmolts	Smolts
Alturas 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	—
Petit 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	—

Lower Granite Dam SAR estimates

Annual estimates of an index of SARs have been generated for Snake River sockeye as the estimated number of smolts at Lower Granite Dam in a given year divided into the number of returning adults 2 years later (NMFS 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 5 of the 9 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

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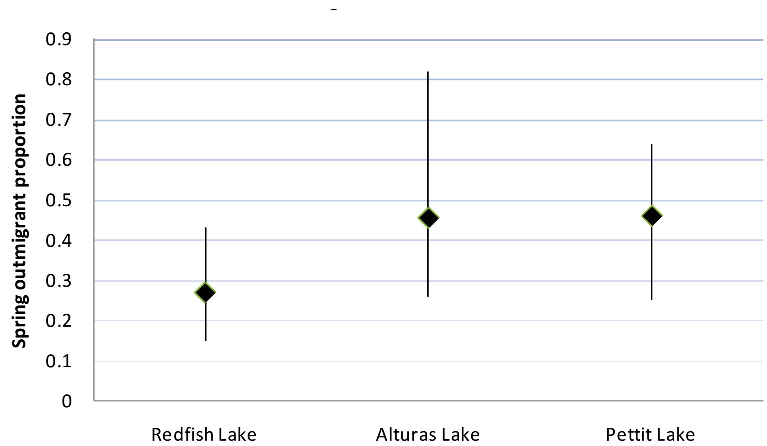

Figure 51. Estimated proportion of fall presmolt plants outmigrating in the spring of the following year (2000–2008). Solid diamonds are median estimate, lines are range of annual estimates. Estimates from Table 15 in Peterson et al. 2010.

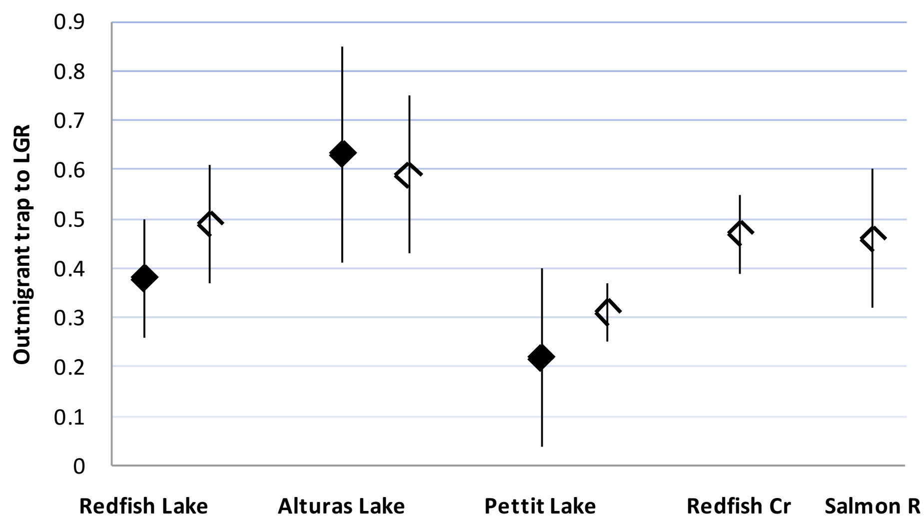

Figure 52. Snake River sockeye salmon juvenile downstream survival estimates for 2008 migration year. Estimated survival from trap or release location to Lower Granite Dam. Closed diamonds are natural-origin smolts; open diamonds are hatchery-origin smolt releases. Bars are 95% confidence limits. Estimates from Table 13 in Peterson et al. 2010.

2010 observed for runs returning to the upper Columbia (Lake Wenatchee and Lake Okanogan) and 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 more than 90%. The median estimated survival of juvenile in-river migrants downriver from Lower Granite Dam through the lower Snake River to McNary Dam on

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the mainstem Columbia River was 67% for the period 1996−2010; individual year estimates ranged from 28% to 76% (Ferguson 2010). The median estimate of juvenile passage survivals for the McNary Dam to the 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 (NMFS 2008). Comparisons of adult sockeye counts at Ice Harbor and Lower Granite dams indicate direct losses are also low for passage through the lower Snake River. Adult passage survival estimates based on passive integrated transponder (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 salmon at Lower Granite Dam versus returning to the Sawtooth Basin indicate relatively high loss rates through this reach in some years. Keefer et al. (2008) 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. (2008) examined current run timing patterns of Snake River sockeye versus 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 salmon. Within the mainstem Columbia River, treaty tribal net fisheries and nontribal 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 1980 fishery impact rates increased briefly due to directed sockeye fisheries on large runs of upper Columbia River stocks (Figure 53).

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 54).

Snake River Sockeye Salmon: Updated Risk Summary

Substantial progress has been made with the Snake River sockeye salmon captive broodstock–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 reestablishing natural

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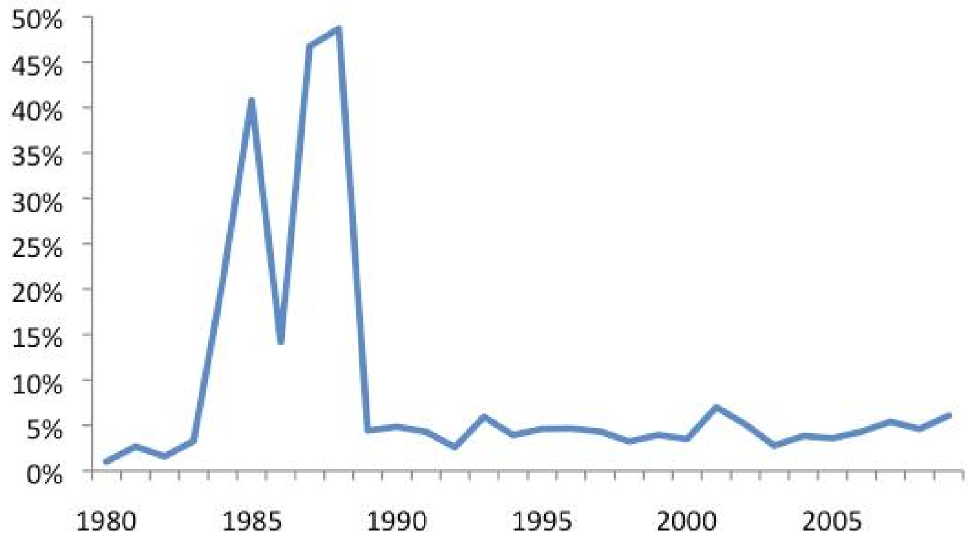

Figure 53. Total exploitation rates (%) by year on Snake River sockeye salmon. Data from Columbia River Joint Staff Report 2010.

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 sockeye salmon for use in supplementation efforts, substantial increases in survival rates across life history stages must occur in order to reestablish 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.

Snake River Basin Steelhead ESU

The Snake River Steelhead DPS "includes all naturally spawned anadromous 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 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 spawning and juvenile rearing occurs across a wide range of freshwater temperature and 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,

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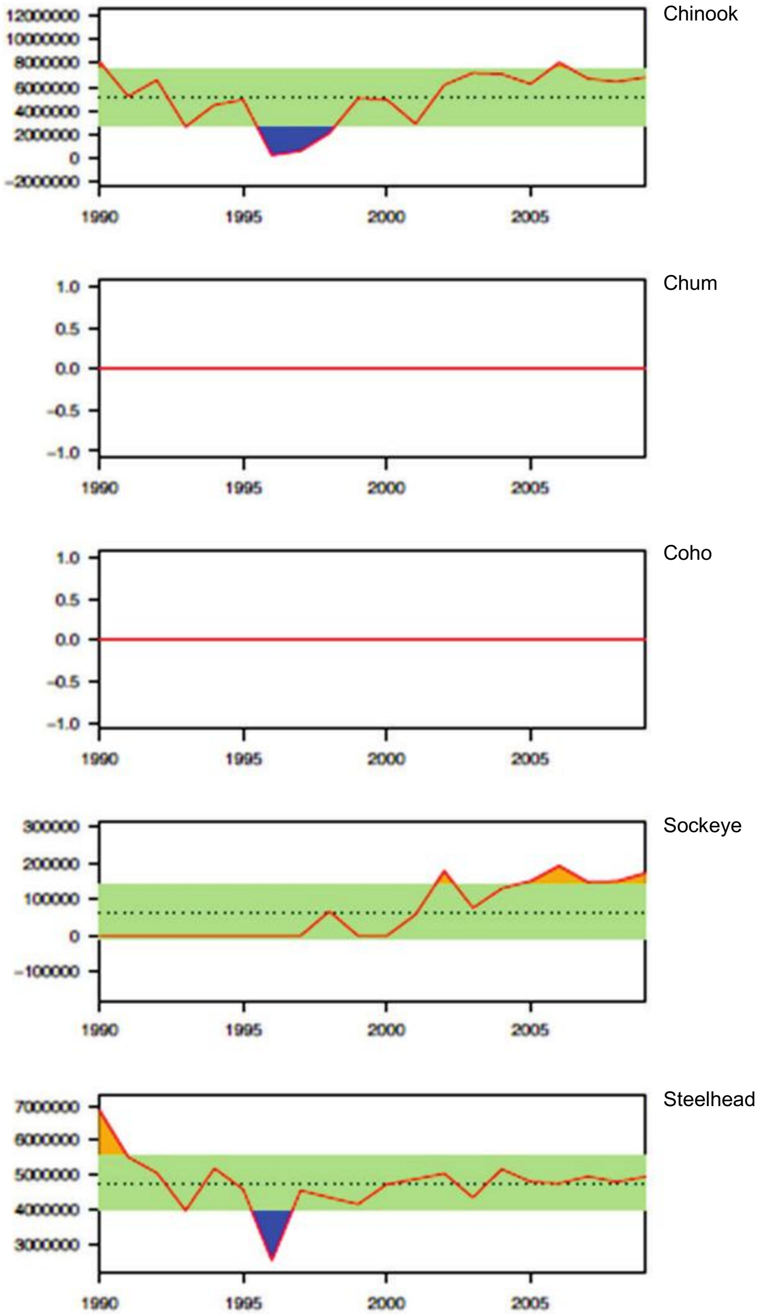

Figure 54. Annual hatchery releases by year within the spawning and rearing areas of the Snake River Sockeye Salmon ESU. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

adult size at return, and migration timing. A-run steelhead predominately spend 1 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. B-run steelhead are believed to be more prevalent in higher elevation drainages.

NMFS has defined DPSs of steelhead to include only the anadromous members of the species (70 FR 67130). Our approach to assessing the current status of a steelhead DPS is based on evaluating information on the abundance, productivity, spatial structure, and diversity of the anadromous component of this species (Good et al. 2005, 70 FR 67130). Many steelhead populations along the U.S. West Coast 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 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 of 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.

Brief Review of Recovery Planning

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 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.

TRT and Recovery Plan Criteria

NMFS 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 LSRB (Washington State) was accepted by NMFS in 2005. The LSRB Plan provides recovery criteria, targets, and tributary habitat action plans for the two

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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. 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 online 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 VSP elements: abundance, productivity, spatial structure, and diversity (McElhany 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 period.

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). 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, Selway, and South Fork Clearwater rivers.

Salmon River MPG

This relatively large MPG includes 12 extant populations. The ICTRT example scenario for this MPG includes consideration for historical population size, inclusion of both major life history patterns (A-run 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 Basin 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.[9] 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.

Population-level abundance data series are available for just two populations within this DPS, both within the Grande Ronde MPG (Table 36). 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 36, Figure 55). 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. These patterns in abundance are also reflected in the short-term trends in natural origin spawner abundance (Table 37) and population growth rate (Table 38) for the two populations with sufficient data series for analysis.

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[9] P. Hassemer, IDFG, Boise, ID. Pers. commun., July 2010.

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Table 36. Recent abundance and proportion natural origin in natural spawning areas compared to estimates at the time of listing and in the previous BRT review. Abundance estimates (5-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.

	Total spawners (5-year geometric mean, range)			**Natural origin (5-year geometric mean)**			**Percent natural origin (5-year average)**		
Population	**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	1,337	2,135 (1,251–3,171)	1,925 (1,212–3,598)	1,337	2,134 (1,251–3,170)	1,925 (1,212–3,597)	100	100	100
Upper Grande Ronde River	1,594	1,772 (1,084–2,756)	1,442 (949–1,943)	1,249	1,332 (767–2,277)	1,425 (941–1,943)	79	76	99

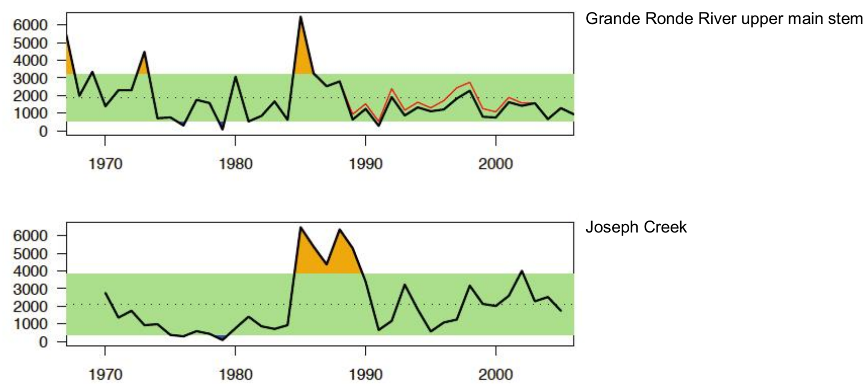

Figure 55. Snake River steelhead population estimates by year. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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Longer term trend estimates for the populations differ slightly (Table 39). 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 to 4% per year for Joseph Creek across the range of long-term trend metrics (Table 40). 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 2 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 lower Grande

Table 37. Short-term (since 1995) population growth rate (lambda) estimates. Current estimates versus 2005 BRT short-term time series.

Population		Hatchery effectiveness = 0		Hatchery effectiveness = 1.0	
		2005 BRT (1990–2001)	**Current (1995–2009)**	**2005 BRT (1990–2001)**	**Current (1995–2009)**
Joseph Creek	Estimate	1.02	1.03	1.02	1.03
	CI	0.33–3.16	0.39–2.74	0.33–3.16	0.39–2.74
	$P > 1.0$	0.57	0.62	0.57	0.62
Upper Grande Ronde River	Estimate	1.03	0.99	0.97	0.96
	CI	0.91–1.167	0.80–1.24	0.82–1.15	0.65–1.44
	$P > 1.0$	0.89	0.38	0.14	0.22

Table 38. Short-term trend in total (natural areas) spawners for Snake River steelhead. Comparison of current trends to prior reviews.

Population		1998 BRT (1987–97)	Previous (1990–2001)	Current (1995–2009)
Joseph Creek	Estimate	0.84	1.04	1.05
	CI	0.73–0.96	0.93–1.16	0.98–1.12
	$P > 1.0$	0.01	0.75	0.93
Upper Grande Ronde River	Estimate	0.98	1.04	1.01
	CI	0.85–1.13	0.94–1.15	0.96–1.06
	$P > 1.0$	0.39	0.79	0.63

Table 39. Long-term trends in spawning abundance for Snake River steelhead populations.

Population	Years	Trend in total spawners	Lambda (HF = 0)		Lambda (HF = 1)	
		Estimate (CI)	**Estimate (CI)**	**$P > 1$**	**Estimate (CI)**	**$P > 1$**
Joseph Creek	1970–2009	1.03 1.01–1.05	1.01 0.85–1.19	0.54	1.01 0.85–1.19	0.54
Upper Grand Ronde	1967–2010	0.99 0.97–1.01	0.98 0.89–1.09	0.36	0.97 0.87–1.07	0.23

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Ronde River abundance estimates are available for years back to the 1986−1987 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 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 5-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 40, Figure 56). Natural-origin and hatchery-origin returns each showed increases, although hatchery fish increased at a higher rate. The aggregate A-run 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.

Index area data series representing portions of three additional populations in the Grande Ronde and Lower Snake MPGs are available (Figure 57). All four series are highly variable and show similar temporal patterns to the population and DPS aggregate-level data sets.

IDFG has routinely collected juvenile steelhead 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 58). Average densities in areas assigned as A-run habitats trended downward 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) versus 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 58). The highest median densities were observed in the small tributaries below Hells Canyon Dam, the Lower Clearwater and Lochsa rivers (Clearwater MPG)

AR054550

Table 40. Recent abundance and proportion natural origin in natural spawning areas for aggregate returns to Lower Granite Dam (LGR) 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.

	Total spawners (5-year geometric mean, range)			Natural origin (5-year geometric mean)			Percent natural origin (5-year average)		
Population	**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

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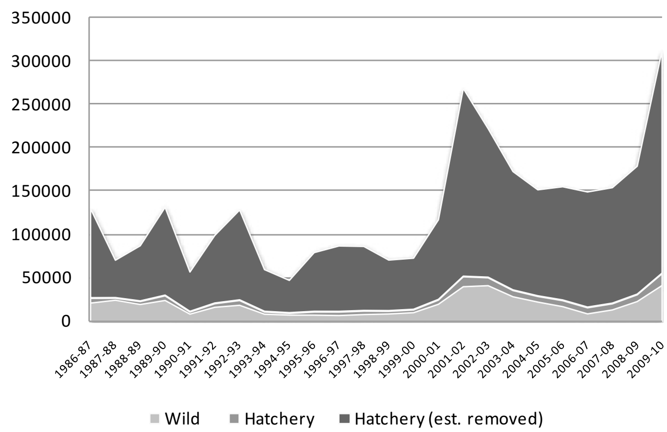

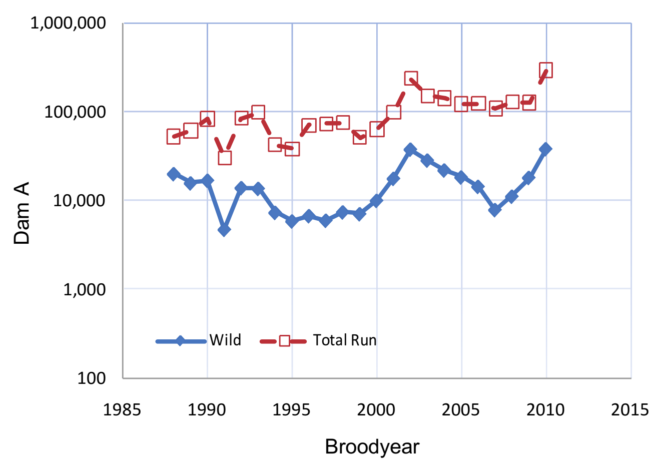

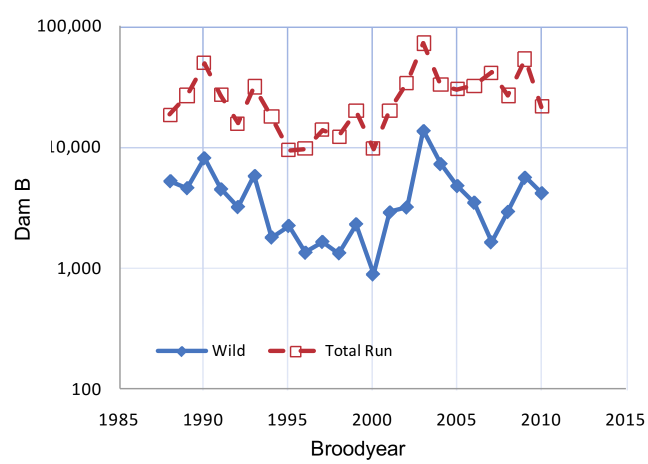

Figure 56. Lower Granite Dam counts for Snake River steelhead.

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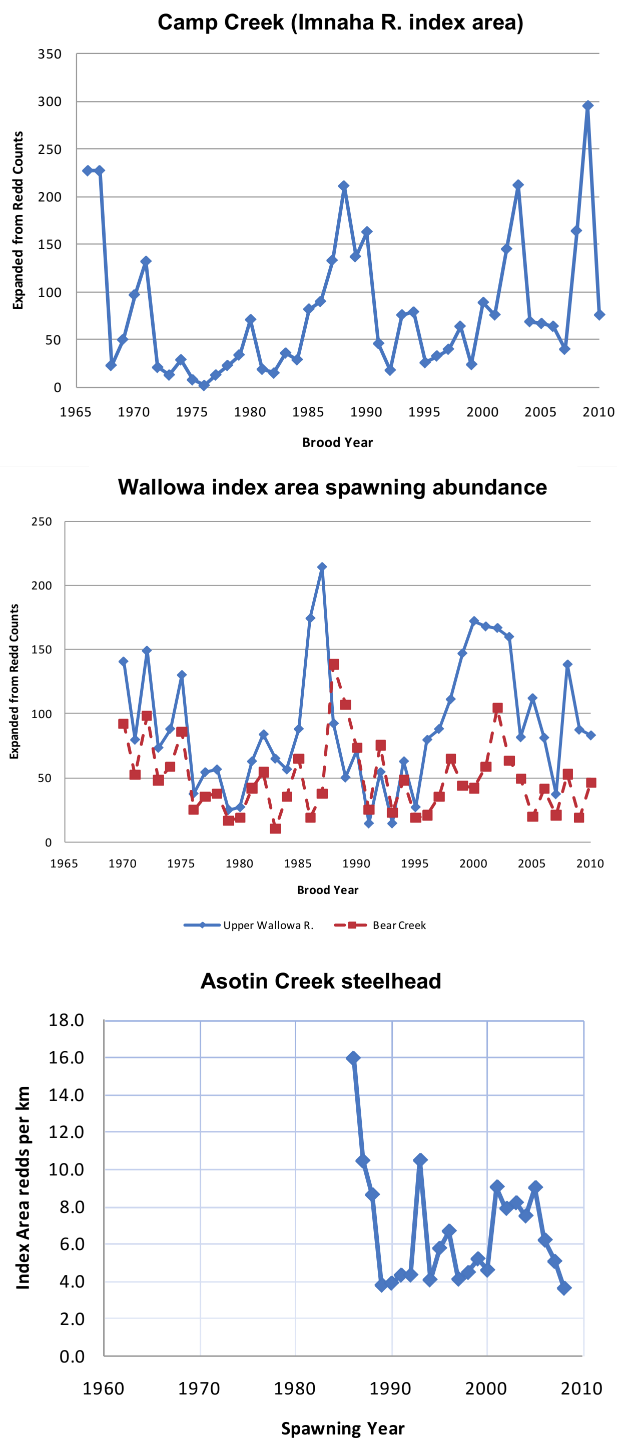

Figure 57. Snake River steelhead index areas. Annual spawner abundance for index area only (natural origin and total).

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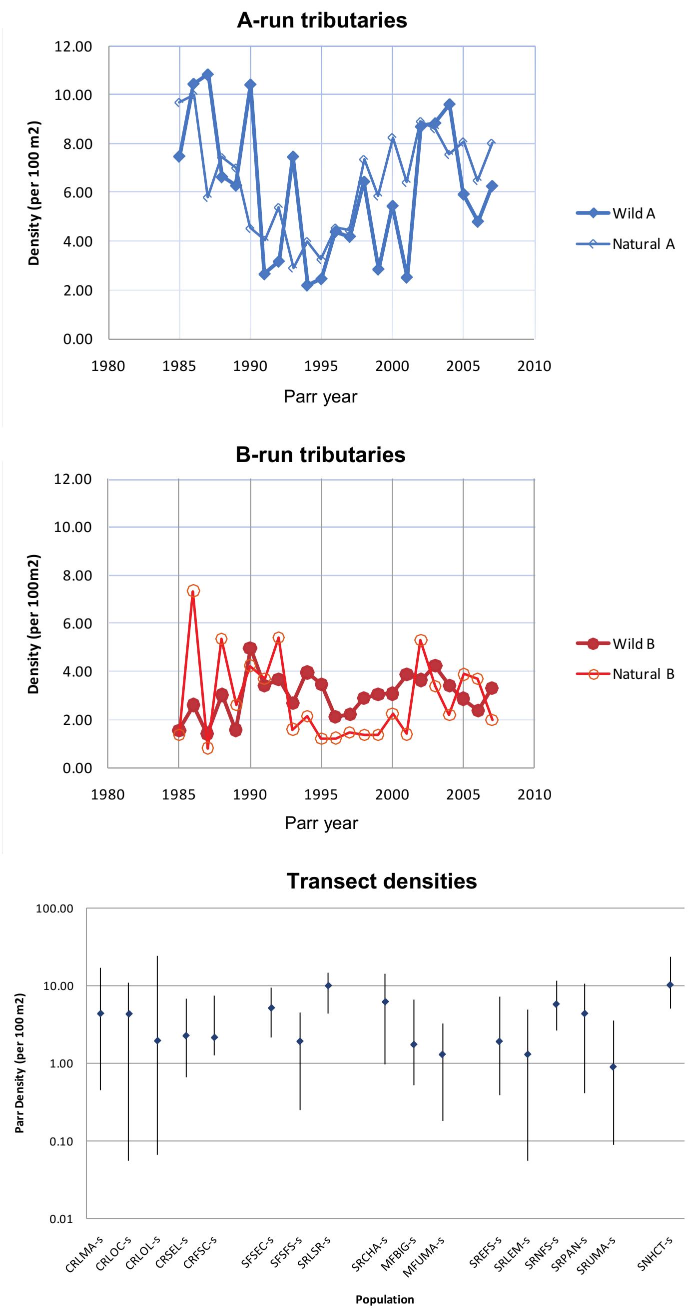

Figure 58. Juvenile Snake River steelhead parr densities observed in IDFG snorkel transects.

and the Secesh River, Little Salmon River, North Fork Salmon River, Panther Creek, and Lemhi River (Salmon MPG).

Current Status: ICTRT Viability Criteria

Only 2 of the 23 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 A/P 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 A/P 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 41.

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-run or B-run may support a mixture of the two run types.[10] 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 5-year status review.

Harvest

Summer-run steelhead from the upper basin are divided into two runs by managers: A-run and B-run. These runs are believed to 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 Basin Steelhead ESU, in the Clearwater, Middle Fork Salmon, and South Fork Salmon rivers.

Steelhead were historically taken in tribal and nontribal gill net fisheries, and in recreational fisheries in the mainstem Columbia River and in tributaries. In the 1970s retention of steelhead in nontribal 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 and 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 gill net and dip net fisheries targeting Chinook salmon. Because of their larger size, the B-run fish are more vulnerable to the gill net gear.

[10] See footnote 9.

AR054555

Table 41. Current status ratings using ICTRT viability criteria for Snake River steelhead populations grouped by MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	ICTRT minimum threshold	Natural spawning abundance	ICTRT productivity	Integrated A/P risk	Natural processes risk	Diversity risk	Integrated SS/D risk	Overall viability rating
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	500			Very low	Very low	Low	Low	Highly viable
2000–2009		2,186 (1,212–4,751)	2.25 (1.61–3.16					
1995–2004		1,878 (573–4,751)	2.63 (2.01–3.46)					
Up. Grande Ronde	1,500			Viable (moderate)	Very low	Moderate	High	Maintained
2000–2009		1,340 (673–1,943)	2.88 (1.09–7.65					
1995–2004		1,240 (673–2,277)	2.70 (1.65–4.41)					
Wallowa River	1,000	Insufficient data		High?	Very low	Low	Low	High risk?
Imnaha River	1,000	Insufficient data	Insufficient data	Moderate?	Very low	Moderate	Moderate	Maintained?
Lower main. Clearwater River	1,500	Insufficient data	Insufficient data	Moderate?	Very low	Low	Low	Maintained?
South Fork Clearwater River	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 River	1,000	Insufficient data	Insufficient data	High	Very low	Low	Low	High risk?

AR054556

Table 41 continued. Current status ratings using ICTRT viability criteria for Snake River steelhead populations grouped by MPG. Natural spawning abundance: most recent 10-year geometric mean (range). ICTRT productivity: 20-year geometric mean for parent escapements below 75% of population threshold (90% confidence limits).

	Abundance and productivity metrics				Spatial structure and diversity metrics			
Population	**ICTRT minimum threshold**	**Natural spawning abundance**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes risk**	**Diversity risk**	**Integrated SS/D risk**	**Overall viability rating**
Lochsa River	1,000	Insufficient data	Insufficient data	High	Very low	Low	Low	High risk?
Little Salmon Riv.	500	Insufficient data	Insufficient data	Moderate	Low	Moderate	Moderate	Maintained?
South Fork Salmon River	1,000	Insufficient data	Insufficient data	High	Very low	Low	Low	High risk?
Secesh River	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 Riv.	1,000	Insufficient data	Insufficient data	High	Very low	Low	Low	High risk?
Upper Middle Fork Salmon Riv.	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 River	500	Insufficient data	Insufficient data	Moderate	Low	Moderate	Moderate	Maintained?
Lemhi River	1,000	Insufficient data	Insufficient data	Moderate	Low	Moderate	Moderate	Maintained?
Pahsimeroi River	1,000	Insufficient data	Insufficient data	Moderate	Moderate	Moderate	Moderate	Maintained?
East Fork Salmon River	1,000	Insufficient data	Insufficient data	Moderate	Very low	Moderate	Moderate	Maintained?
Upper mainstem Salmon River	1,000	Insufficient data	Insufficient data	Moderate	Very low	Moderate	Moderate	Maintained?

*Question mark (?) = uncertain due to lack of data, only a few years of data, or large gaps in the data series.

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Consequently, this component of the summer run experiences higher fishing mortality than the A-run component (Figure 59). 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%.

Hatchery releases

Steelhead hatchery releases within the ESU have generally trended downwards since 1990. The most recent 5-year average release is approximately 20% below the 1997−2001 average (Figure 60).

Snake River Basin 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.

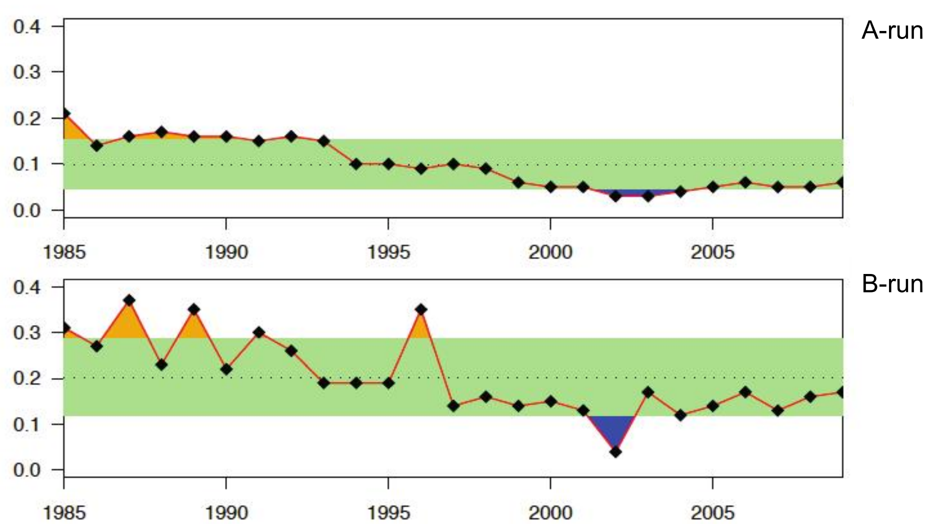

Figure 59. Total exploitation rate by year for natural summer steelhead above Bonneville Dam. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data for 1985−1998 from NMFS biological opinion[11] and for 1999−2008 from TAC run reconstruction.[12]

[11] See footnote 4.
[12] See footnote 5.

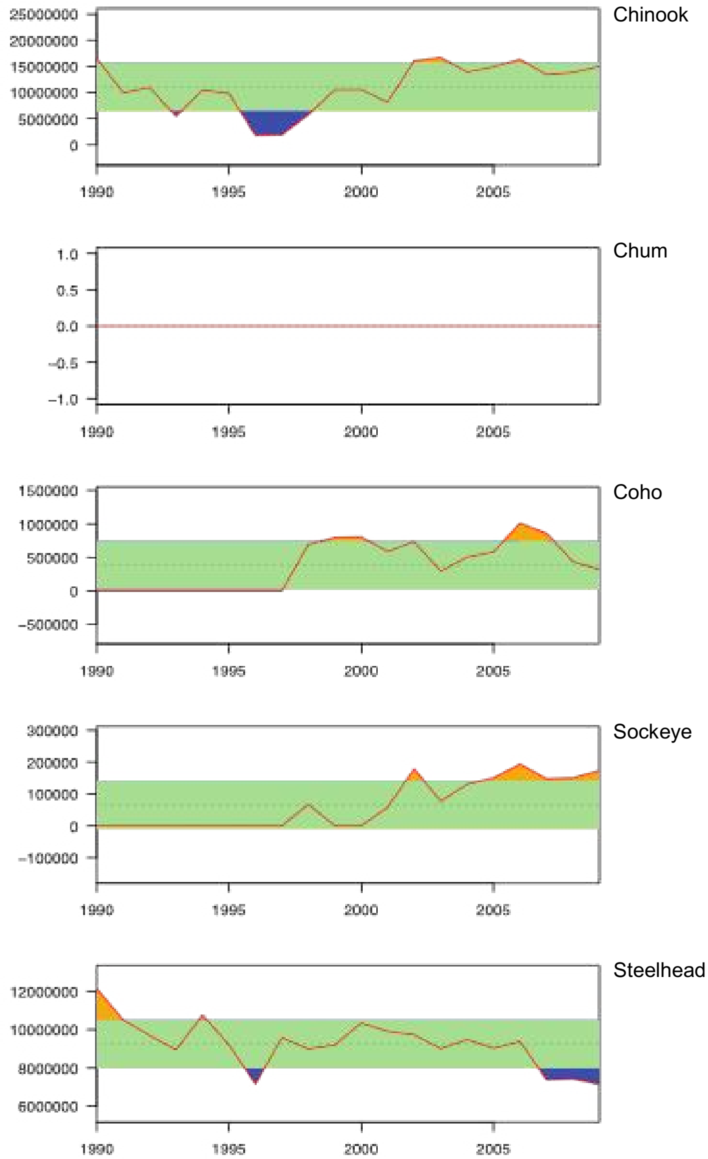

Figure 60. Hatchery releases by year within the Snake River Steelhead DPS. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

Willamette/Lower Columbia River Domain Status Summaries

Lower Columbia River Chinook Salmon ESU

Listed ESU/DPS

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

ESU/DPS Boundary Delineation

Utilizing new information, the ESU Boundaries Review Group (see ESU Boundaries section above) undertook a revaluation of the boundary between all lower Columbia and mid-Columbia ESUs and DPSs. The review conclusions emphasize the transitional nature of 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 conducted the most recent update in 2005 (Good et al. 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 Chinook Salmon ESU. The 1998 BRT identified naturally reproducing (but not necessarily self-sustaining) populations: the Lewis and Sandy river 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 believed 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

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concluded that the lower Columbia River ESU was likely to become endangered in the foreseeable future. A minority believed 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 Willamette/Lower Columbia TRT (WLC-TRT) estimated 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 61 and Figure 62) are used in this status update and were used for status evaluations in recent recovery plans by ODFW and LCFRB. Lower Columbia River Chinook populations exhibit three different life history types base on return timing and other features: fall run (aka tules), late fall run (aka brights), and spring run.

In 2010 ODFW completed a recovery plan that included Oregon populations of the 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 recovery plans include an assessment of the current status of lower Columbia River Chinook populations. These assessments relied and built upon 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 63 through Figure 65.

These analyses indicate that all but one of the 21 fall Chinook salmon populations are most likely in the very high risk category (also described as extirpated or nearly so). Very high risk is a broad category ranging from 100% extinction probability (already extirpated) to 60% probability of extinction in 100 years (Table 42). 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 population 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.

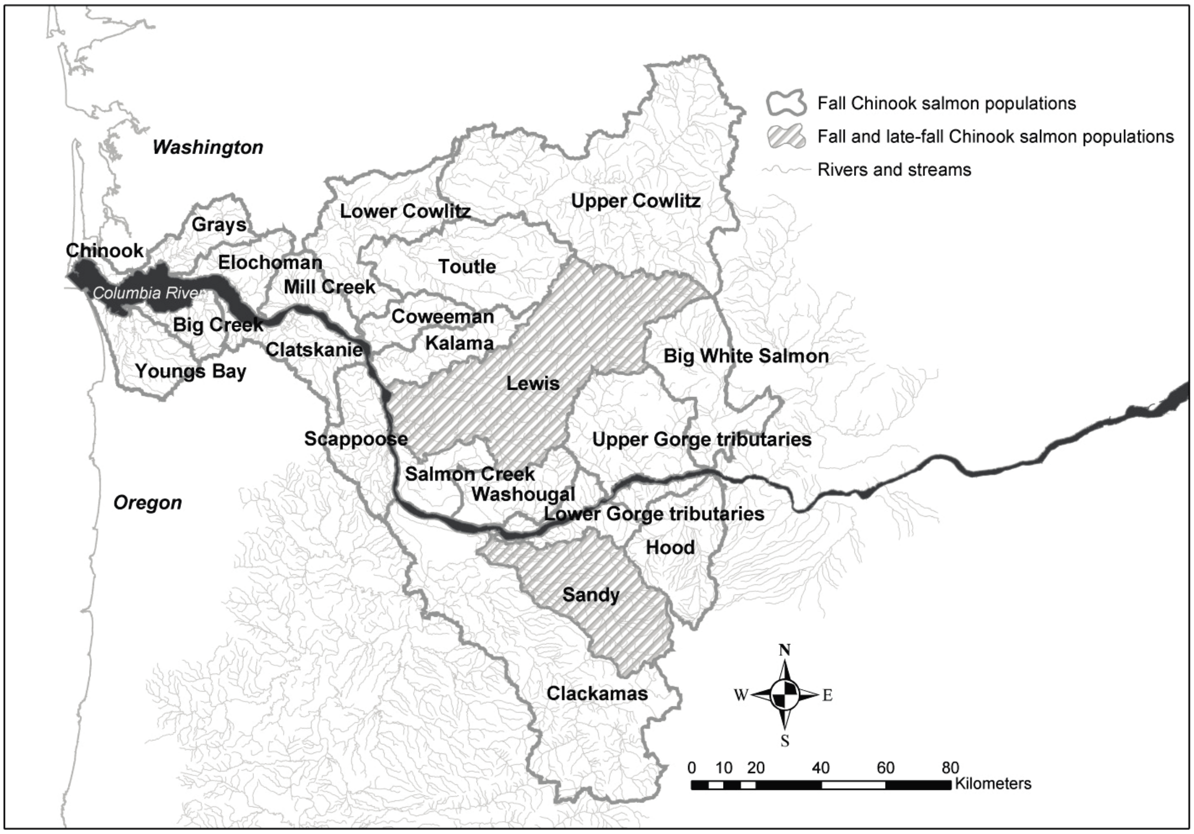

Figure 61. Historical lower Columbia River fall and late fall-run Chinook salmon populations. (Reprinted from Myers et al. 2006.)

In addition to the recovery plans, two analyses of lower Columbia River fall Chinook salmon 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 to various recovery scenarios involving harvest, hatchery, and habitat changes. The analysis results can be summarized by this paragraph of the report's discussion subsection 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 approximately 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 (Mill-Abernathy-German) 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.

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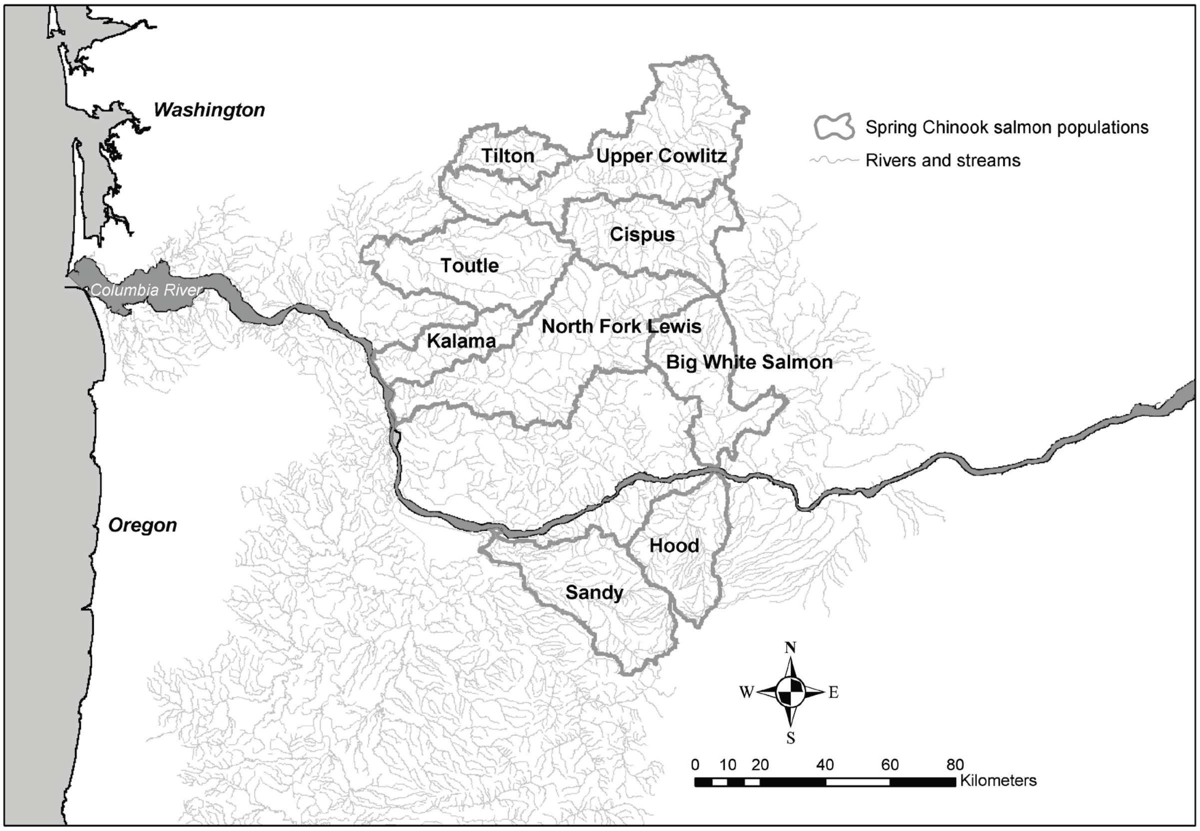

Figure 62. Historical lower Columbia River spring-run Chinook salmon populations. (Reprinted from Myers et al. 2006.)

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.

New Data and Analyses

The 2005 BRT status evaluation included abundance data for most lower Columbia River Chinook salmon populations up to the year 2001. For the current evaluation, we 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 66 through Figure 69. Since the last status evaluations, all of the populations increased in abundance during the early 2000s, 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 show no dramatic changes in abundance or fraction of hatchery-origin spawners since the 2005 BRT evaluation.

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

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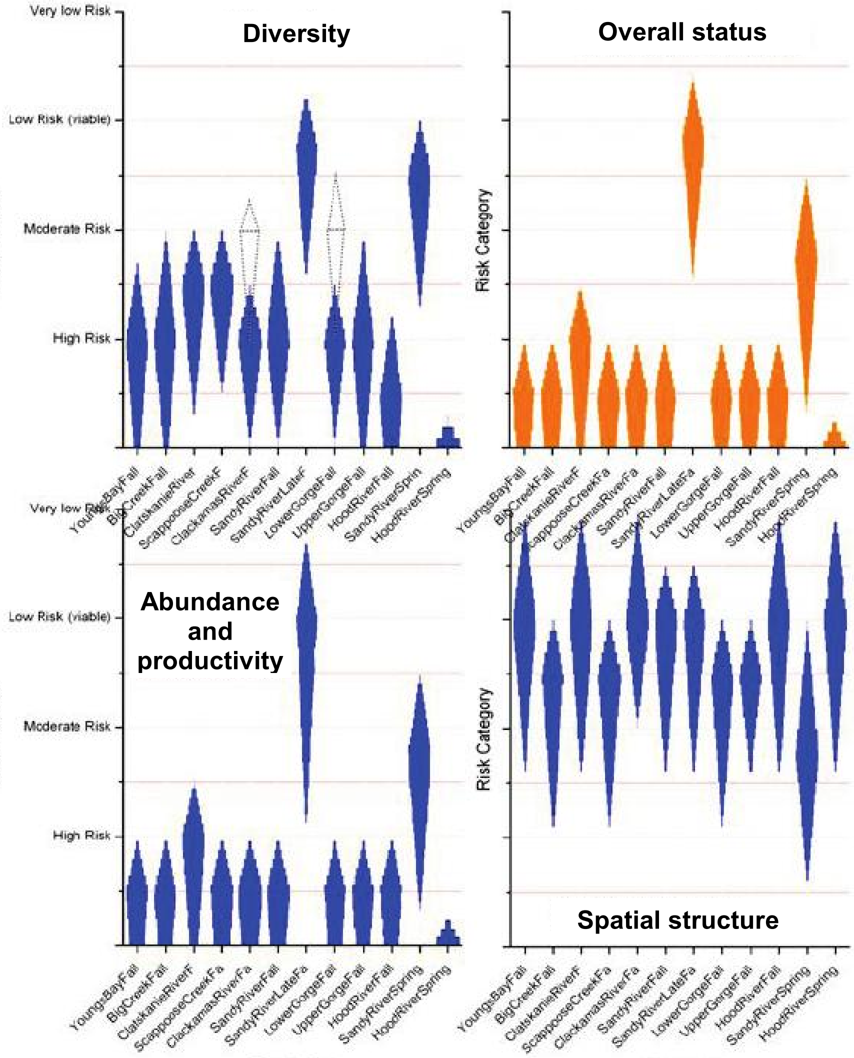

Figure 63. Extinction risk ratings for lower Columbia River Chinook salmon populations in Oregon for the assessment attributes A/P, diversity, overall status, and spatial structure, as well as an overall rating for populations that combines the three attribute ratings. Where updated ratings differ from those presented by McElhany et al. 2007, the older rating is shown as an open diamond with a dashed outline. (Reprinted from Beamesderfer et al. 2010.)

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 70). 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).

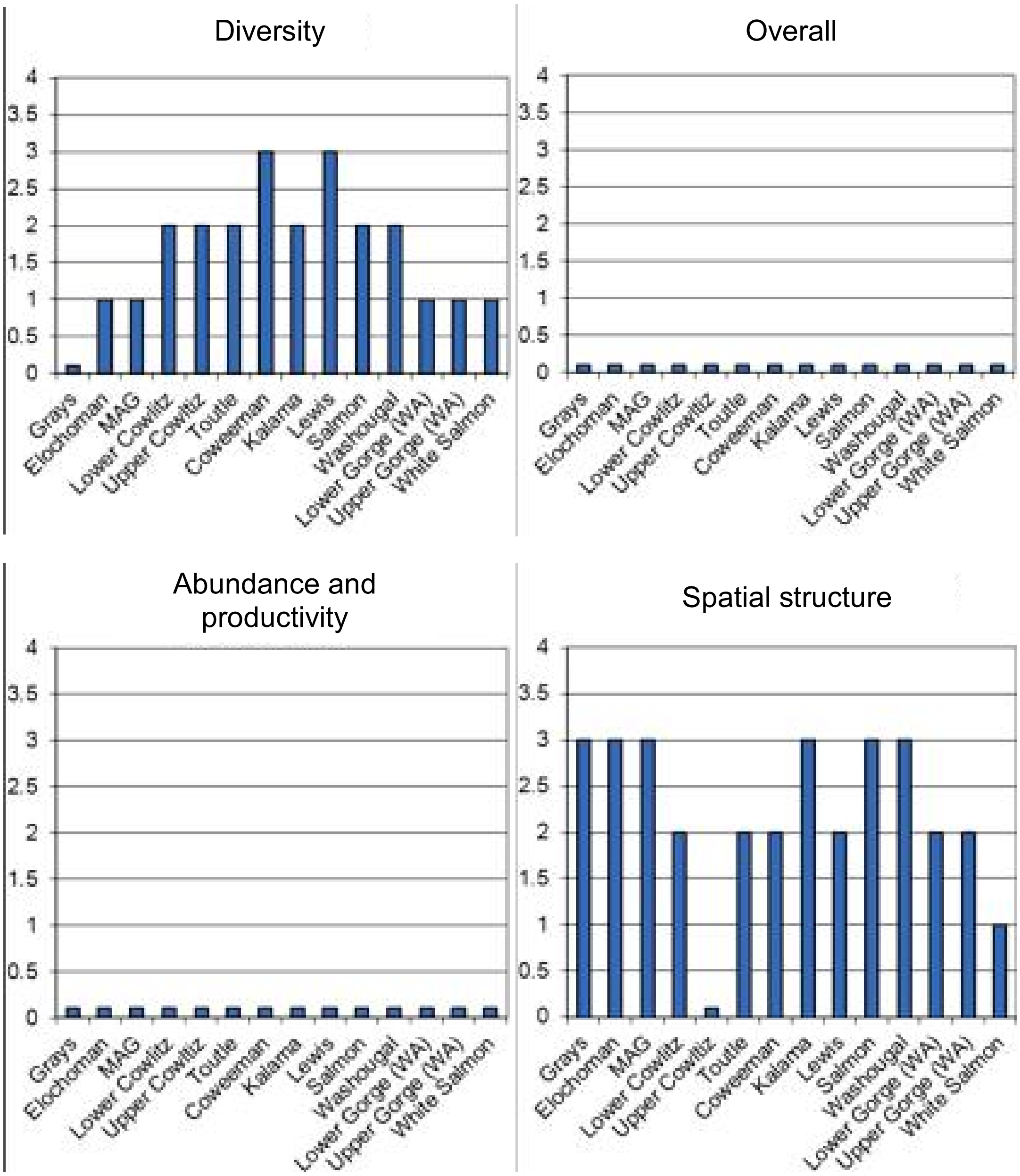

Figure 64. Current status of Washington lower Columbia River fall-run (tule) Chinook salmon populations for the VSP parameters and overall population risk (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk (viable), and 4 is very low risk. MAG = Mill, Abernathy, and German.

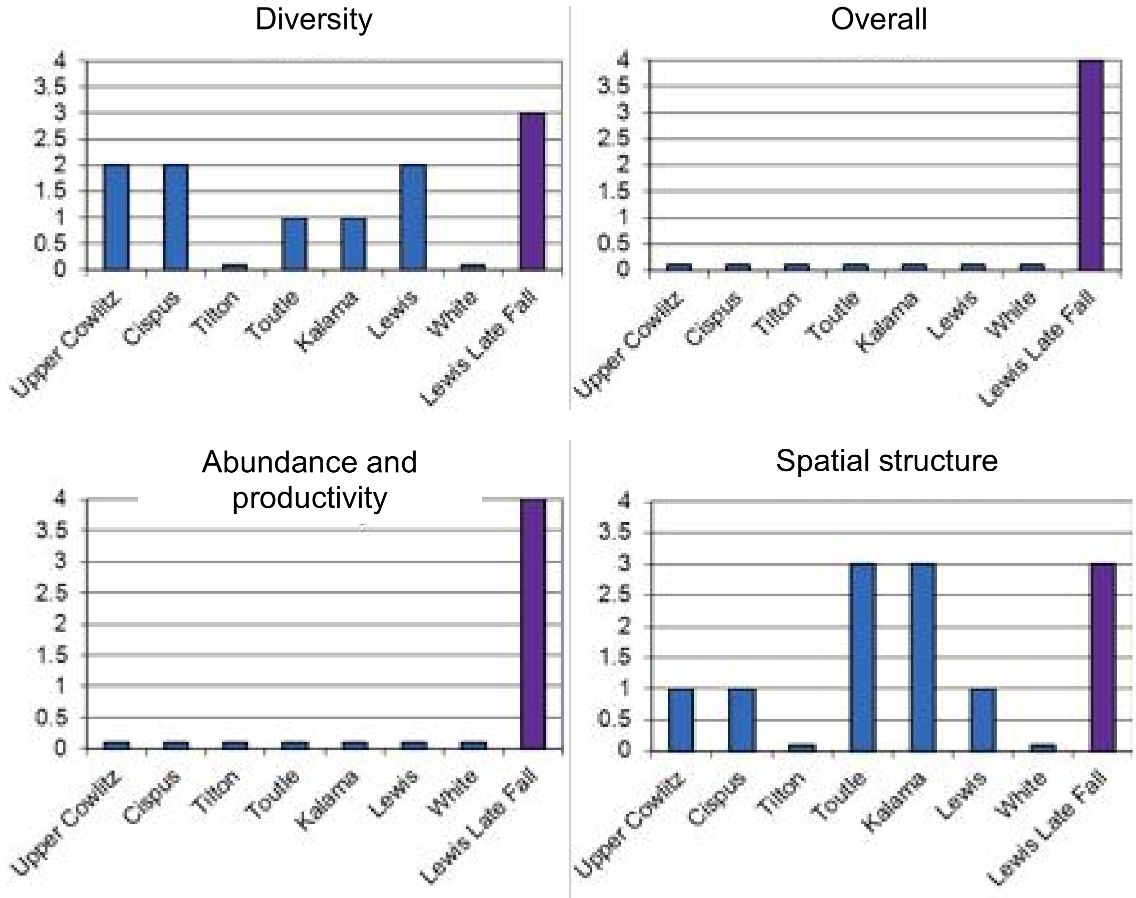

Figure 65. Current status of Washington lower Columbia River spring Chinook and late fall-run (bright) Chinook salmon populations for the VSP parameters and overall population risk (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk (viable), and 4 is very low risk.

Table 42. Population persistence categories (from McElhany et al. 2006).

Category	Persistence in 100 years	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 (VSP).
4	>99%	<1%	Very low risk of extinction in 100 years.

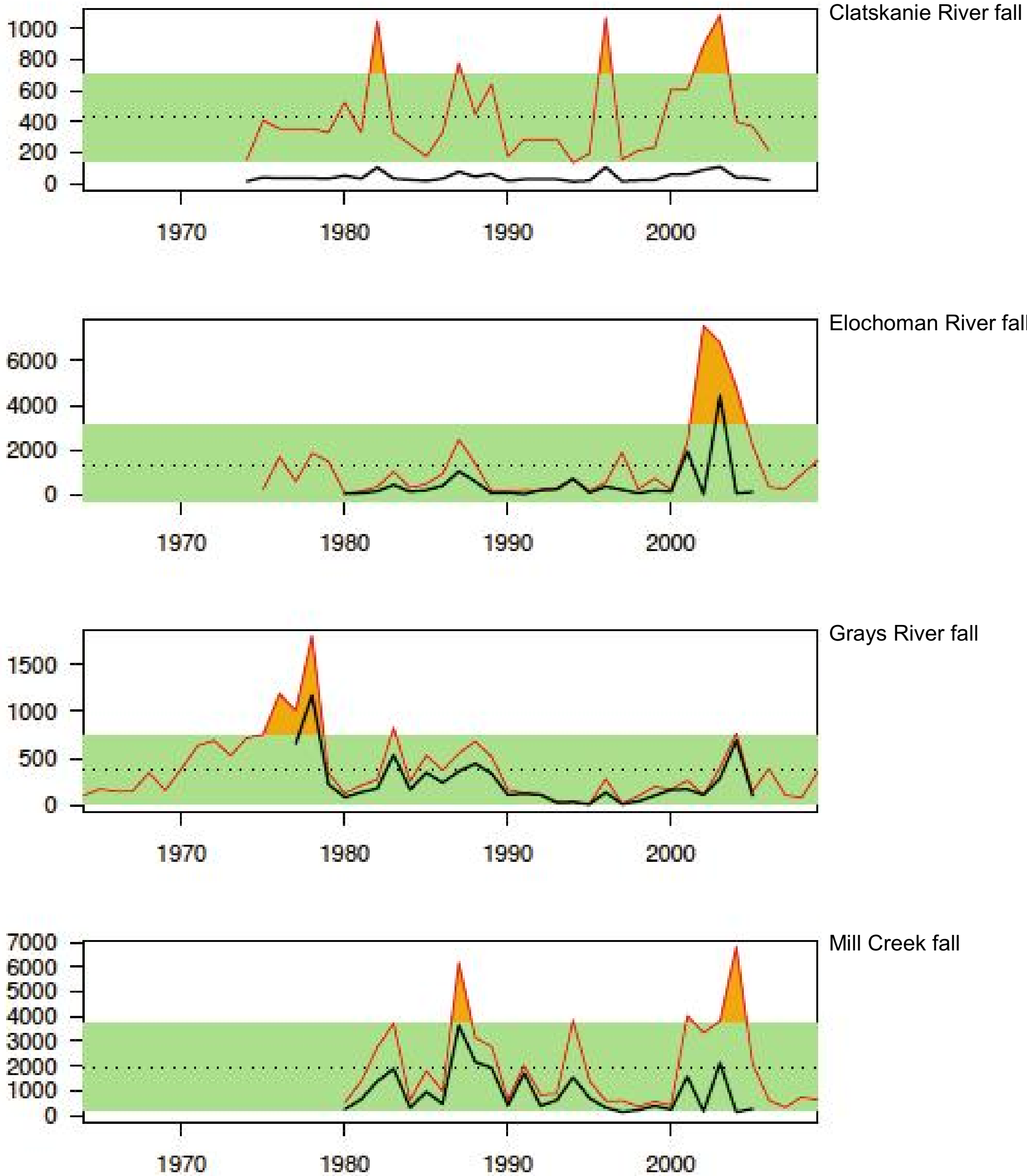

Figure 66. Estimated spawning abundance by year for the coastal MPG (stratum). The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

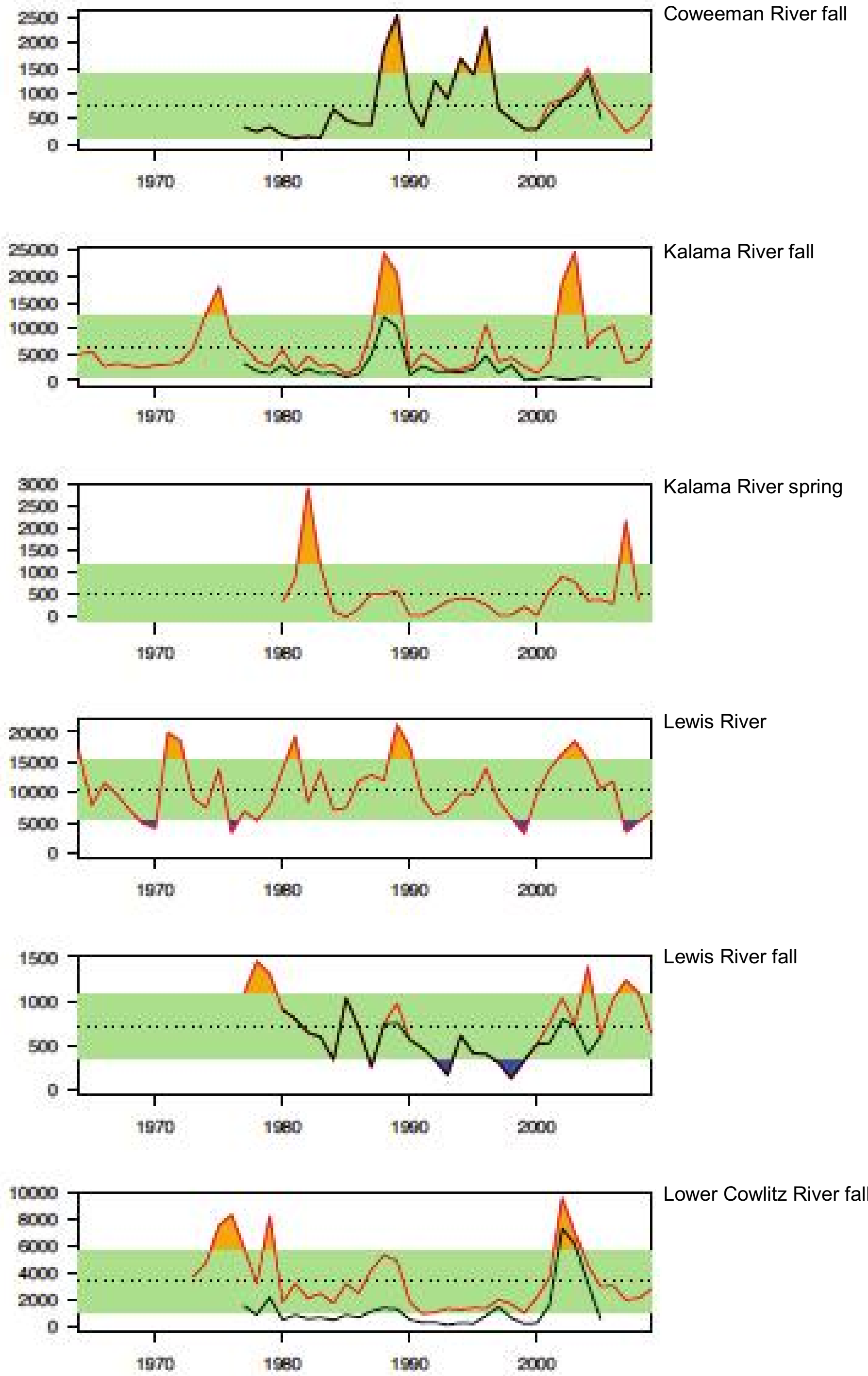

Figure 67. Estimated spawning abundance by year for the Cascade fall and spring-run MPG (strata). The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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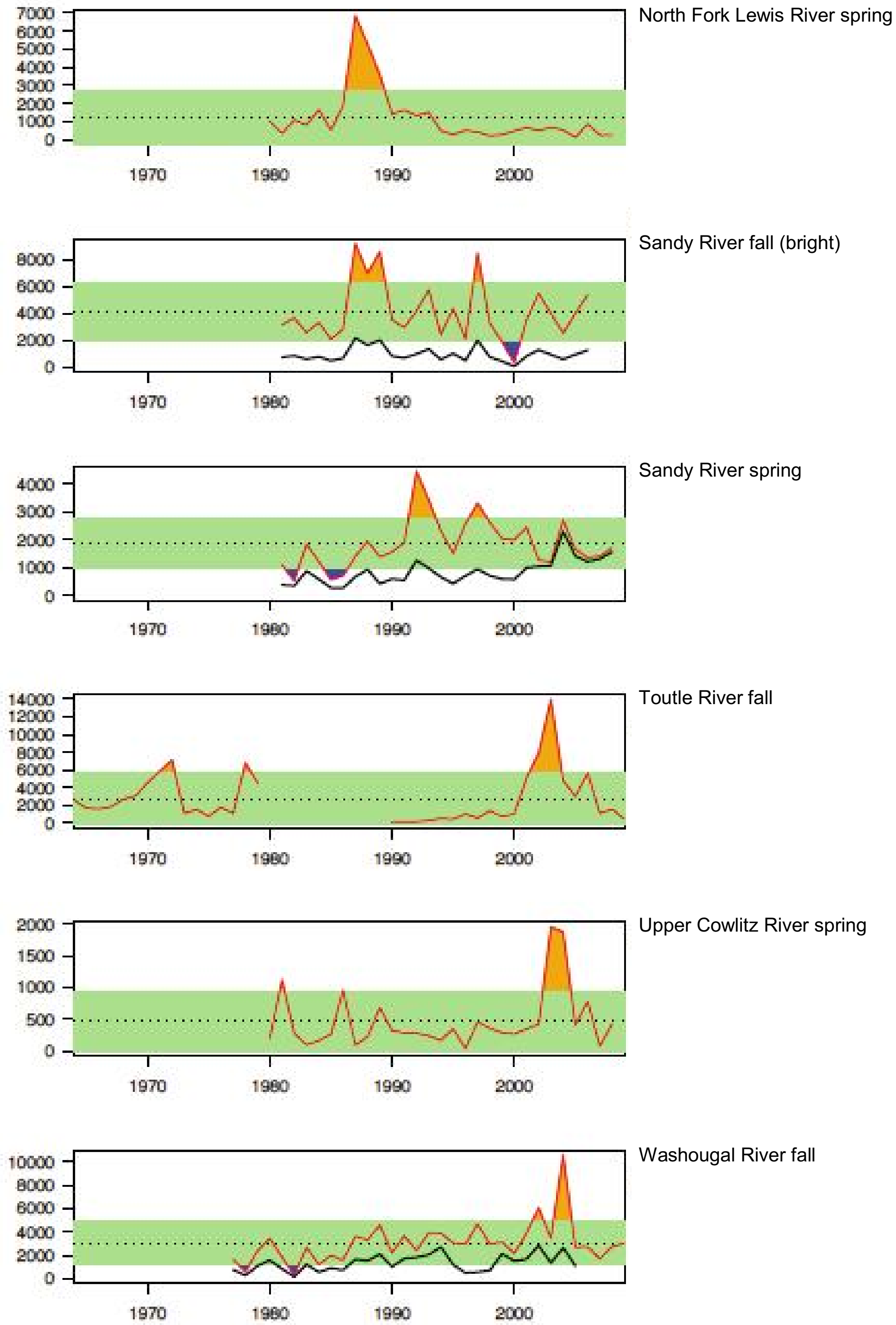

Figure 68. Estimated spawning abundance by year for the Cascade fall and spring-run MPG (strata). The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

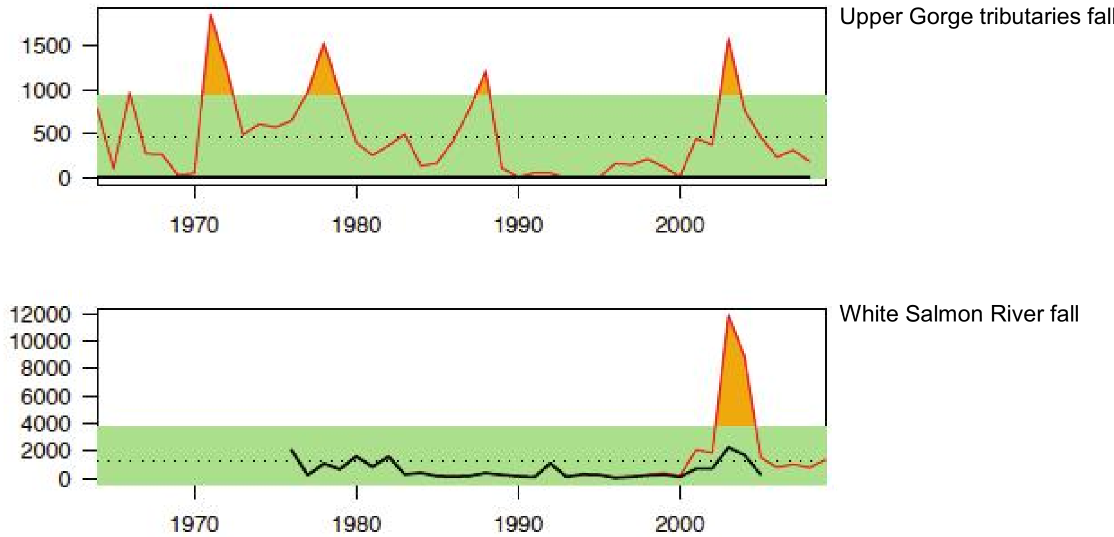

Figure 69. Estimated spawning abundance by year for the Gorge fall-run MPG (stratum). The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

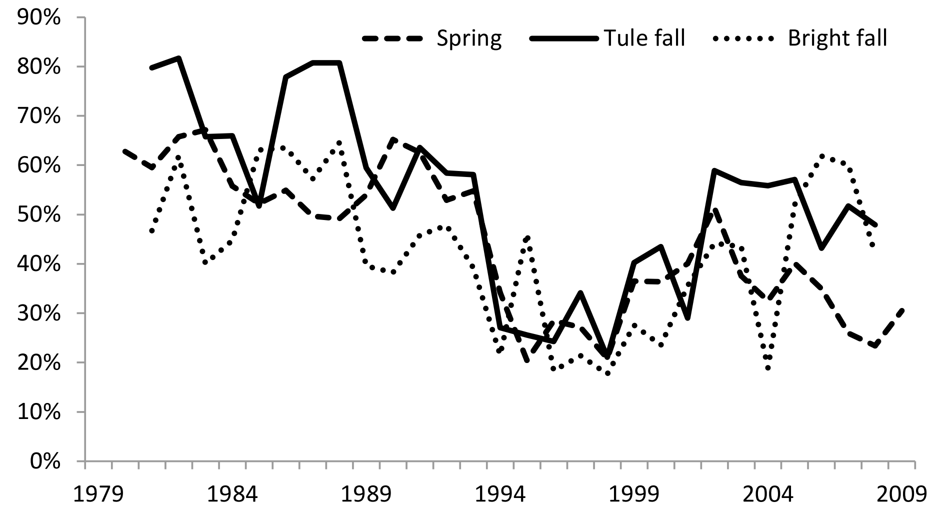

Figure 70. Total exploitation rates (%) by year for the three components of the Lower Columbia River Chinook Salmon ESU. Data for tule fall-run Chinook are from exploitation rate analysis of aggregate tule stock made up of tag codes from the Big Creek, Cowlitz, Kalama, and Washougal hatcheries. Data 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 from NMFS BiOp, 1980–2001,[13] and TAC run reconstruction data, 2002–2009,[14] for in-river impacts.

[13] See footnote 4.
[14] C. LeFleur, WDFW, Vancouver, WA. Pers. commun., 18 November 2010.

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Hatcheries

Total hatchery releases of all Chinook salmon life histories in the Lower Columbia River Chinook Salmon ESU have been relatively stable since the last status review update (Figure 71). Although recovery plans call for multiple actions to the reduce the impact of hatchery fish on the 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.

Lower Columbia River Chinook Salmon: Updated Risk Summary

Three status evaluations of lower Columbia River Chinook salmon status, all based on WLC-TRT criteria, have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, Beamesderfer et al. 2010, LCFRB 2010). McElhany et al. (2007) concluded that the ESU is currently at high risk of extinction. The ODFW plan concluded that the Oregon portion of the ESU is currently at high risk. The LCFRB plan does not provide a statement on ESU-level status, but describes the high fraction of populations in the ESU that are at high or very high risk. Of the 32 historical populations in the ESU, 28 are considered extirpated or at very high risk. Based on 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 salmon 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-run Chinook population, without a mainstem dam, is considered at moderate risk and is the only spring Chinook population not considered extirpated or nearly so. 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.

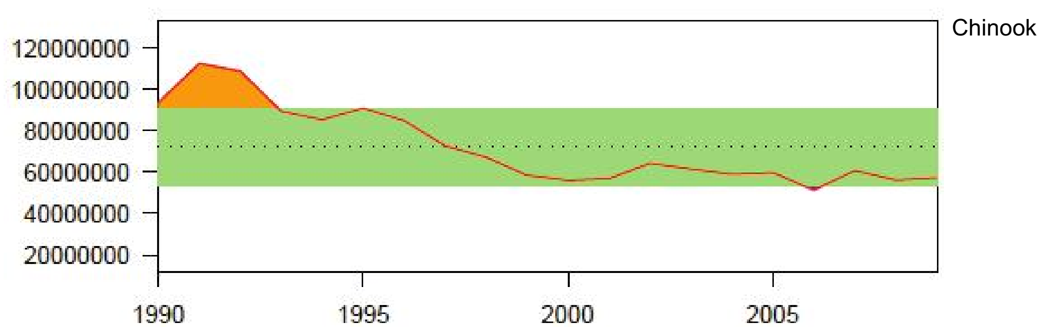

Figure 71. Total Chinook hatchery releases by year in the Lower Columbia River Chinook Salmon ESU. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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Overall, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

Upper Willamette River Chinook Salmon ESU

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 (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 section above) identified no new information suggesting a revaluation of the Upper Willamette River Chinook Salmon ESU. This status evaluation was conducted based on existing ESU boundaries.

Summary of Previous BRT Conclusions

NMFS reviewed the status of the 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 ESU and the high proportion of hatchery fish in the remaining runs. The 1998 BRT noted with concern that 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 Chinook Salmon ESU to extensive habitat blockages caused by dam construction. A majority of the 1998 BRT concluded that the ESU was likely to become endangered in the foreseeable future. A minority of 1998 BRT members believed 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 fish and loss of access to historical habitat are important risk factors. The McKenzie River population was the only one identified as potentially self-sustaining, and increases in abundance were noted for this population in the most recent returns

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available at the time (2000 and 2001). However, the BRT was concerned about the long-term potential for this population. The majority (70%) of 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 river salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The upper Willamette spring Chinook population designations in that report (Figure 72) are used in this status update and were used for status evaluations in a recent recovery plan by Beamesderfer et al. (2010).

A draft recovery plan for upper Willamette 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 73. 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 42), the WLC-TRT criteria require a viable ESU to have an average population score greater than 2.25. The average for the Upper Willamette River Chinook Salmon 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 prespawning mortality and increased human development in the entire Willamette Basin.

New Data and Analyses

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

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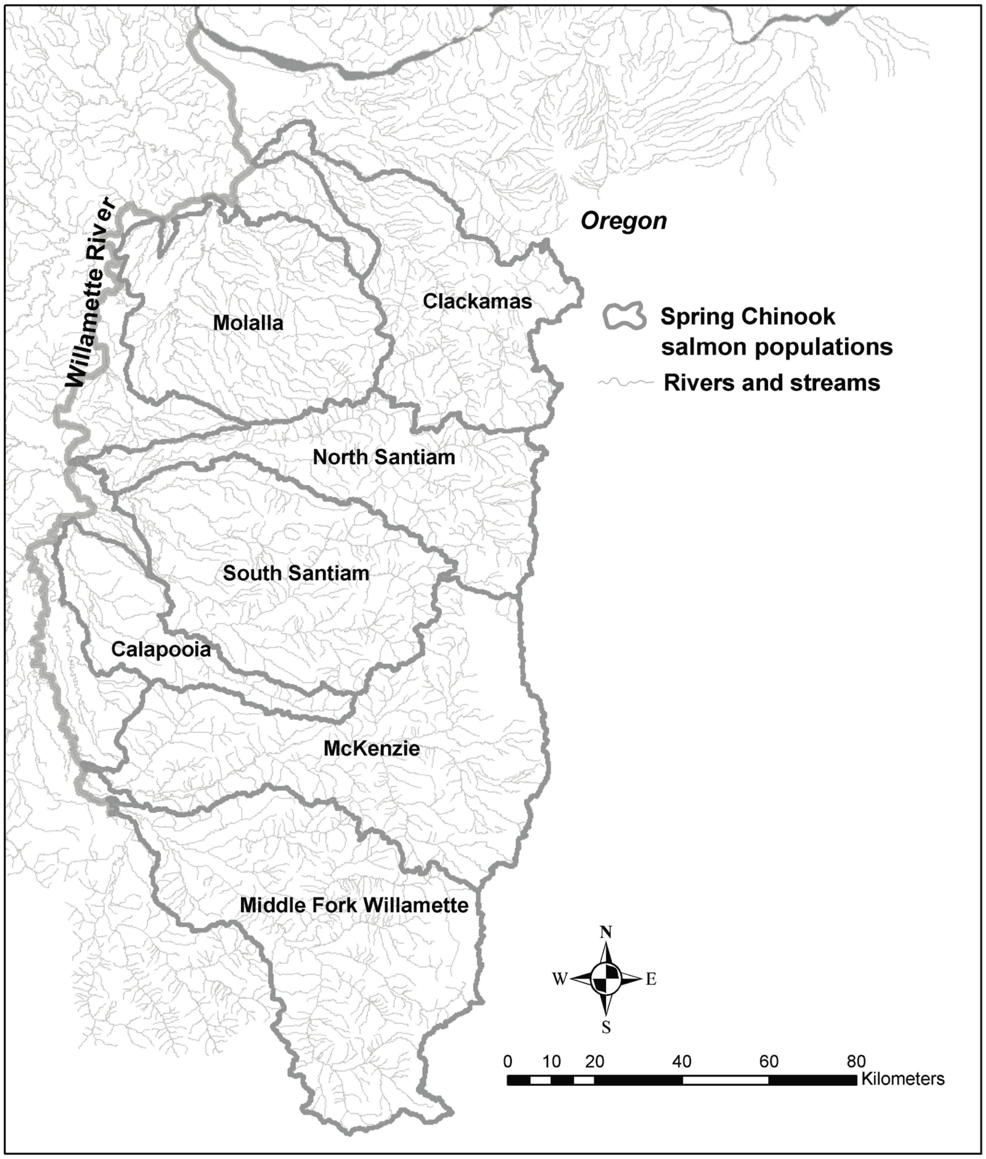

Figure 72. Upper Willamette spring-run Chinook salmon populations. (Reprinted from Myers et al. 2006.)

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 (PGE 2010) (Figure 74). 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 more than 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 5 years is 850 fish.

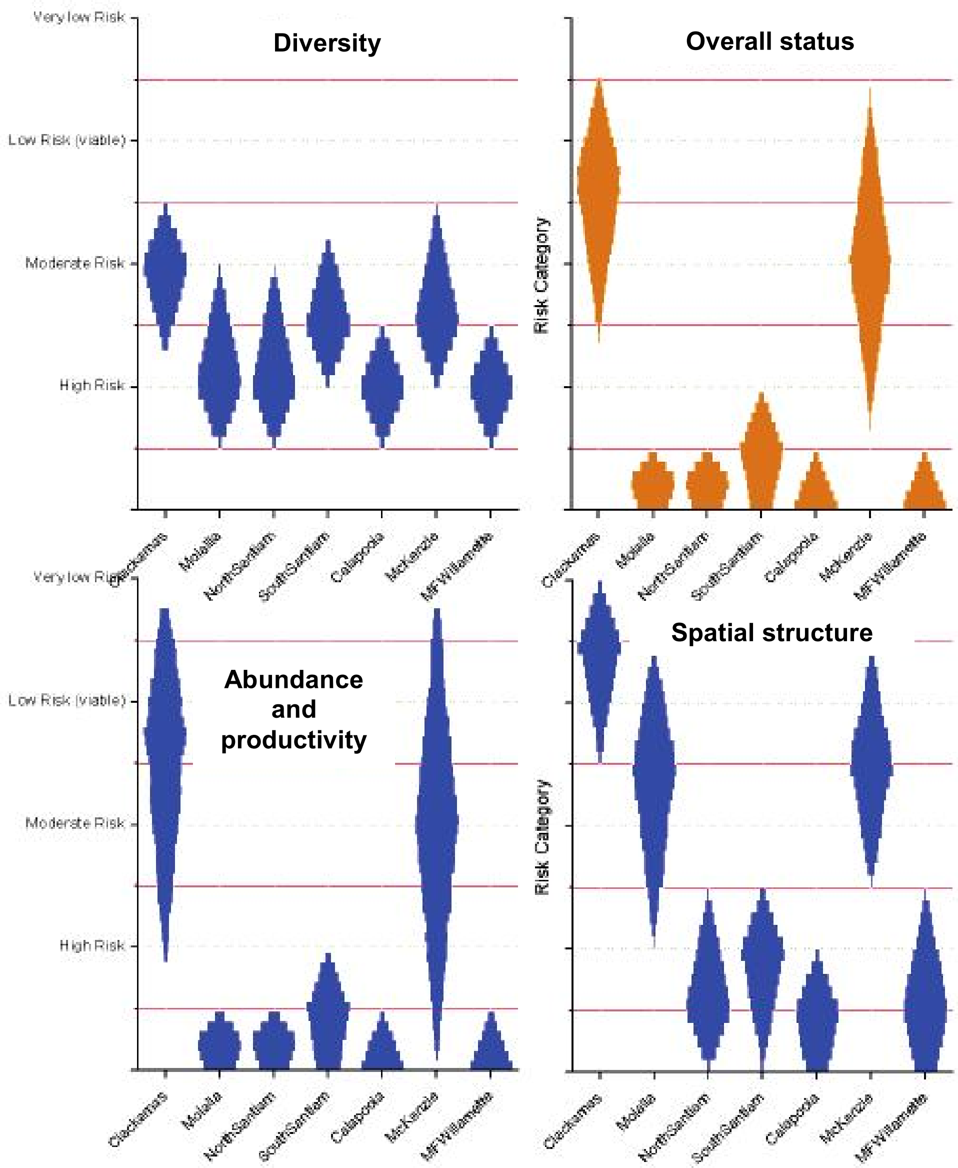

Figure 73. Status evaluation for upper Willamette spring-run Chinook salmon populations. (Reprinted from McElhany et al. 2007.)

Willamette Falls

Except for those returning to the Clackamas River, all the fish in this ESU are counted at Willamette Falls (Figure 75). The count does not identify whether returning Chinook salmon are of hatchery or natural origin, but spawning ground surveys in Willamette tributaries indicate that the vast majority are hatchery origin. The primary source of naturally produced spring Chinook above Willamette Falls is the McKenzie River population upstream of Leaburg Dam. Figure 75 shows 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).

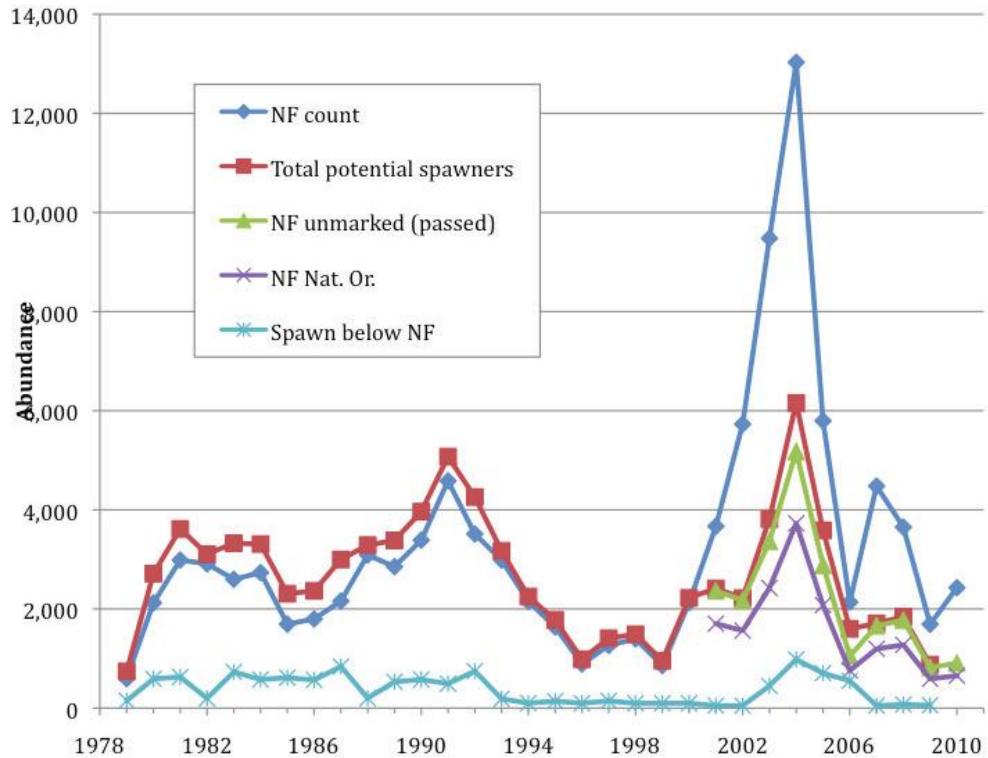

Figure 74. Clackamas River spring-run Chinook salmon abundance estimates by year. The NF count is the total number of Chinook counted at the North Fork Dam. Since 2001 all hatchery fish returns have been marked with an adipose fin clip. Only unmarked fish have been passed above North Fork Dam. The count 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 Fork 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. Peak return at North Fork Dam occurs May-July but the tail of the return extends into October, so the final count for 2010 was slightly higher than shown here. Data for 1979−2009 are from ODFW 2010 FMEP report. Data for 2010 from the PGE fish count database, http://portlandgeneralelectric.net/community_environment/initiatives/protecting_fish/clackamas_river/default.aspx. Note that PGE data only include the count up to 9 September 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 salmon population for the years 1970−2001. The most recent abundance time series for the Clackamas River population combines data in the ODFW 2010 FMEP report with data from the ODFW online database (Figure 76 and Figure 77). Data acquired since the 2005 BRT report

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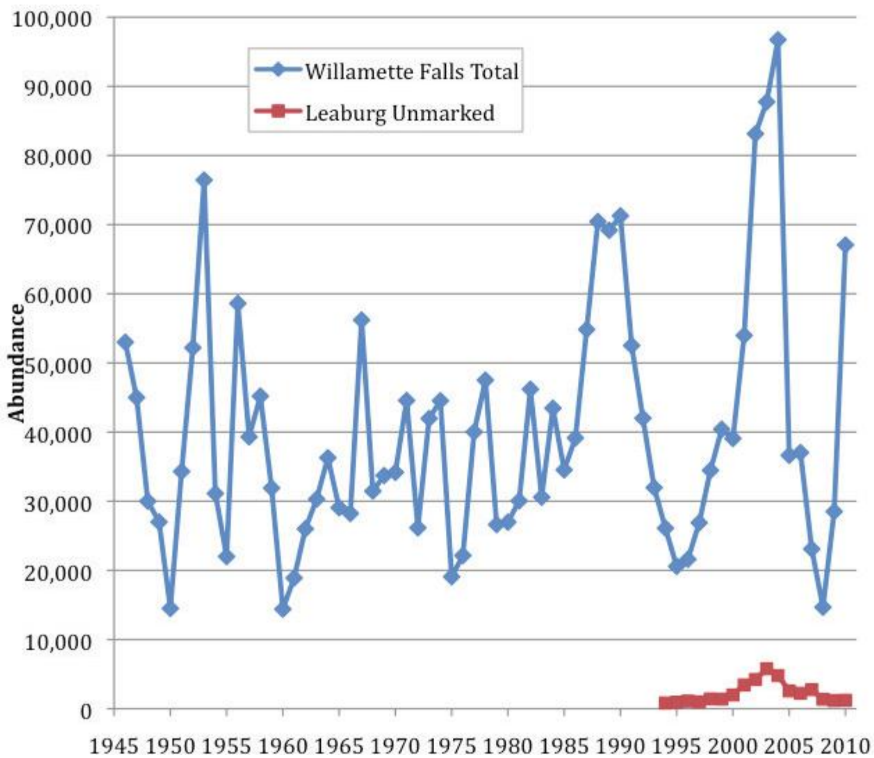

Figure 75. Willamette Falls total spring-run Chinook salmon count (line with diamond symbols includes natural and hatchery origin) and the count of unmarked fish at Leaburg dam on the McKenzie (line with square symbols, unmarked fish are about 70% natural origin). Willamette Falls data from ODFW online database, http://www.dfw.state.or.us/fish/fish_counts/willamette%20falls .asp. McKenzie data from ODFW FMEP report 2010.

show an increase in abundance peaking in 2004 that has 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 remained 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 multiple factors are at play that have not yet been completely evaluated.

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

The 2005 BRT analysis reported that nearly all fish returning and spawning in these other populations are hatchery origin. The analysis of hatchery fraction data collected since the 2005 BRT report supports 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, Beamesderfer et al. 2010). In addition, these populations appear to be experiencing significant risks from prespawning mortality (Schroeder et al. 2005, McElhany et al. 2007, Schroeder et al. 2007).

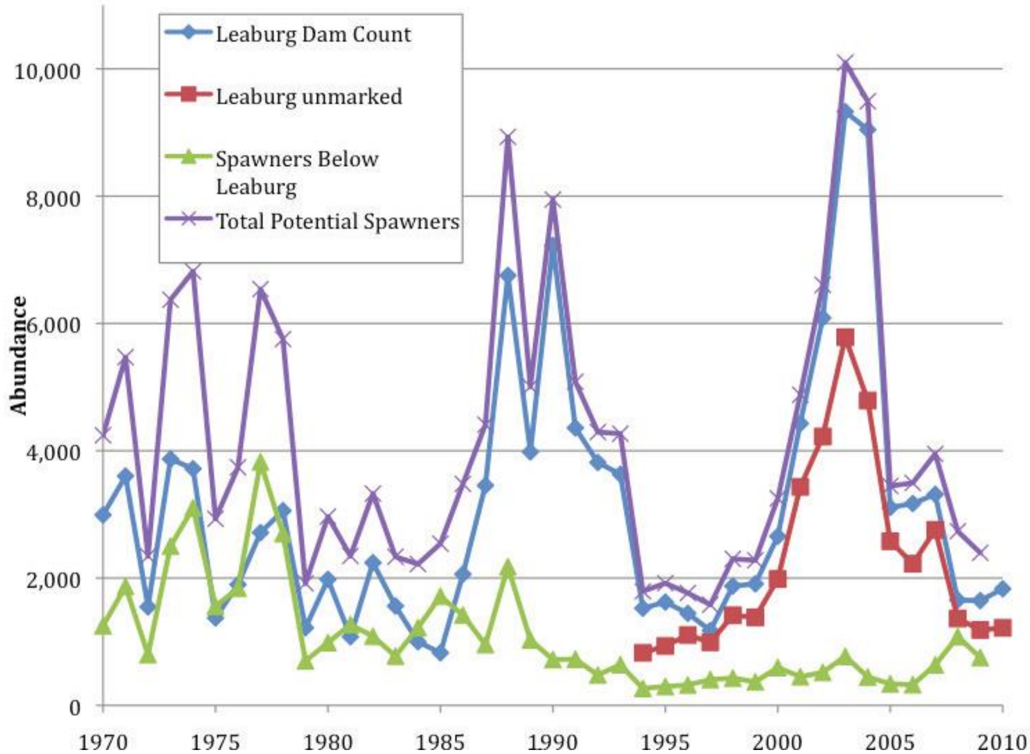

Figure 76. McKenzie River spring Chinook salmon abundance estimates. The Leaburg Dam count is the total number of Chinook counted at Leaburg Dam. The count without a hatchery mark (fin clip) is shown in the series labeled Leaburg unmarked. Studies have shown that because of incomplete marking, only a 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.

Harvest

Upper Willamette River spring Chinook salmon are taken in ocean fisheries primarily in Canada and Alaska. They are also taken in lower mainstem Columbia River commercial gill net 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 78).

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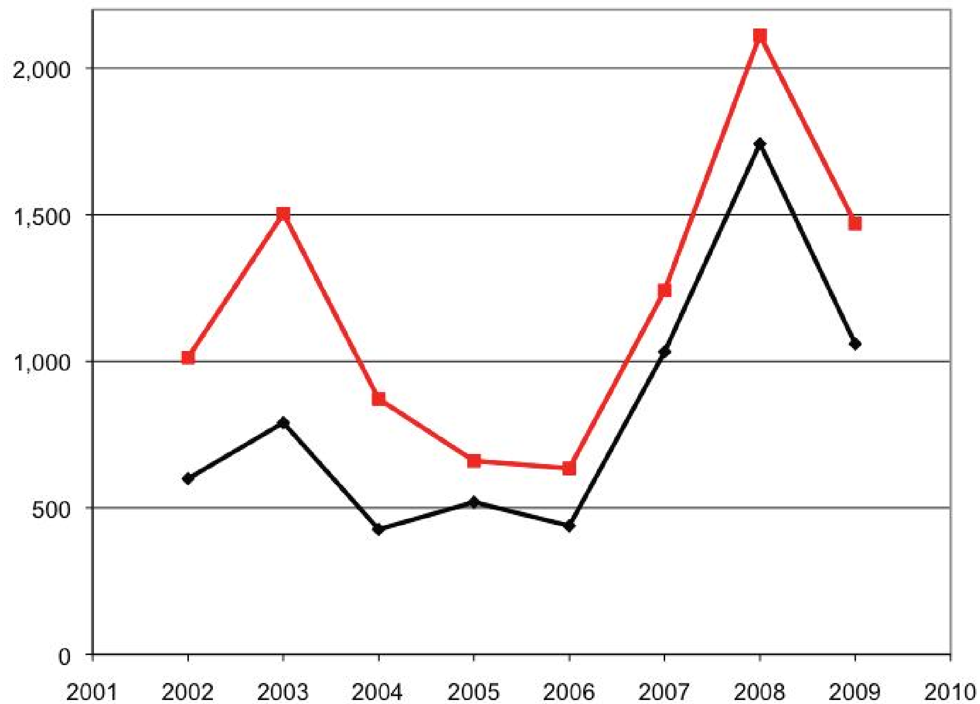

Figure 77. Natural-origin (lower line) and total spawner (upper line) abundance estimates by year for the McKenzie River based on the run reconstruction in ODFW 2010 FMEP report. Estimates differ from those shown in Figure 76 because of different extrapolation assumptions.

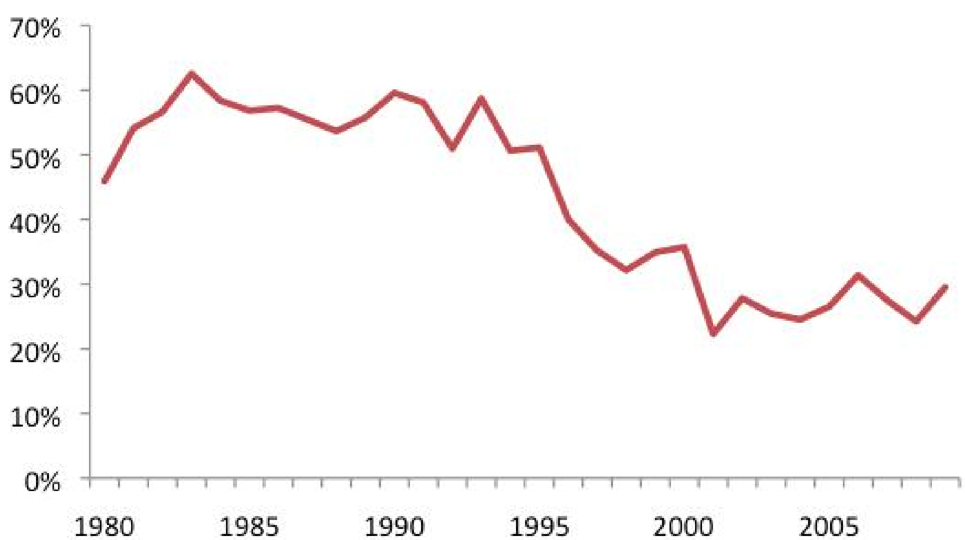

Figure 78. Total exploitation rates (%) by year on Willamette River spring-run Chinook salmon. Data from CTC in prep. exploitation rate analysis for ocean impacts, from TAC 2010 for inriver impacts from 1980−1997, and ODFW for 1998−2008.[15]

[15] C. Kern, ODFW, Clackamas, OR. Pers. commun., 1 July 2010.

Hatcheries

Since 1995 total spring Chinook salmon hatchery production has remained relatively constant in the upper Willamette River at about 5 million smolts (Figure 79). As noted above, the majority of populations are dominated by hatchery-origin spawners. No major hatchery production changes have been noted since the last BRT report (2005).

Upper Willamette River Chinook Salmon: Updated Risk Summary

Two related status evaluations of upper Willamette Chinook salmon have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, Beamesderfer et al. 2010). Both evaluations were based on the WLC-TRT viability criteria. The ODFW evaluation concluded that the ESU is currently at very high risk of extinction and the McElhany et al. (2007) review concluded that the ESU is currently at a 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 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 prespawning 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.

Columbia River Chum Salmon ESU

Listed ESU/DPS

This 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 1999a). As documented in that report, the previous BRTs 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 Columbia River 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

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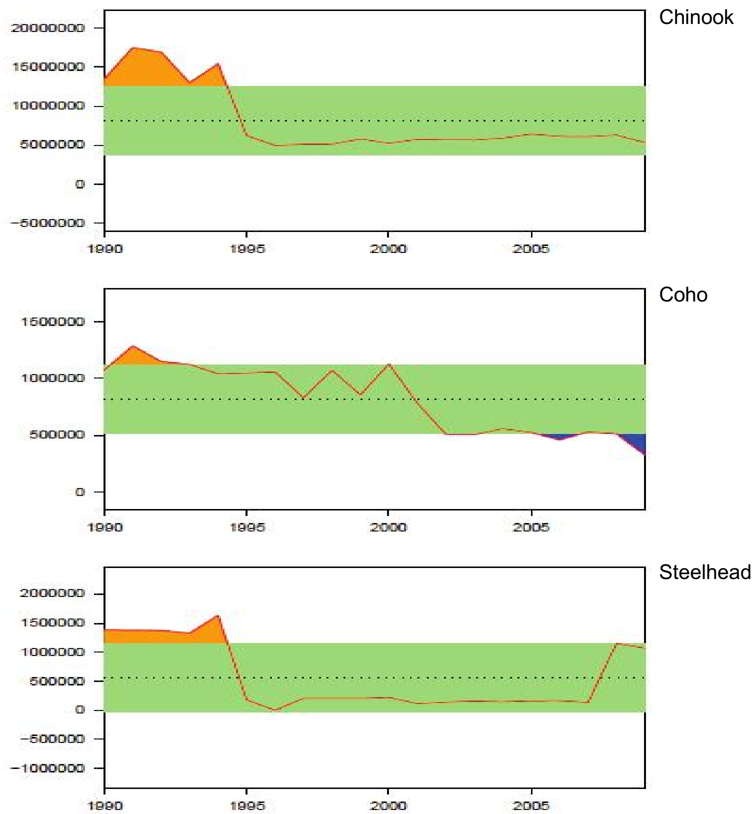

Figure 79. Hatchery releases by year for Chinook, coho, and steelhead in the area of the Upper Willamette River Chinook Salmon ESU. Dotted lines indicate the means, shaded areas indicate the SDs. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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 River salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The chum population designations in that report (Figure 80) are used in this status update and were used for status evaluations in recent recovery plans by ODFW and LCFRB.

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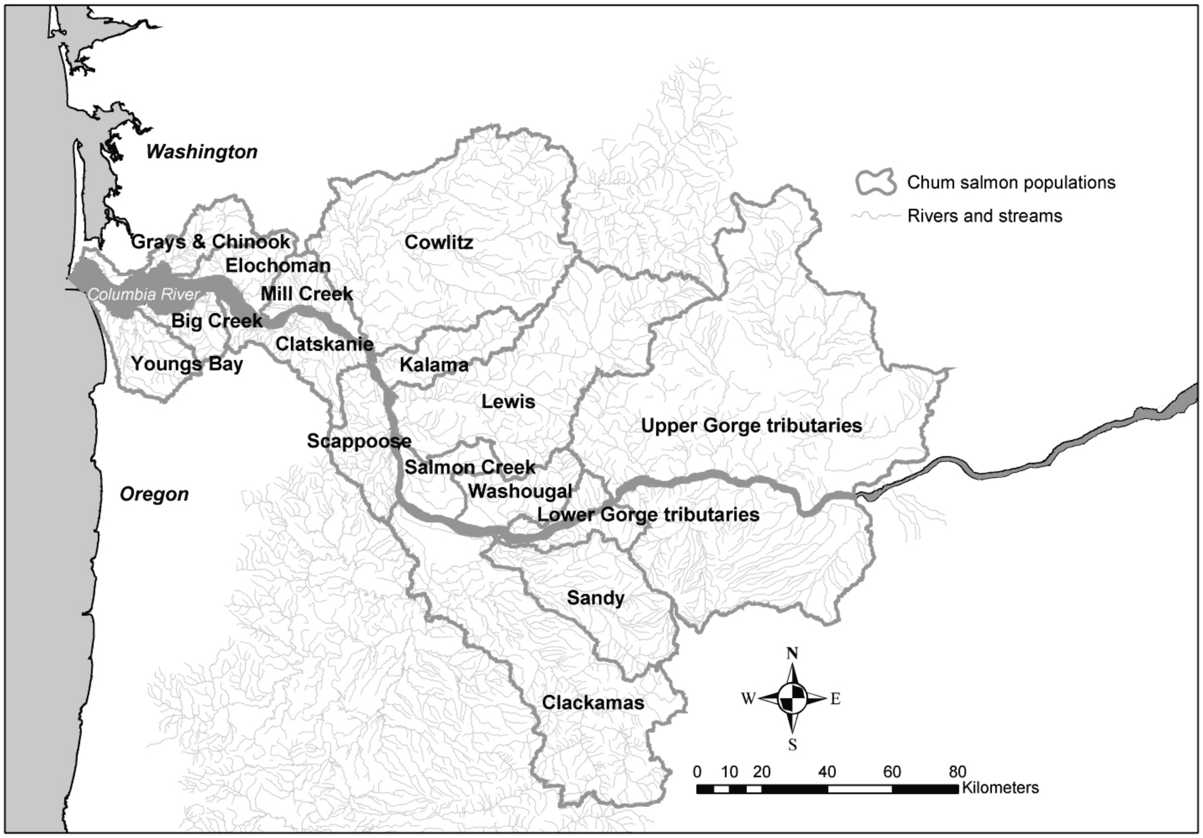

Figure 80. Historical Columbia River chum salmon populations. (Reprinted from Myers et al. 2006.)

In 2010 ODFW completed a recovery plan that included Oregon populations of the Columbia River Chum Salmon 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 these are likely either strays from one of the Washington populations 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 salmon. This plan includes an assessment of the current status of Columbia River chum populations. This assessment relied and built on 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 A/P, spatial structure, and diversity (McElhany et al. 2000). The result of this analysis is shown in Figure 81. The 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 to be at low risk. The very high risk status assigned to the majority of Washington populations (and all the Oregon populations) reflects the very low abundance observed in these populations (e.g., <10 fish/year).

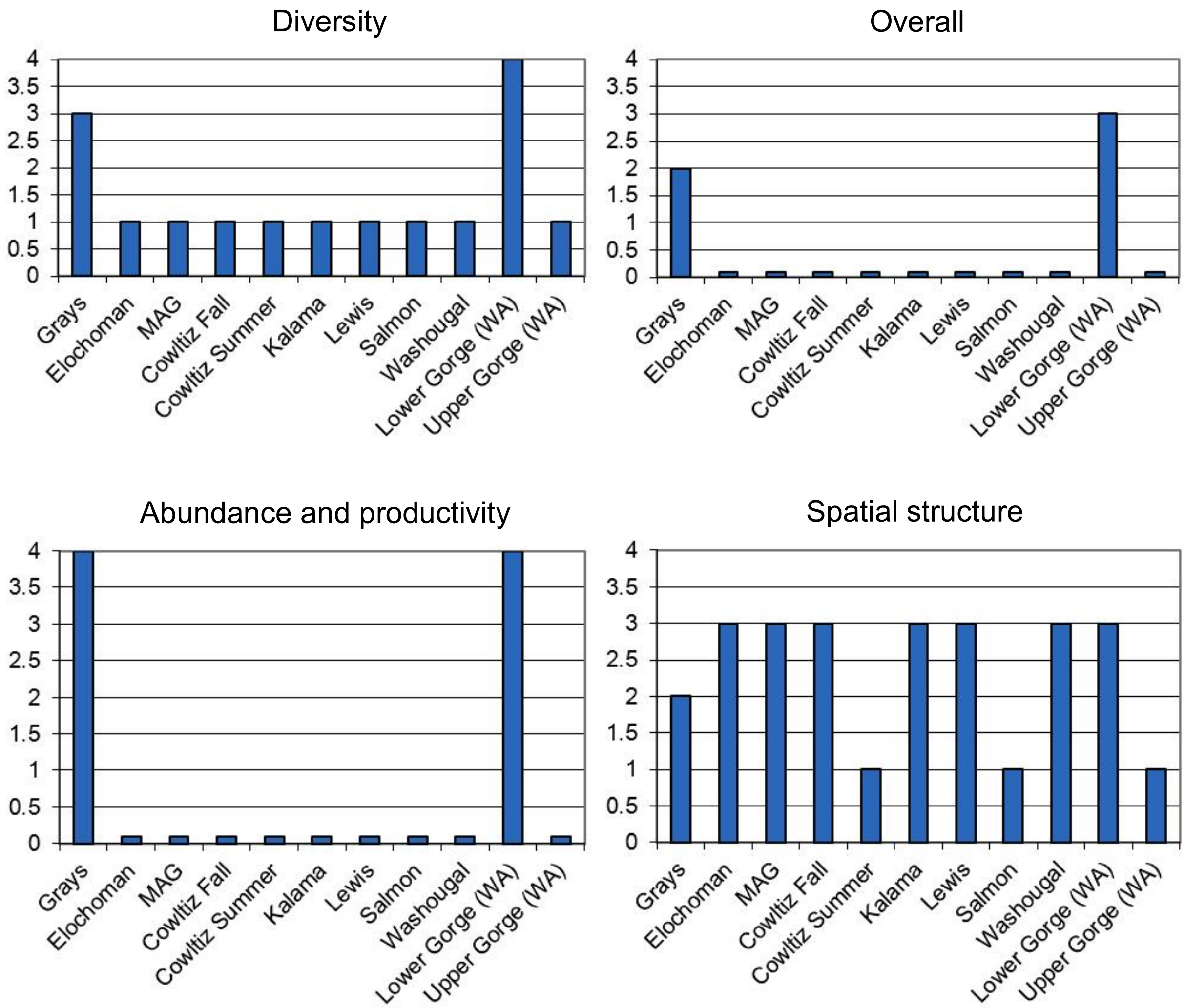

Figure 81. Current status of Washington Columbia River chum salmon populations for the VSP parameters and overall population risk (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk (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.

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Grays and lower Gorge

Grays River and the lower Gorge area are the only locations that have consistently maintained natural spawning. Surveys for chum salmon are regularly conducted in these areas, but a consistent methodology for obtaining population-level abundance estimates is still in development. Figure 82 and Figure 83 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 the 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 River data are confounded by the initiation of a hatchery program in the early 1999, so the Grays River time series contains an 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.

Washougal

The 2005 BRT report noted the discovery of a chum spawning group in the mainstem Columbia River beneath the I-205 bridge within the area of the Washougal River population.

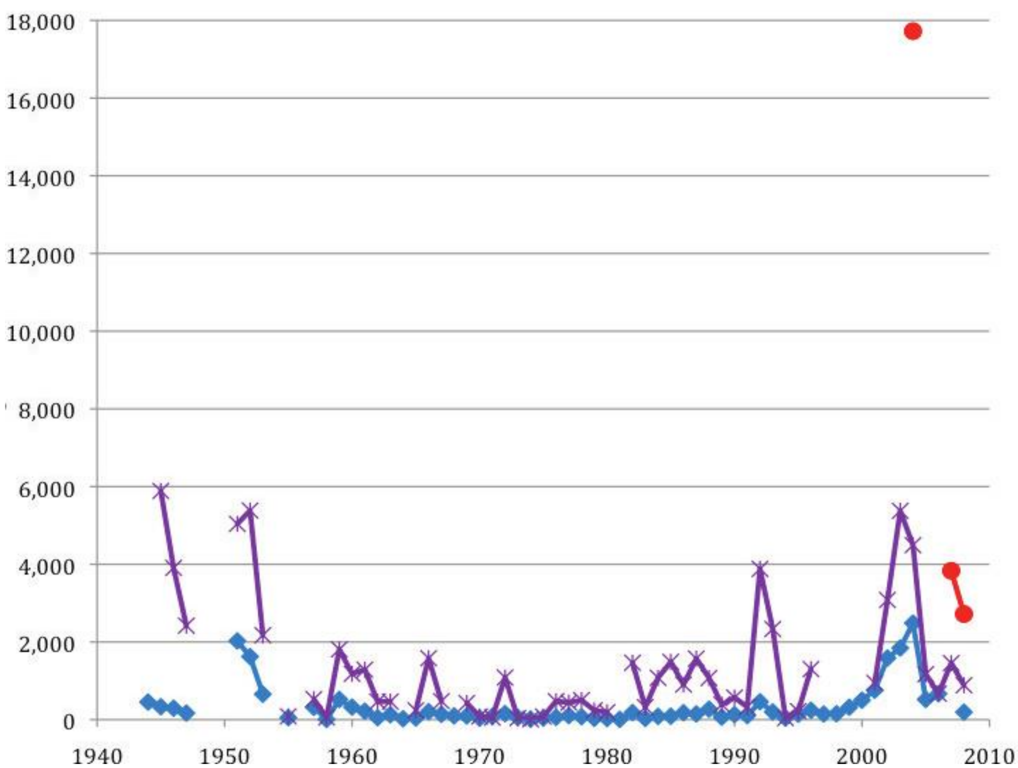

Figure 82. Grays River chum salmon spawner time series. The line with diamond symbols is spawners per mile from the WDFW salmonid stock inventory (SaSi) database. The lines with star symbols are the total live count from the Streamnet database. The line with circle symbols is the estimate of total spawners from the WDFW SaSi database.

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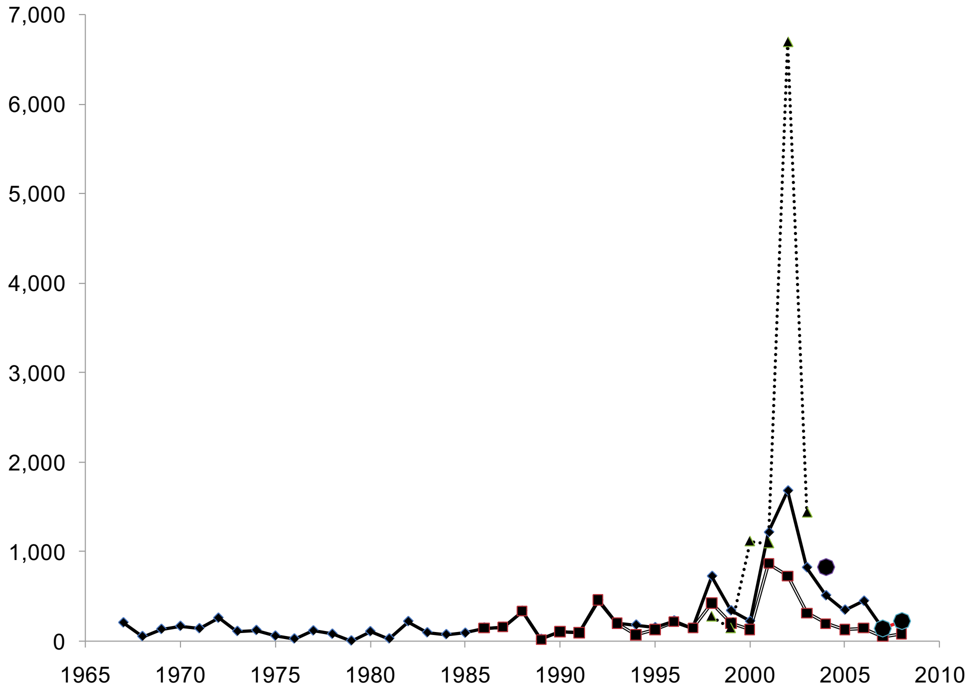

Figure 83. Lower Gorge chum salmon spawner time series. The line with diamonds is the spawner index from the WDFW SaSi database. The line with squares is spawners per mile from the WDFW SaSi database. The line with triangles is the total live count from the Streamnet database. The black circles are total spawners from the WDFW SaSi database.

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 salmon migrate past Bonneville Dam to the upper Gorge population area (Figure 84). Spawning above Bonneville is thought to be limited, however; for the first time chum fry were observed outmigrating past Bonneville in 2010.[16]

Other Washington populations

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.

[16] L. Krasnow, NMFS, Portland, OR. Pers. commun., 20 April 2010.

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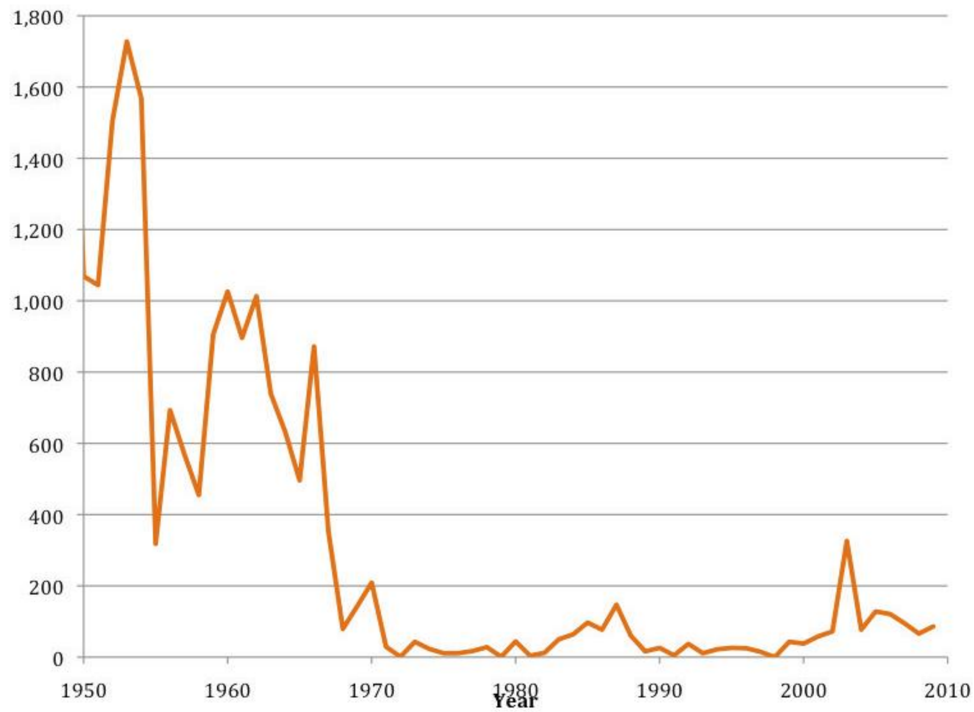

Figure 84. Chum salmon count by year at Bonneville Dam. Some chum fall back over the dam after being counted. Data from Fish Passage Center online database.

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 gill net 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 85). The hatchery fish are not externally marked. The Hatchery Scientific Review Group (HSRG) has recommended that the hatchery sunset in three generations.

Columbia River Chum Salmon: Updated Risk Summary

The vast majority (14 out of 17) of chum salmon 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 rivers show similar increases in the early 2000s followed by declines to typical recent levels, suggesting the increase in chum may be related to ocean conditions. Recent data on the

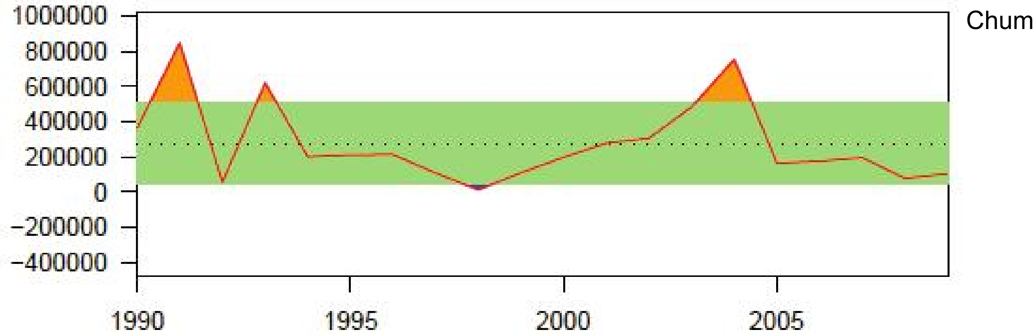

Figure 85. Columbia River chum salmon hatchery releases by year. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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.

Lower Columbia River Coho Salmon ESU

Listed ESU/DPS

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 28 June 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 25 artificial propagation programs: 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 section above) undertook a revaluation of the boundary between all lower Columbia and mid-Columbia ESUs and DPSs. The review conclusions emphasize the transitional nature of the boundary between the lower Columbia ESUs and the mid-Columbia ESUs. The original lower Columbia coho salmon ESU boundary was assigned based largely on extrapolation from

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information about the boundaries for Chinook and steelhead. The ESU Boundaries Review Group considered it reasonable to assign the Klickitat Chinook and steelhead populations to the appropriate lower Columbia ESU/DPS. The ESU Boundaries Review Group concluded, "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 (Good et al. 2005). In the 2001 review, the BRT was very concerned that the vast majority (more than 90%) of historical populations in the 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 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 2001 BRT votes were for at risk of extinction with a substantial minority voting for 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 86) 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 Lower Columbia River Coho Salmon ESU. Also in 2010 the LCFRB completed a revision of its recovery plan that includes Washington populations of lower Columbia coho. Both recovery plans include an assessment of current status of lower Columbia River coho populations. These assessments relied and built on 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 A/P, spatial structure, and diversity (McElhany et al. 2000). The results of these analyses are shown in Figure 87 and Figure 88.

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 88, 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 at very high risk. The results from Oregon and Washington are largely driven by the very low A/P of naturally produced lower Columbia River coho salmon.

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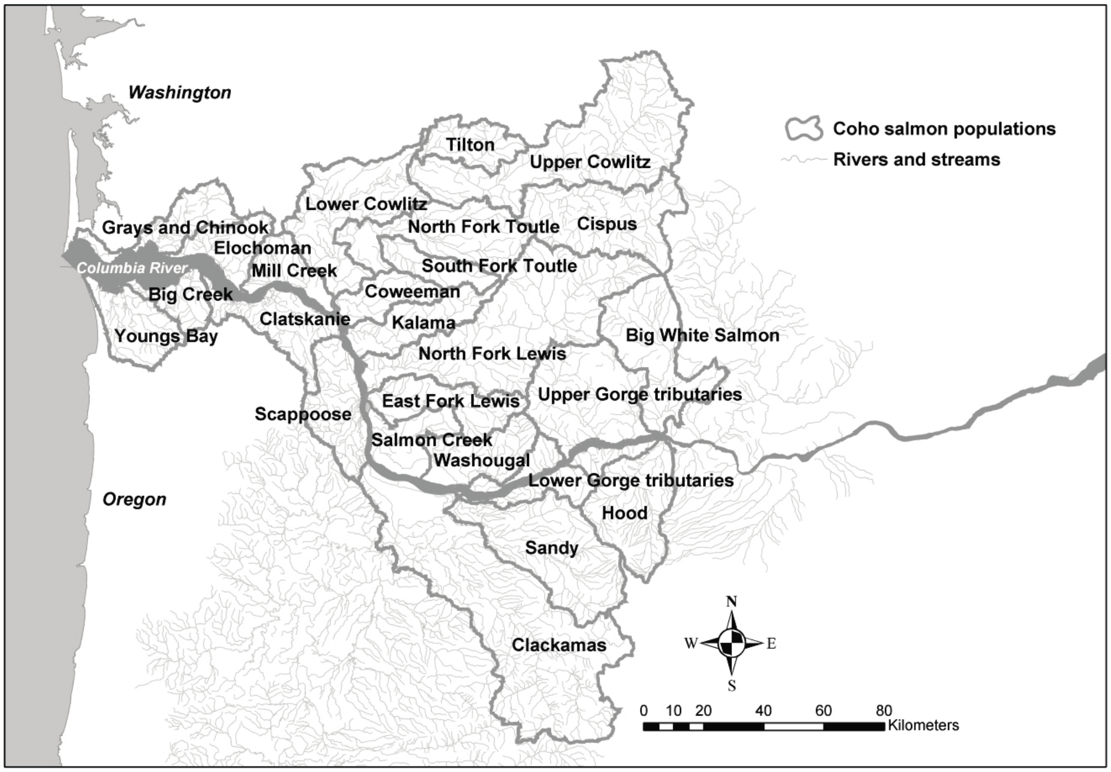

Figure 86. Historical populations of lower Columbia River coho salmon. (Reprinted from Myers et al. 2006.)

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 to 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 the Sandy and Clackamas populations. These time series are shown in Figure 89 with summary statistics in Table 43. The total abundance over the years since the last status review (2003−2008) have remained within 1 SD of each population's long-term mean, with the exception of 2008 in the Clackamas, which is slightly above 1 SD. 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 combine 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).

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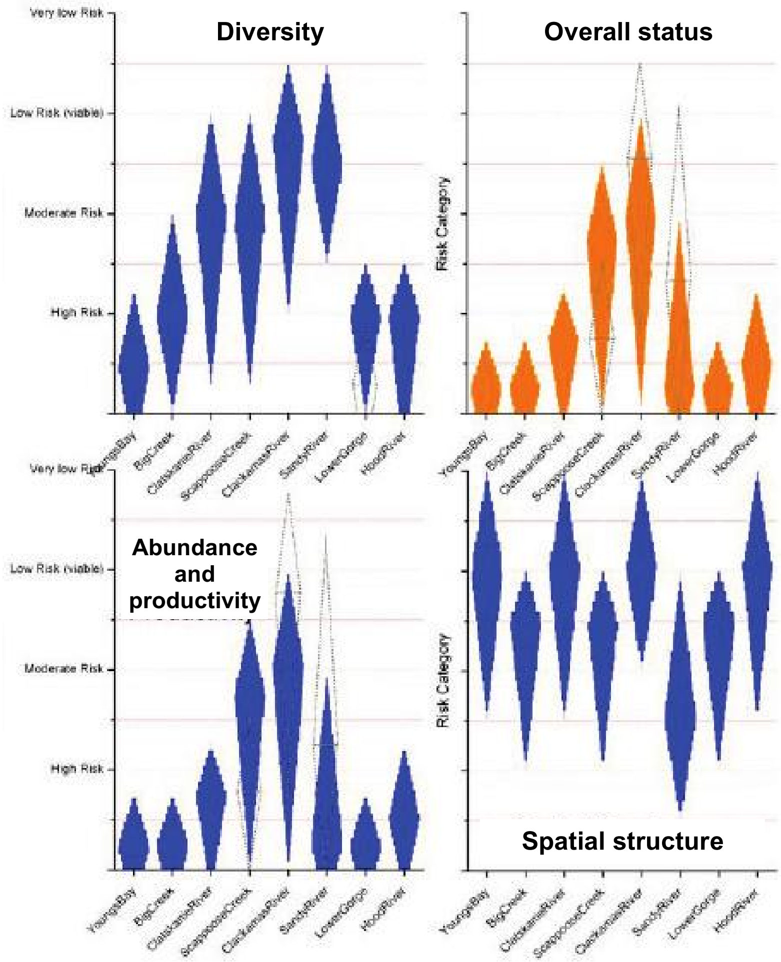

Figure 87. Extinction risk ratings for lower Columbia River coho salmon populations in Oregon for the assessment attributes A/P, diversity, and spatial structure, as well as an overall rating for populations that combines the three attributes ratings. Where updated ratings differ from those presented by McElhany et al. 2007, the older rating is shown as an open diamond with a dashed outline. (Reprinted from Beamesderfer et al. 2010.)

Other Oregon populations

In 2002 ODFW initiated a monitoring program for lower Columbia River coho salmon spawners based on a stratified random sample survey design. A report covering monitoring results for the years 2002−2004 was published in 2006 (Suring et al. 2006). Abundance estimates and hatchery fish fractions from that study are summarized in Table 44 through Table 46. In 2010 ODFW published a report covering lower Columbia River coho monitoring for the years 2004−2008. The reports indicate overall relatively low abundance of natural-origin fish in the Oregon portion of the Lower Columbia River Coho Salmon 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

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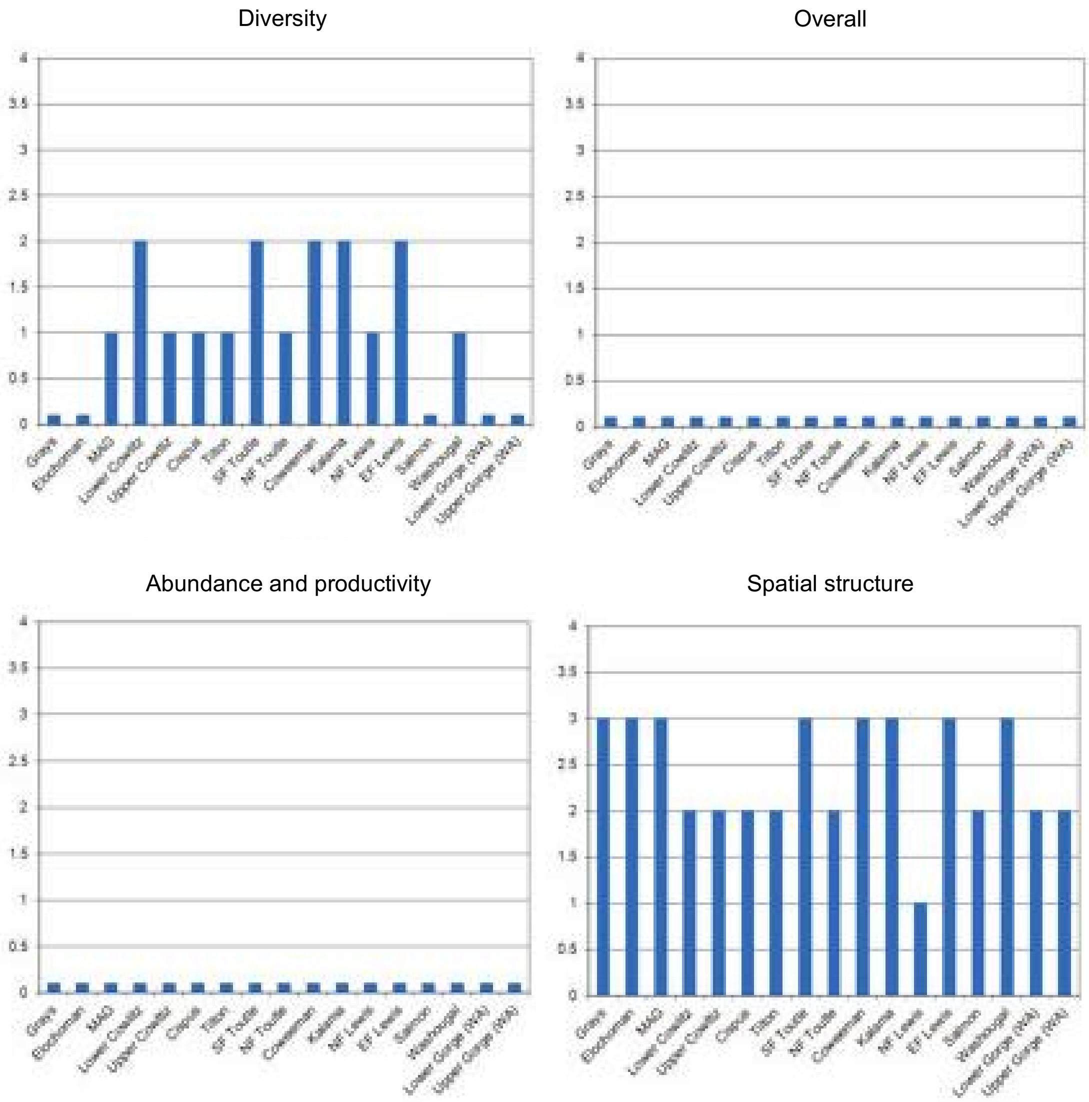

Figure 88. Current status of Washington lower Columbia River coho salmon populations for the VSP parameters and overall population risk (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk (viable), and 4 is very low risk.

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 MAT long-term geometric mean of 1,000 spawners in a small watershed (McElhany et al. 2007).

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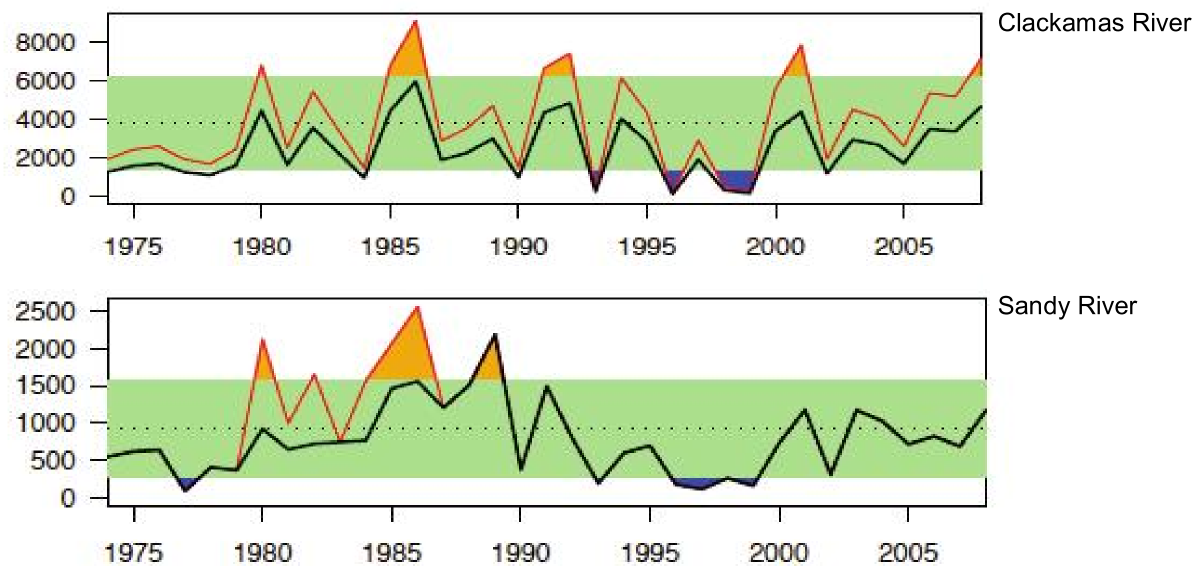

Figure 89. Abundance of lower Columbia River coho salmon populations by year. The dark line indicates natural-origin spawner numbers and light line indicates total natural spawners. The dotted line indicates the overall geometric mean abundance of natural-origin spawners and the shaded area indicates ±1 SD around the mean.

Washington populations (Grays, Elochoman, Mill/Germany/Abernathy, Cispsus, Tilton, Upper Cowlitz, Lower Cowlitz, North Fork Toutle, South Fork Toutle, Coweeman, Kalama, North Fork Lewis, East Fork 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 coho salmon 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 90). These data show an estimated 3,150 spawners with slightly more than 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 and indicate some natural production does occur in these streams (Figure 91). The new Mill/Germany/Abernathy smolt production data (2003−2005) is similar to the data (2001−2002) considered in the 2005 BRT report.

Smolt trap data are also available for Cedar Creek, a tributary of the North Fork Lewis River population (Table 47). 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 1,000 coho spawned in Cedar Creek to produce the observed number of smolts (e.g., if the

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Table 43. Summary statistics for lower Columbia River coho salmon. The 95% confidence intervals (CIs) are shown in parentheses. Cells highlighted in italic indicate negative population indicators and cells in boldface 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% CI is entirely above or below one.

Population	Analysis window	Years	Geomean natural-origin spawners	Trend in log natural-origin spawners	Lambda with hatchery reproduction = 0	Lambda with hatchery reproduction = 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

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Table 44. 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.)

			Survey effort		Adult coho spawner abundance[a]			
					Total		Wild[b]	
Year	Population complex	Spawning miles[c]	Number of surveys	Miles	Estimate	95% CI	Estimate	95% CI
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	316.6	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.

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Table 45. Mark rates based on observations of adipose fin clips on live and dead coho salmon spawners in random coho surveys during the 2002–2004 spawning seasons. (Reproduced from Suring et al. 2006.)

	2002				2003				2004			
	Live		Carcasses		Live		Carcasses		Live		Carcasses	
Population complex	**Total**	**Percent marked**	**Total**	**Percent marked**	**Total**	**Percent marked**	**Total**	**Percent marked**	**Total**	**Percent marked**	**Total**	**Percent 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*	202	82.9	138	85.4	192	34.0	76	38.5	317	23.4	36	19.4
Total	1,027	64.5	694	77.6	531	29.0	208	47.4	844	29.5	264	42.5

*Live percent marked is corrected for scale analysis results which indicate that 76.5% in 2002, 28.4% in 2003, and 19.4% in 2004 of unmarked coho salmon were of hatchery origin. Carcasses percent marked is based on scale analysis.

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Table 46. Lower Columbia River Coho Salmon 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	Wild	5,630	4,820	6,422	5,785	4,987
ESU	Hatchery	1,882	3,432	12,230	1,820	1,718
(Oregon only)	% 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	NAS	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	NAS*	2,555	880	399	219
	% hat.		62.7%	59.6%	57.2%	43.3%
Lower Gorge	Wild	NAS	263	226	126	223
tributaries	Hatchery	NAS	1,512	538	261	191
	% hat.		85.2%	70.4%	67.4%	46.1%
Hood River	Wild	129	1,260	370	173	64
	Hatchery	NAS	1,043	342	138	28
	% hat.		45.3%	48.0%	44.4%	30.4%

*NAS = not adequately surveyed.

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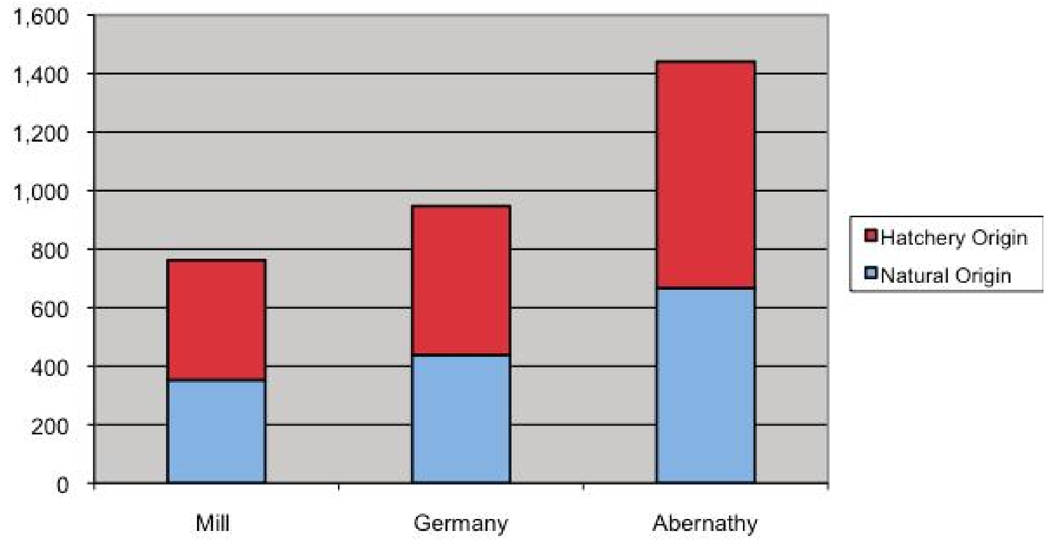

Figure 90. Coho salmon spawner estimates for the Mill, Germany, and Abernathy population in 2006. Total coho spawner estimate for the population was 3,150, with 51% of hatchery origin. Data from WDFW.

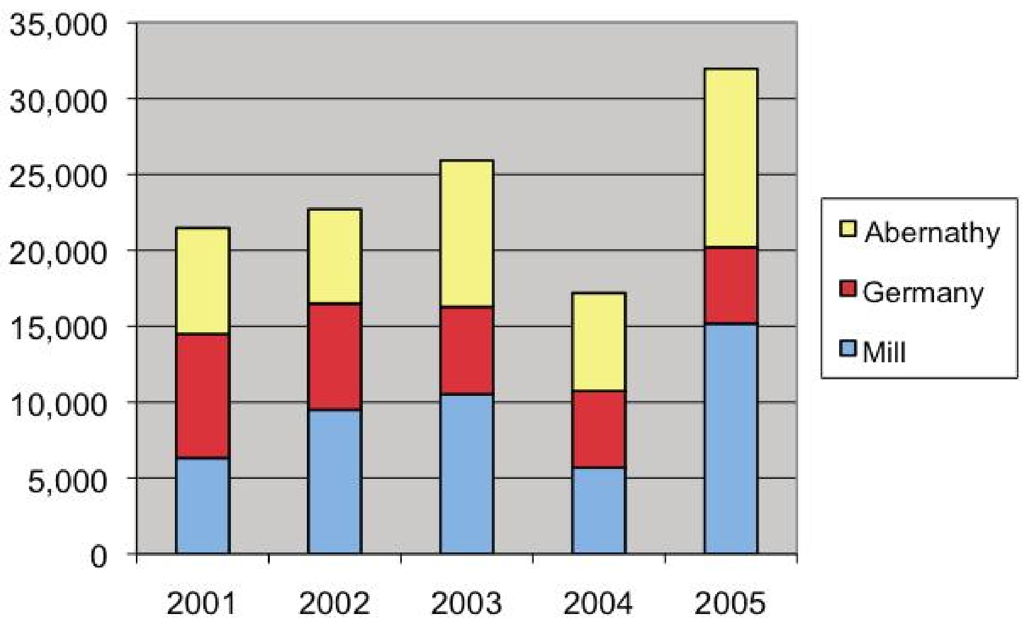

Figure 91. Coho salmon smolt production estimates for Mill, Germany, and Abernathy creeks. Data for 2001−2001 from 2005 BRT report; data for 2003−2005 from WDFW, http://wdfw.wa.gov/fish /wild_salmon_monitor/lower_columbia.htm#mag.

Table 47. Coho salmon smolt production from Cedar Creek (tributary in the North Fork Lewis population). Question mark (?) indicates uncertainty. 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, and 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-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 North Fork 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 salmon outmigrant year for the Coweeman population (Sharpe and Glaser 2007). They estimated 17,389 smolts (±1,769), indicating some production potential for this basin.

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 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 closed ever since. Ocean fisheries for coho off 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 92).

Hatcheries

Hatchery releases have remained relatively steady at 10–15 million since the 2005 BRT report (Figure 93). 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

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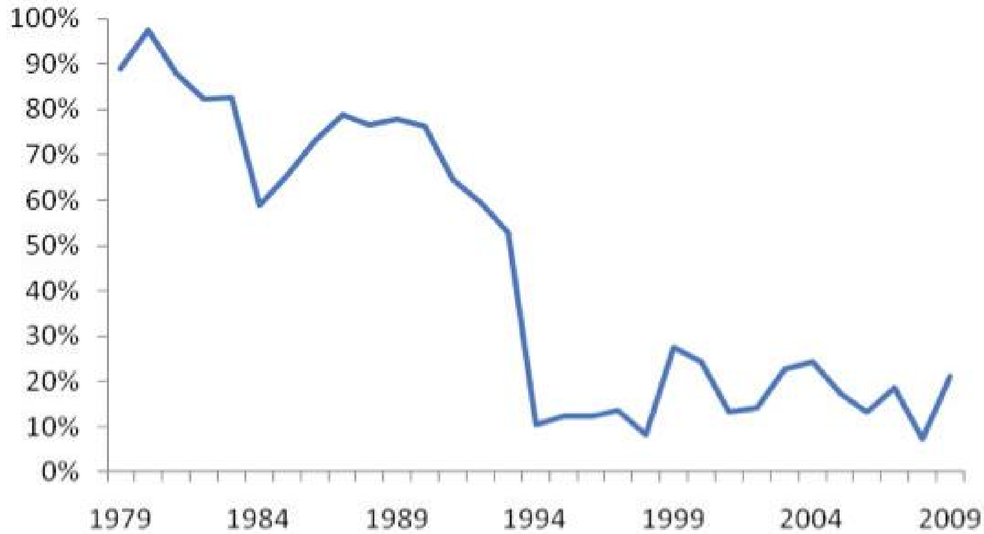

Figure 92. Total exploitation rate (%) by year on lower Columbia River natural coho salmon. Data from TAC 2010.

areas (e.g., Youngs Bay and Big Creek) in order to reduce hatchery fish pressure in other populations (e.g., Scappoose and Clatskanie) are considered as in transition at this time. It is important to note that direct data on the fraction of hatchery-origin spawner are available for only 1 of Washington's 17 coho populations (Mill/Germany/Abernathy) for a single year (2006). This lack of data contributes greatly to uncertainty about the ESU's status.

Lower Columbia River Coho Salmon: Updated Risk Summary

Three status evaluations of lower Columbia River coho salmon status, all based on WLC-TRT criteria, have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, Beamesderfer et al. 2010, LCFRB 2010). McElhany et al. (2007) concluded that the ESU is currently at high risk of extinction. The ODFW plan concluded that the Oregon portion of the ESU is currently at very high risk. The LCFRB plan does not provide a statement on ESU-level status, but describes the high fraction of populations in the ESU that are at high or very high risk. Of the 27 historical populations in the ESU, 24 are considered at very high risk. The remaining three (Sandy, Clackamas, and Scappoose) 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.

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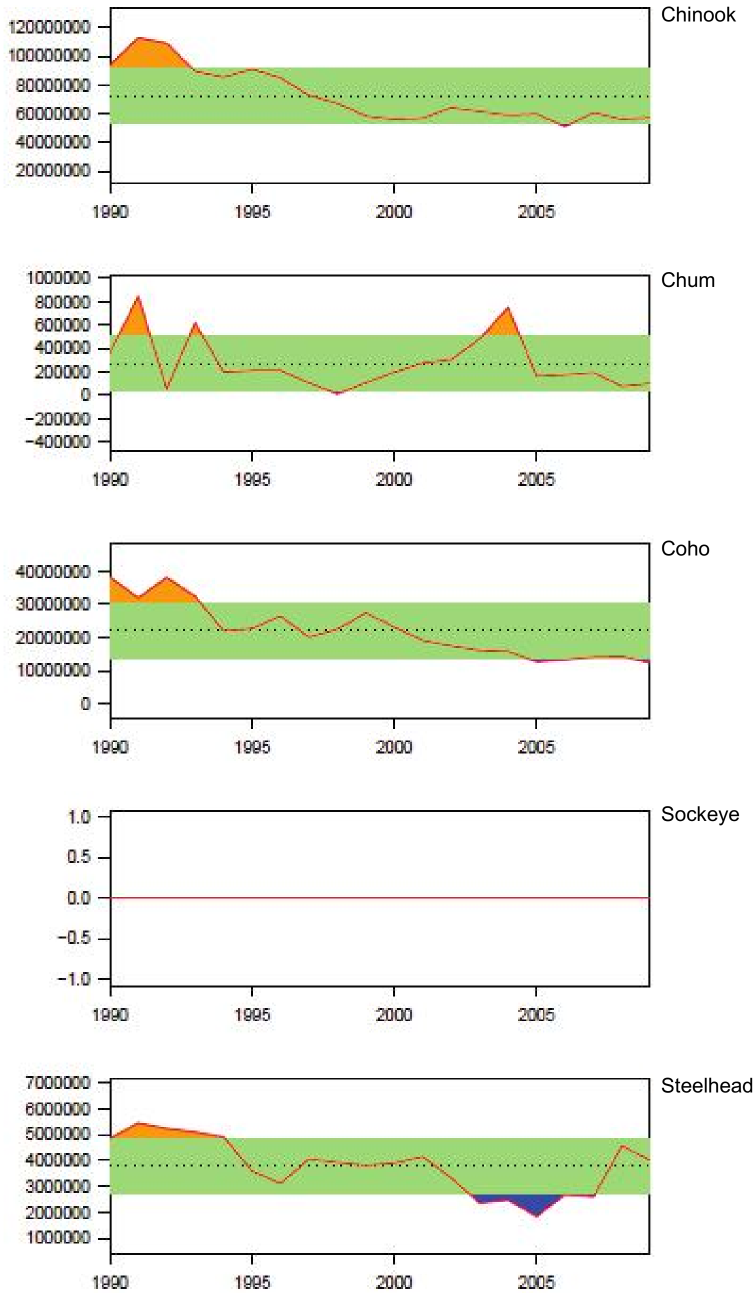

Figure 93. Lower Columbia River hatchery releases by year for all salmon and steelhead species released within the spawning and rearing area of the Lower Columbia River Coho Salmon ESU. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively.

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Lower Columbia River Steelhead ESU

Listed ESU/DPS

The DPS includes all naturally spawned anadromous steelhead populations below natural and man-made 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 10 artificial propagation programs: the Cowlitz Trout Hatchery (in the Cispus, upper Cowlitz, lower Cowlitz, and Tilton rivers), Kalama River Wild (winter run and summer run), Clackamas Hatchery, Sandy Hatchery, and Hood River (winter run and summer run) Steelhead Hatchery programs. Excluded are steelhead 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 (see ESU Boundaries section above) undertook a revaluation of the boundary between all lower Columbia and mid-Columbia river ESUs and DPSs. The review conclusions emphasize the transitional nature of 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 1998a, 1998d). 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.

Lower Columbia River steelhead were most recently reviewed by the BRT in 2005 (Good et al. 2005). A large majority (more than 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 VSP categories. All major risk factors identified by previous BRTs 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). WLC-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.

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Summary of Recent Evaluations

A report on the population structure of lower Columbia River salmon and steelhead populations was published by WLC-TRT in 2006 (Myers et al. 2006). The steelhead population designations in that report (Figure 94) are used in this status update and were used for status evaluations in recent recovery plans by ODFW and LCFRB. Lower Columbia River 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 the Lower Columbia River Steelhead DPS. Also in 2010 the LCFRB completed a revision of its recovery plan that includes Washington populations of lower Columbia River steelhead. Both of these recovery plans include an assessment of current status of lower Columbia River steelhead populations. These assessments relied and built upon the viability criteria developed by 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 A/P, spatial structure, and diversity (McElhany et al. 2000). The results of these analyses are shown in Figure 95 and Figure 96.

These analyses indicate that only 2 of the 26 lower Columbia River 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 whose habitat is above impassible dams (e.g., North Fork Lewis) or in highly urbanized watersheds (e.g., Salmon Creek).

New Data and Analyses

The 2005 BRT status evaluation included abundance data for most of the lower Columbia River steelhead populations up to the year 2001. For the current evaluation, we compiled data through 2008 for most populations. Trend data are presented in Figure 97 and Figure 98. Since the last status evaluations, all of the populations increased in abundance during the early 2000s, generally peaking in 2004. Most populations have since declined back to levels within 1 SD of the long-term mean. Exceptions are the Washougal summer run and North Fork Toutle winter run, which are still higher than the long-term average, and the Sandy, which is lower. The North Fork Toutle winter run appears to be experiencing a longer term increasing trend since 1990, which is partially attributed to watershed recovery from the eruption of Mt. St. Helens in 1980. The abundance of the Sandy winter steelhead population is well below the long-term mean and did not experience the 2004 increase seen in the other populations in the ESU, suggesting that the population lacks 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.

Harvest

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-

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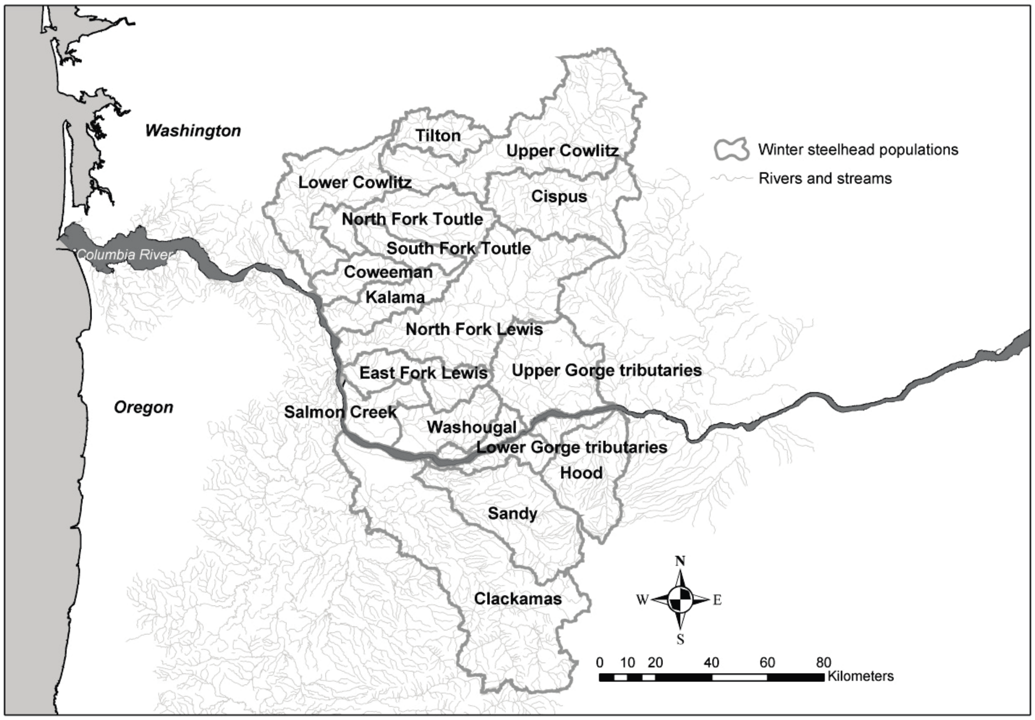

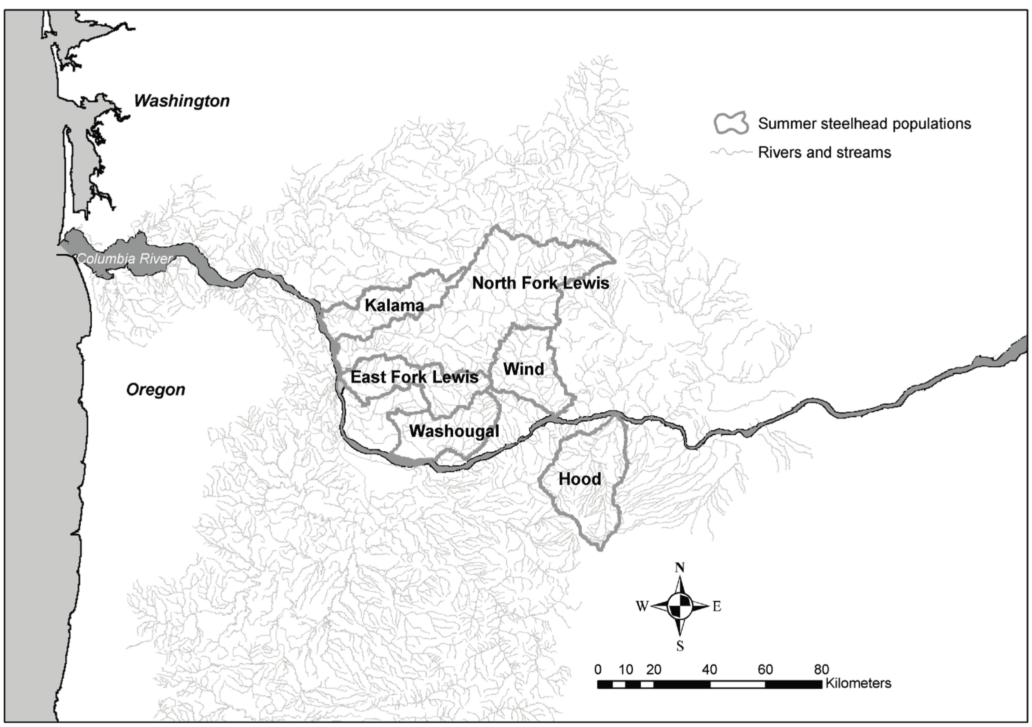

Figure 94. Populations of lower Columbia River winter steelhead (upper) and summer steelhead (lower). (Reprinted from Myers et al. 2006.)

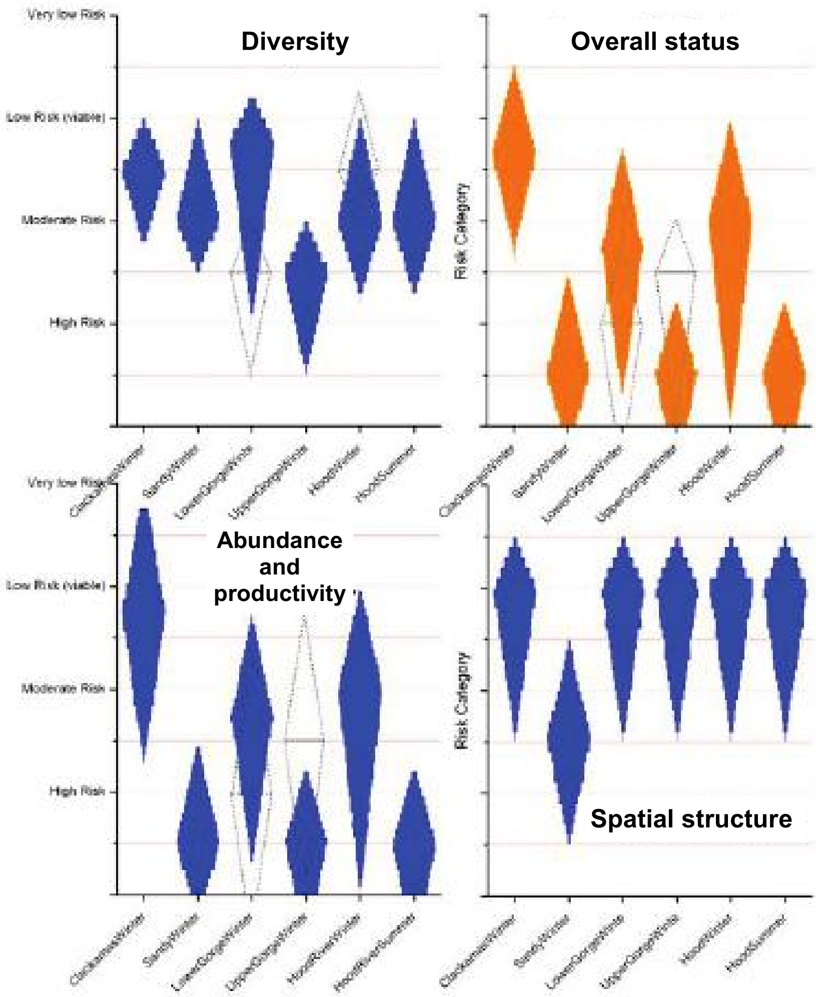

Figure 95. Oregon lower Columbia River steelhead population status. (Reprinted from ODFW 2010.)

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 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 99). In that time period, exploitation rates have been below the consultation standard of 2% in all years except 2002.

Hatcheries

Total steelhead hatchery releases in the Lower Columbia River Steelhead ESU have increased since the last status evaluation in 2005 from about 2 million to around 3 million (Figure 100). Some populations (e.g., Hood River, Kalama) have relatively high fractions of hatchery-origin spawners, whereas others (e.g., Wind) have relatively few hatchery-origin

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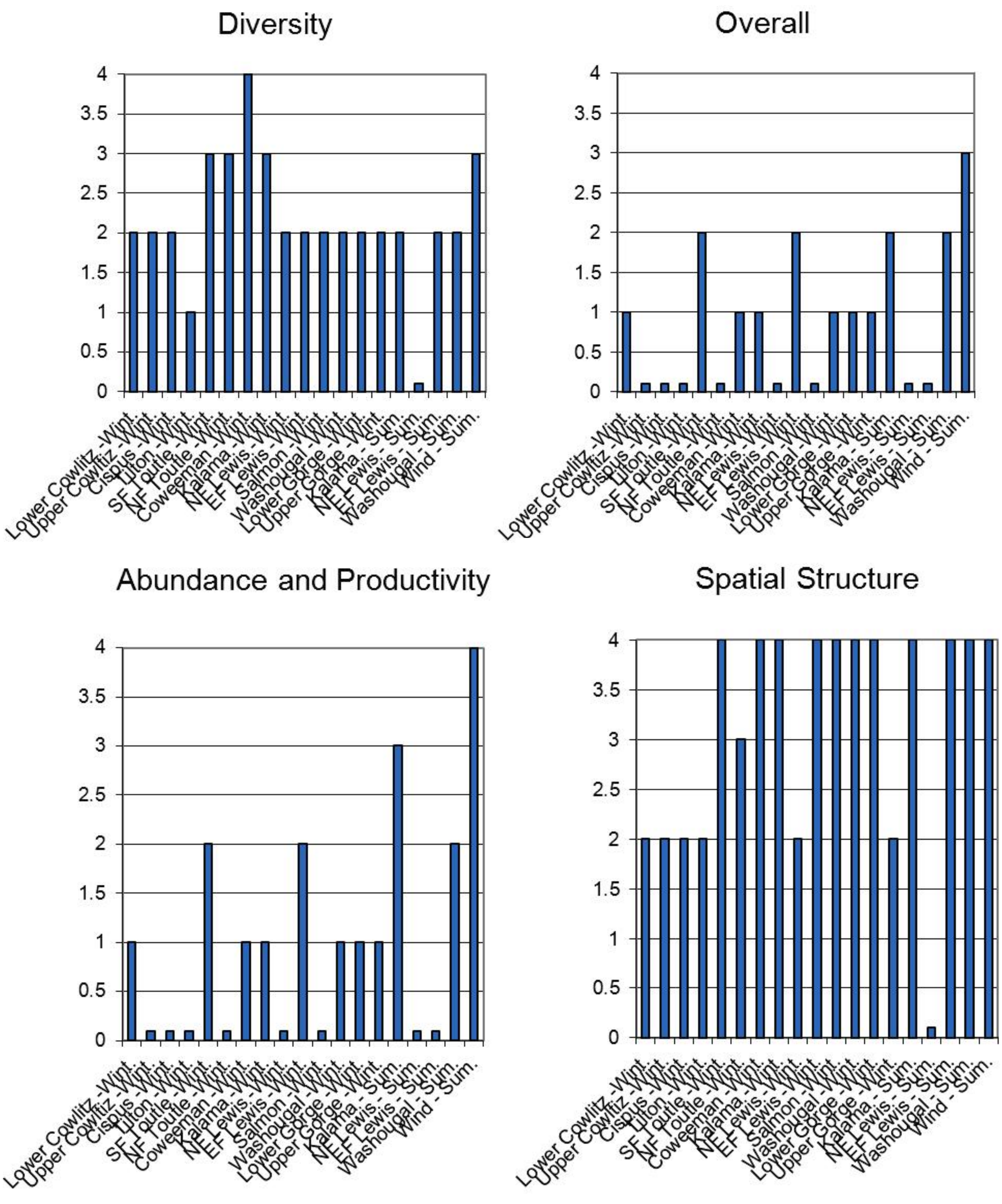

Figure 96. Current status of Washington lower Columbia River steelhead populations for the VSP parameters and overall population risk (LCFRB 2010 recovery plan, chapter 6). A population score of zero indicates a population extirpated or nearly so, a score of 1 is high risk, 2 is moderate risk, 3 is low risk (viable), and 4 is very low risk.

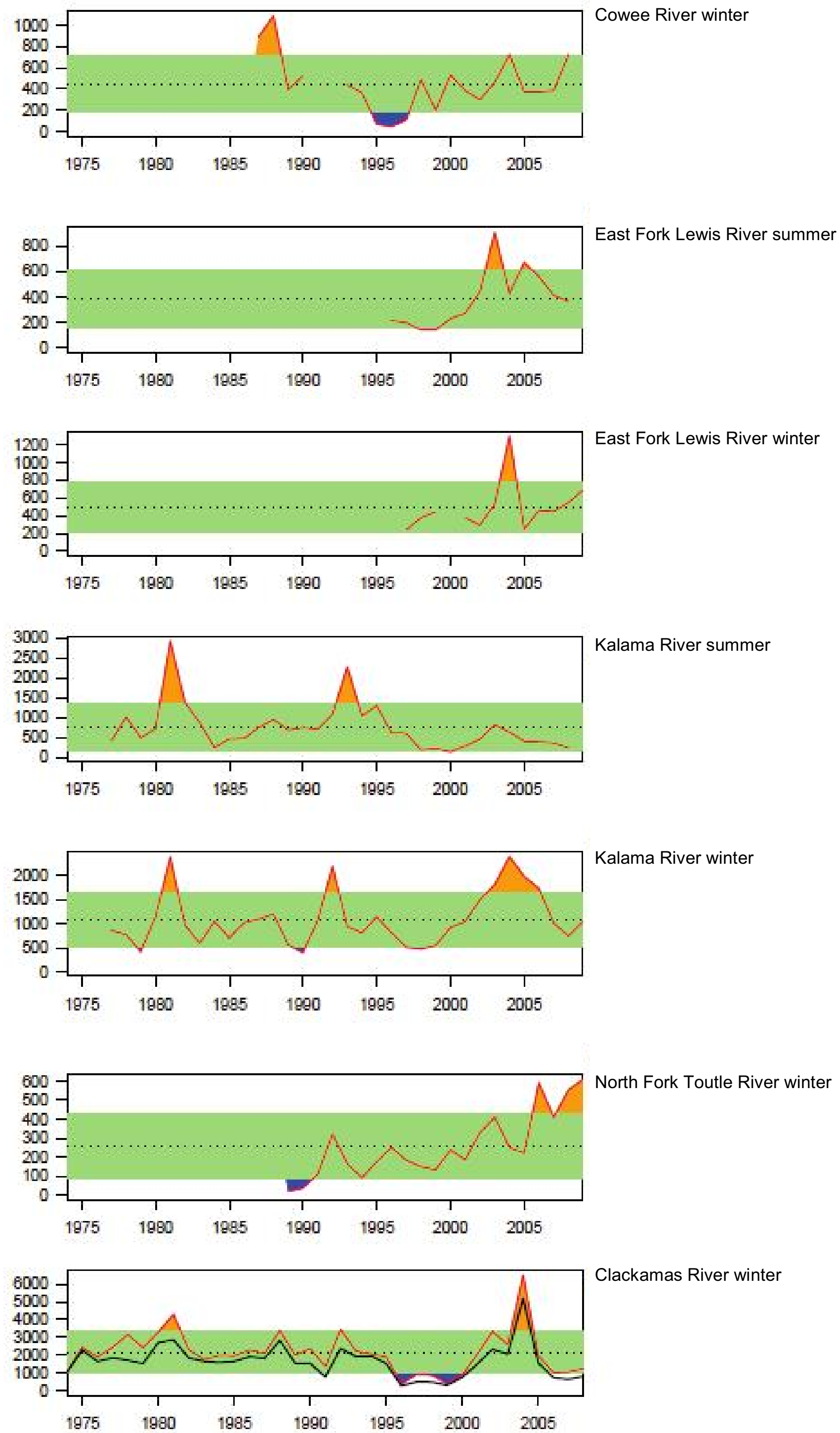

Figure 97. Lower Columbia River steelhead trends in abundance by year. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

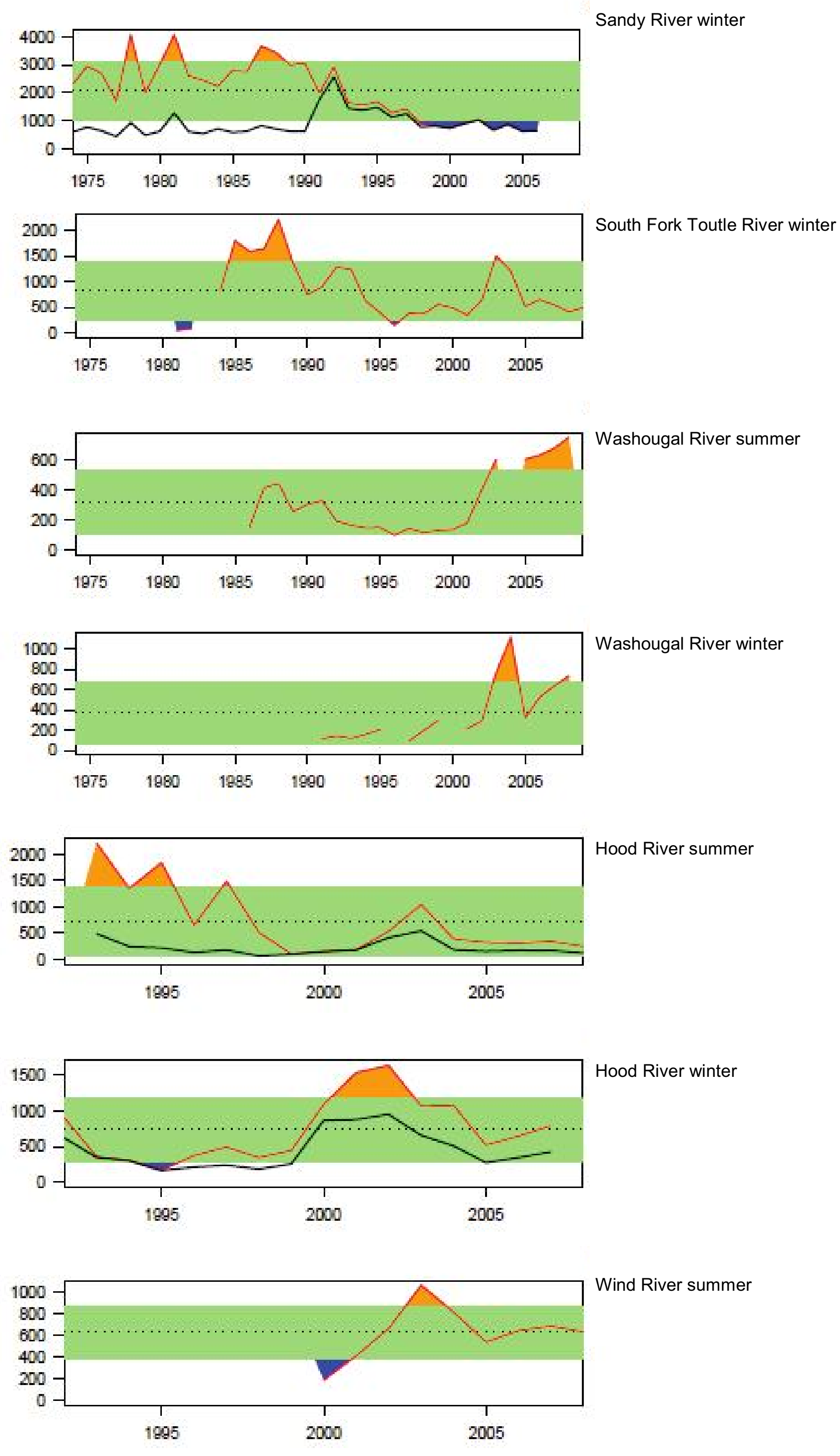

Figure 98. Lower Columbia River steelhead trends in abundance by year. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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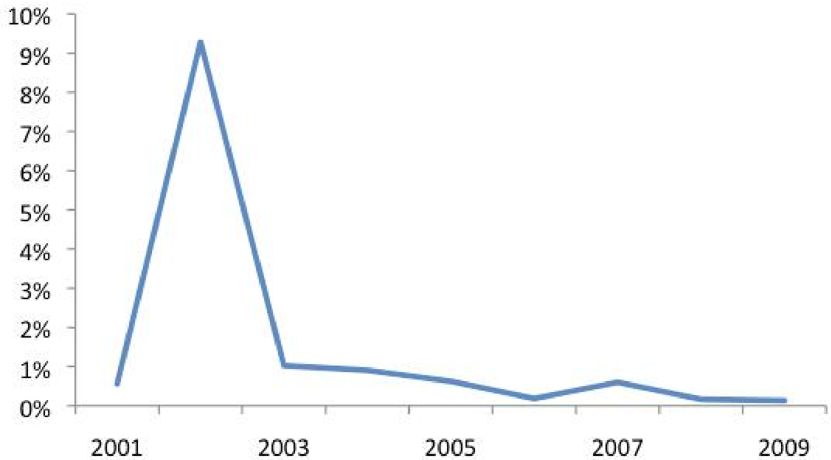

Figure 99. Total exploitation rates (%) on natural winter steelhead from the Columbia Basin by year. Winter-run steelhead include the lower Columbia River ESU, upper Willamette River ESU, and portions of the middle Columbia River and Washington coastal ESUs. Data from TAC 2010.

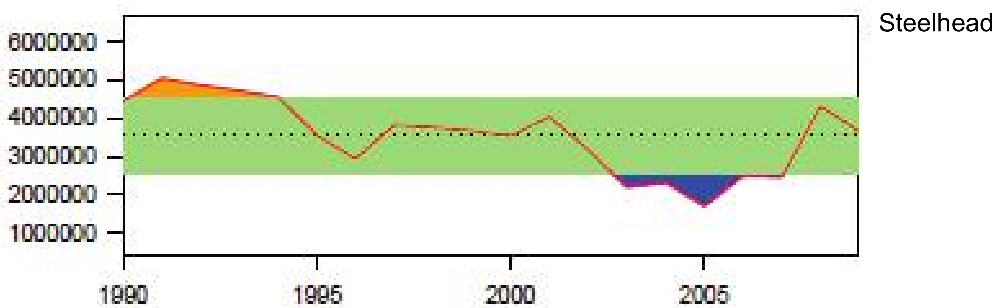

Figure 100. Annual lower Columbia River steelhead hatchery releases by year. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

spawners. Although recovery plans and the HSRG recommend some changes in hatchery programs, there have been no substantial changes from the last status review.

Lower Columbia River Steelhead: Updated Risk Summary

Three status evaluations of lower Columbia River steelhead status, all based on WLC-TRT criteria, have been conducted since the last BRT status update in 2005 (McElhany et al. 2007, Beamesderfer et al. 2010, LCFRB 2010). McElhany et al. (2007) concluded that the ESU is currently at high to moderate risk of extinction. The ODFW plan concluded that the Oregon portion of the ESU is currently at moderate risk. The LCFRB plan does not provide a statement on ESU-level status, but describes the high fraction of populations in the ESU that are at high or very high risk. 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.

Upper Willamette River Steelhead ESU

Listed ESU/DPS

The DPS includes all naturally spawned anadromous steelhead populations below natural and man-made 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 section 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 1999b). 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 nonnative 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 of becoming endangered in the foreseeable future.

In the most recent status update (Good et al. 2005), a majority (more than 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 river salmon and steelhead populations was published by the WLC-TRT in 2006 (Myers et al. 2006). The upper Willamette steelhead population designations in that report (Figure 101) are used in this status update and were used for status evaluations in a recent recovery plan by Beamesderfer et al. (2010).

A draft recovery plan for upper Willamette Chinook and steelhead was released for comment by ODFW in 2010. The status evaluation in the ODFW recovery plan provided an

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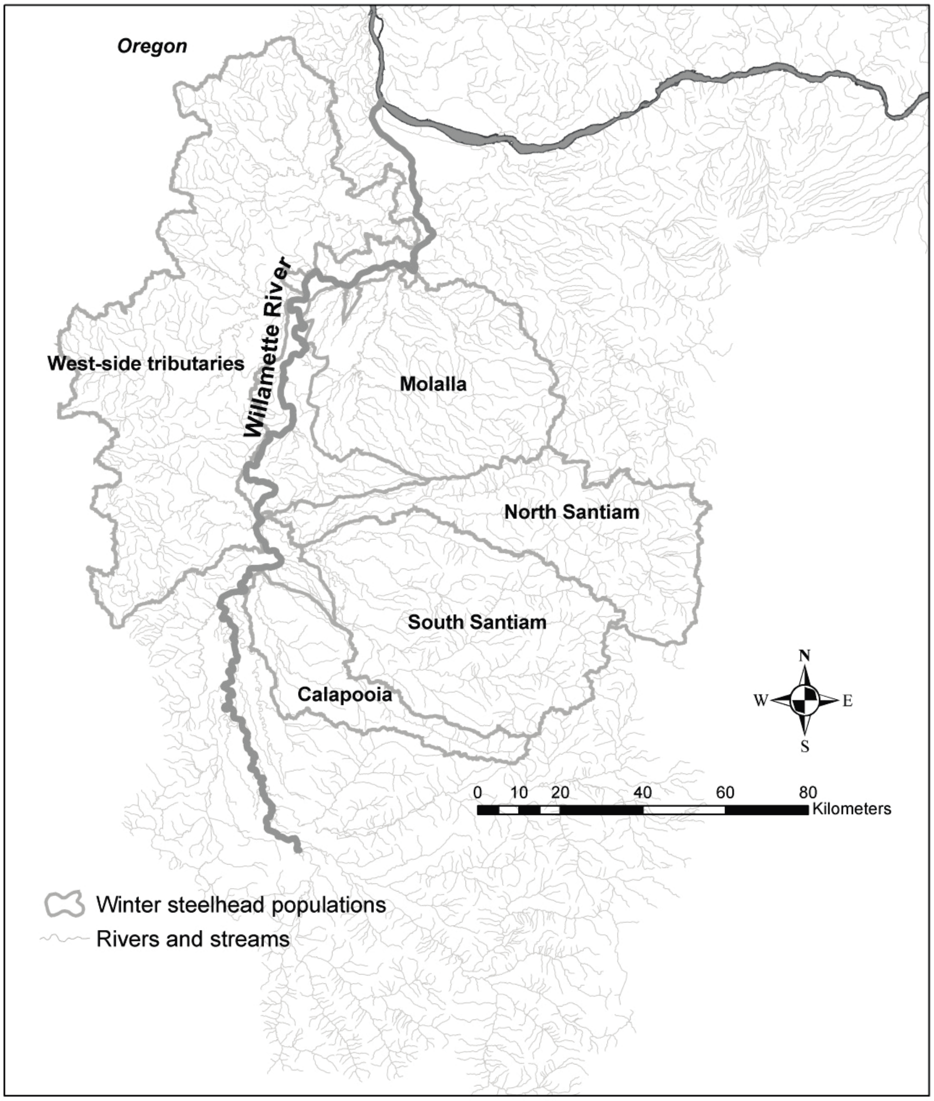

Figure 101. Upper Willamette River steelhead populations. (Reprinted from Myers et al. 2006.)

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 102. 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 Santiam populations was low risk rather than moderate risk. The McElhany et al. (2007) analysis used data up to 2005, whereas the ODFW analysis used data through 2008. Extinction risk modeling in the ODFW 2010 recovery plan (Beamesderfer et al. 2010) suggests that, based only on biological information, the ESU is viable. However, the recovery plan indicates that increasing threats to the ESU place it at considerable risk.

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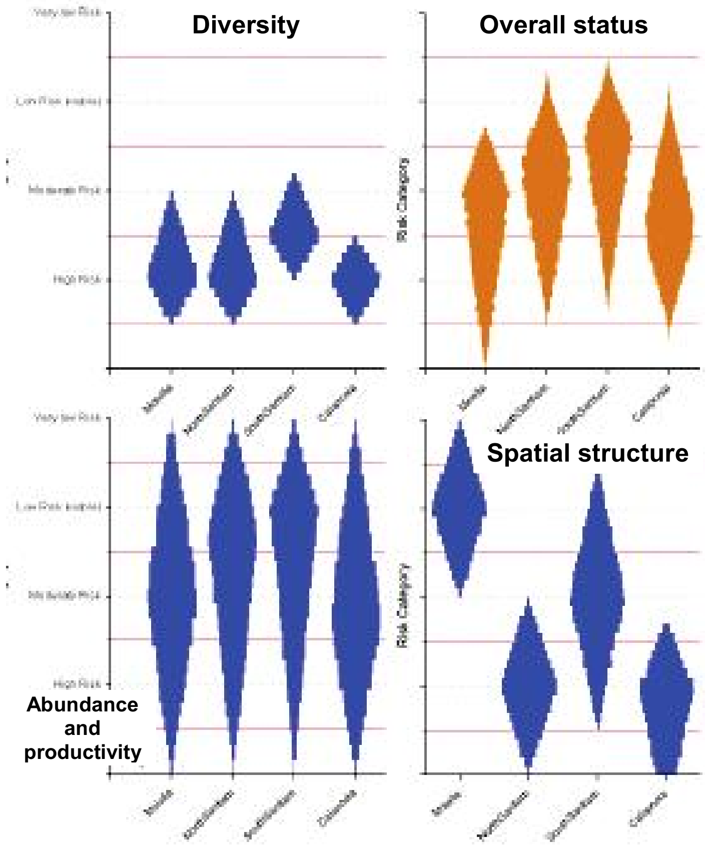

Figure 102. Status of upper Willamette steelhead populations. (Reprinted from McElhany et al. 2007.)

New Data and Analyses

Willamette Falls

All steelhead in the Upper Willamette River Steelhead ESU pass Willamette Falls (Figure 103). 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 has since returned to the relatively low abundance of the 1990s. The late-returning abundance for the entire ESU in 2009 was 2,110 fish.

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 104). The population estimates mirror the patterns at Willamette Falls with declines in the most recent years. In 2008 the total abundance of winter steelhead at Willamette Falls was 4,915, which was distributed (minus in-basin mortality) into the four populations.

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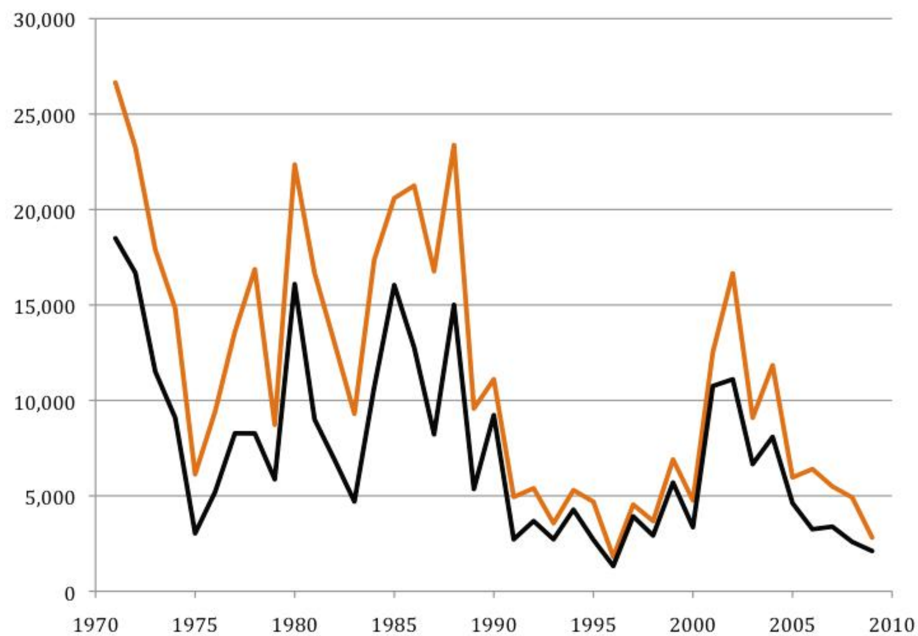

Figure 103. Count of winter-run steelhead spawners by year at Willamette Falls. The upper line shows the total winter steelhead run. The lower line shows the late winter steelhead run, which is considered the native life history. Hatchery releases of winter-run steelhead in the Willamette River were discontinued in 1999. Data from ODFW Willamette Falls count database, http://www.dfw.state.or.us/fish/fish_counts/willamette%20falls.asp.

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 1989−1999. Total fishery exploitation rates for the natural component are only available back to 2001 (Figure 105). In that time period, exploitation rates have been below the consultation standard of 2% in all years except 2002.

Hatcheries

Winter steelhead hatchery releases in the upper Willamette ceased in 1999. However, there is still a substantial hatchery program for nonnative summer steelhead. In recent years, returning summer steelhead have outnumbered the native winter-run steelhead, which raises genetic and ecological concerns (Figure 106). Total steelhead releases in the basin are shown in Figure 107.

Upper Willamette River Steelhead: Updated Risk Summary

Since the last BRT status update, upper Willamette steelhead initially increased in abundance but subsequently declined, 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 River Chinook Salmon ESU, but continues to demonstrate the overall low abundance

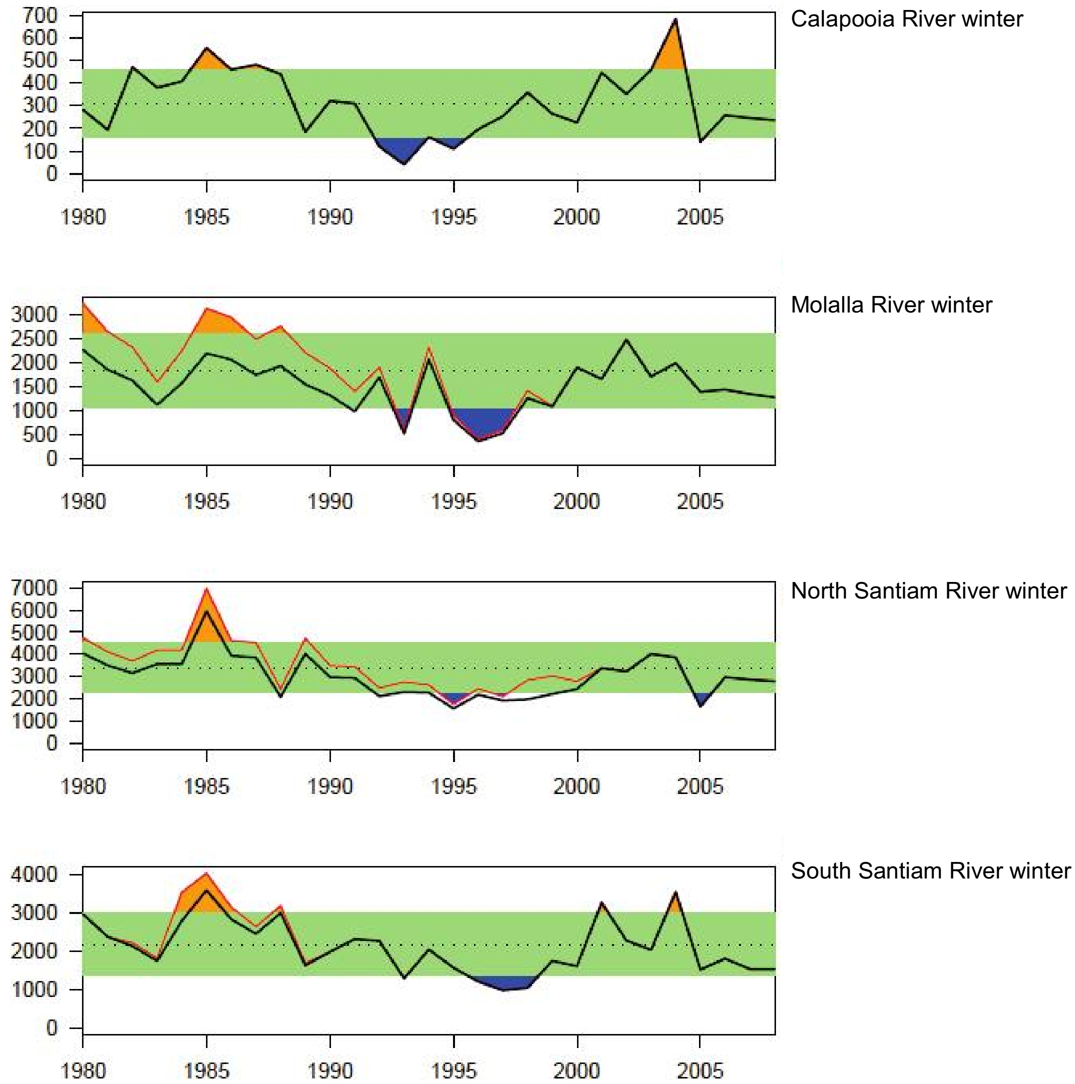

Figure 104. Spawner abundance of upper Willamette steelhead populations by year. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

pattern that was of concern during the last BRT review. The elimination of the winter-run hatchery release in the basin reduces hatchery threats, but nonnative 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.

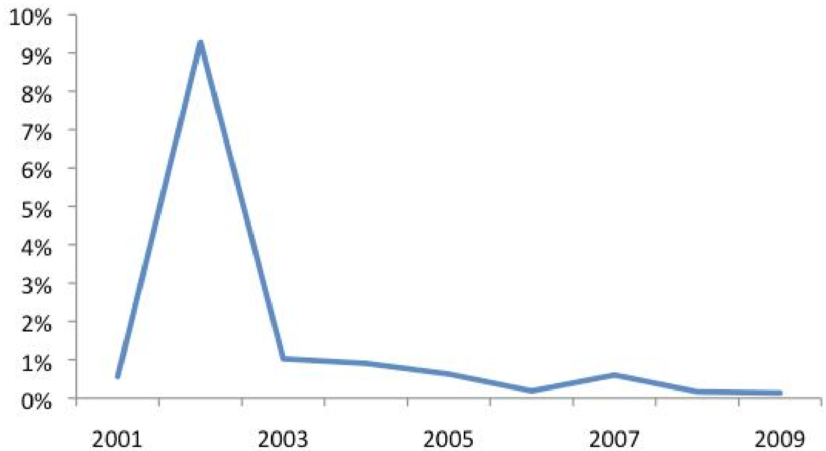

Figure 105. Total exploitation rates (%) by year on natural winter-run steelhead from the Columbia Basin. Winter-run steelhead include the lower Columbia River ESU, upper Willamette River ESU, and portions of the middle Columbia River and Washington coastal ESUs. Data from TAC 2010.

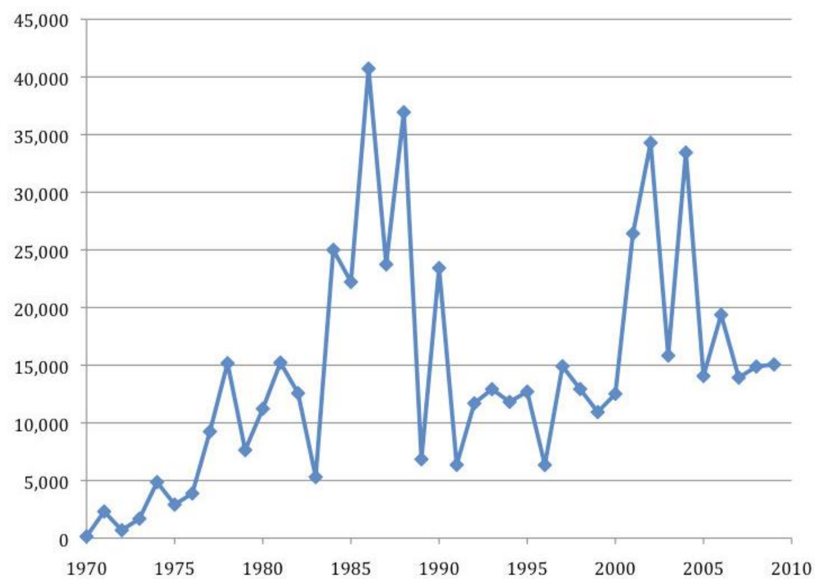

Figure 106. Nonnative, summer-run steelhead count of spawners by year at Willamette Falls. Data from ODFW online Willamette Falls count database.

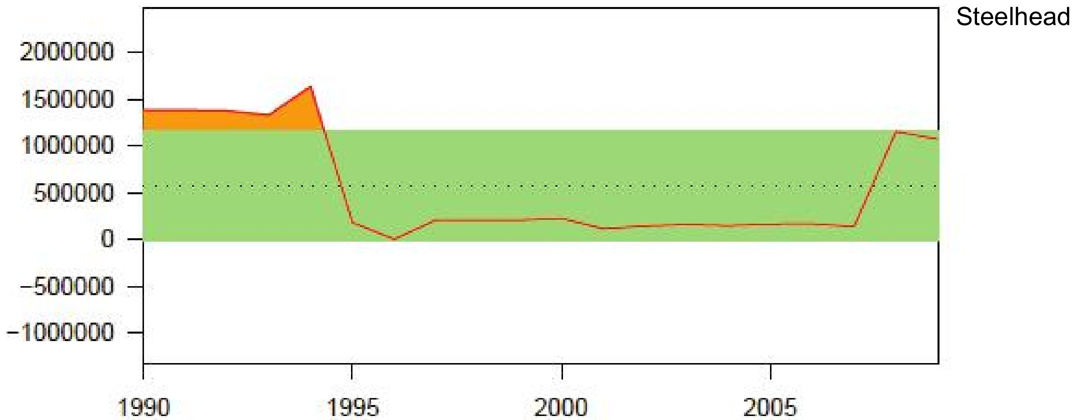

Figure 107. Steelhead hatchery releases by year in the upper Willamette Basin. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively.

Puget Sound/Lake Ozette Domain Status Summaries

Puget Sound Chinook Salmon ESU

The ESU was identified and assessed as part of the Chinook salmon coast-wide 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 24 March 1999 and the threatened status was reaffirmed on 28 June 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, rivers and streams flowing into Hood Canal, south sound, north sound, and the Strait of Georgia in Washington, as well as 26 artificial propagation programs: the Kendal Creek Hatchery, Marblemount Hatchery (fall and 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, and Elwha Channel Hatchery Chinook programs.

Previous Status Reviews and Recovery Documents

The 2005 review (Good et al. 2005) determined that the natural spawning escapement for Puget Sound Chinook salmon populations were improved relative to the previous status review in 1998 (Myers et al. 1998). Also, overall trends in natural spawning escapements for Puget Sound Chinook salmon populations estimated in 2005 remained similar to that presented in the 1998 status review.

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
ESU average productivity	3.2
ESU total recruit and spawner levels given no harvest	289,000
ESU total spanner level given MSY harvest levels	68,180
Population productivity and abundance levels	See Table 48
Number of populations per region with low extinction risk for ESU to be viable	2–4

AR054616

The Puget Sound TRT developed its viability planning ranges in 2002 (PSTRT 2002) and finalized its population identification for this ESU in 2006 (Ruckelshaus et al. 2006). A recovery plan was submitted by Shared Strategy and adopted by NMFS in January 2007. Recovery criteria involve attaining productivity and abundance levels as described by a Beverton-Holt spawner-recruit function, and attaining spatial structure and diversity as described in the TRT viability document (PSTRT 2002) and Shared Strategy (2007).

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 five 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 its viability report, while the Puget Sound Recovery Plan gave abundances for 20[17] of the populations (Table 48). For this status review, values for the missing populations are extrapolated based on a linear relationship between basin size and the replacement point on the spawner-recruit function under historical conditions and properly functioning conditions over the populations with estimates. Productivity for populations without estimates was assumed to be equal to the average productivity of the remaining populations (recruits per spawner [R/S] = 3.2). The high productivity planning target for abundance was then calculated from the spawner-recruit function, defined by the replacement value and the maximum sustained yield (MSY) productivity. These should be considered to be tentative estimates until population specific estimates are available. In Table 48, 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.

New Data and Updated Analyses

This status report incorporates population data through 2009. Spawning abundance data were obtained from WDFW and the Puget Sound tribes as a 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 were obtained from the annual postseason harvest reports provided by WDFW and the Puget Sound tribes. Age data are not available for all years. Missing age distribution data were 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 review focuses on data starting in 1985, when we have escapement data from all populations in the ESU. In addition to including additional recent years of spawning data

[17] Although estimates were given for 20 of the populations, the numbers given for the Elwha River seem to be in error, as there has not been an EDT analysis done for this watershed (waiting for dams to be removed) and the numbers given for planning targets do not describe a Beverton-Holt spawner-recruit function.

AR054617

Table 48. Extant populations of Chinook salmon in the Puget Sound Chinook ESU, grouped by geographic region, their minimum viability spawning abundance and abundance at equilibrium or replacement, and spawning A/P at 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, those in italics are derived as explained in the text). The TRT minimum viability abundance was the equilibrium abundance or 17,000, whichever was less.

Region and population	TRT minimum viability abundance	Under properly functioning conditions (PFC) Equilibrium abundance	Spawners at MSY	Productivity 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[a]	*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[b]	*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

[a] The Sammamish population was referred to as North Lake Washington population in the TRT viability report.
[b] The mid Hood Canal population consists of spawning aggregations from Dosewallips, Duckabush, and Hamma Hamma rivers. Only the Dosewallips was listed in the TRT viability report.

compared to the 2005 status review, the report also incorporates updates and 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

AR054618

analysis of CWT hatchery indicator stocks. Estimates were available through the 2006 broodyear age-2 catch (catch in 2008). To complete estimates for broodyears 2004 to 2006, the average age-specific rate for the previous 3 years of available data was used. Productivity was estimated using cohort run reconstruction as described by Sands (2009).

Abundance of natural spawners and natural-origin preharvest recruits

During 1985−2009, for which we have escapement data for all populations in the ESU, ESU natural spawning abundance was fairly stable from 1985 to 1990, declined during 1991−1999, increased from 2000 to 2004, and then decreased again from 2004 to 2009, with 2009 back down at the 1990s levels (Figure 108). The highest abundances were in 2002, 2004, and 2006. The year 2004 had the highest abundance, with 45,000 natural-origin spawners and 60,000 total (natural origin + hatchery) natural spawners. Hatchery fish contributed from 15 to 40% of the natural spawners for the ESU as a whole during these years.

Average escapements (geometric mean) for 5-year intervals are given in Table 49 along with estimates of trends[18] over the intervals for natural escapement (hatchery + natural origin) and for natural-origin only escapement. Annual escapement data, both total natural spawners and natural-origin spawners, are provided in Table 50. 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 nearly 10,345 fish (in the upper Skagit population) (Table 49, Figure 109 through Figure 114). Most populations contain natural spawners numbering in the high hundreds (median recent natural escapement = 909). There is no obvious trend for the total ESU escapements; trends for individual populations are variable.

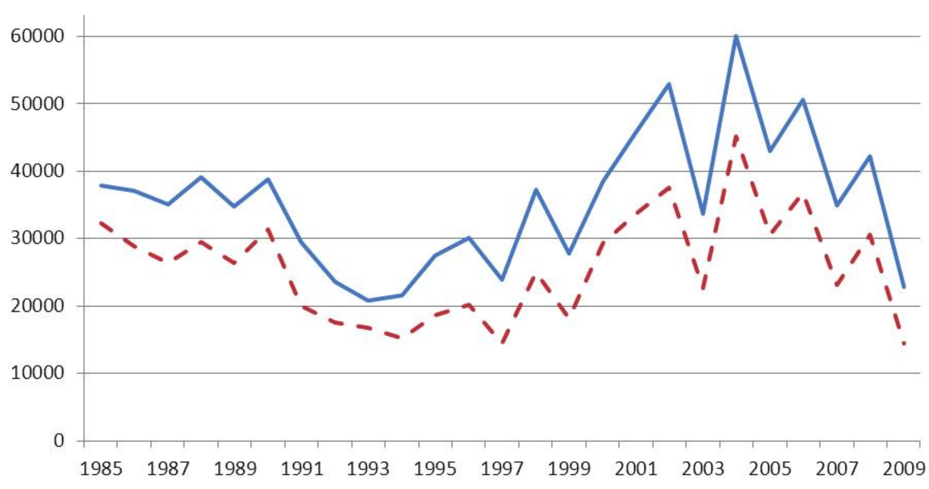

Figure 108. Total natural spawners (natural and and hatchery origin combined) (y-axis) by year for the Puget Sound Chinook Salmon ESU (solid line) and the natural-origin spawners (dashed line).

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

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Table 49. The abundance trend. Five-year geometric means are calculated 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.

Year range	Natural escapement			Natural-origin escapement		
	ESU	**Population range**	**Population median**	**ESU**	**Population range**	**Population median**
1985–1989	36,750	46–8,276	770	28,601	30–7,965	725
1990–1994	26,094	101–5,511	395	19,511	20–5,304	381
1995–1999	28,981	104–6,792	479	19,011	18–5,982	380
2000–2004	45,214	202–12,109	999	32,794	71–11,678	430
2005–2009	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

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

Short-term and long-term trends and growth rates (lambda) are provided in Table 51. Estimates of lambda are provided for two alternative assumptions: that hatchery fish have zero reproductive success when spawning naturally or that their spawning success is equivalent to natural-origin fish. For the Puget Sound Chinook salmon populations, estimates of natural population productivity are quite sensitive to the alternative assumptions about hatchery fish reproductive success. It would therefore be useful to obtain estimates of hatchery fish reproductive success on the spawning grounds.

Productivity

Productivity was estimated based on cohort run reconstruction using the Puget Sound TRT A/P Microsoft Excel files (Sands 2009). Median R/S and spawners per spawner for each population over the 5-year intervals are summarized in Table 52 and provided in detail in Table 53. Recruits are estimated for all broodyears through 2006 (Figure 115). Because CWT data are only available through 2009, estimates of 2005 age-5 returns and 2006 age-4 and age-5 returns were made using forecast methods as described above. The estimates for these 2 years are therefore not as precise as for earlier years and will be updated as data become available.

While natural-origin spawning escapements have remained fairly constant during this time period (1985−2009), returns and productivity have continued to decline (Figure 115, Table 52). Median R/S for the last 5-year period (from broodyear 2002−2006) was the lowest over any of the 5-year intervals.

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Table 50. Puget Sound Chinook average natural (natural origin and hatchery) and natural-origin (NOR) only spawners and percent hatchery contributions for 5-year intervals. Spawning abundance averages are geometric means and hatchery contribution averages are arithmetic.

	Return year														
	1985–1989			1990–1994			1995–1999			2000–2004			2005–2009		
Population	**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	2,442	1,440	4	1,385	1,006	4	968	2,715	3	2,626	2,163	4	2,067
Upper Skagit	8,276	4	8,627	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	2,967	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	3,569	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	1,094	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	1,226	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 natural spawners	2,248	42	1,543	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

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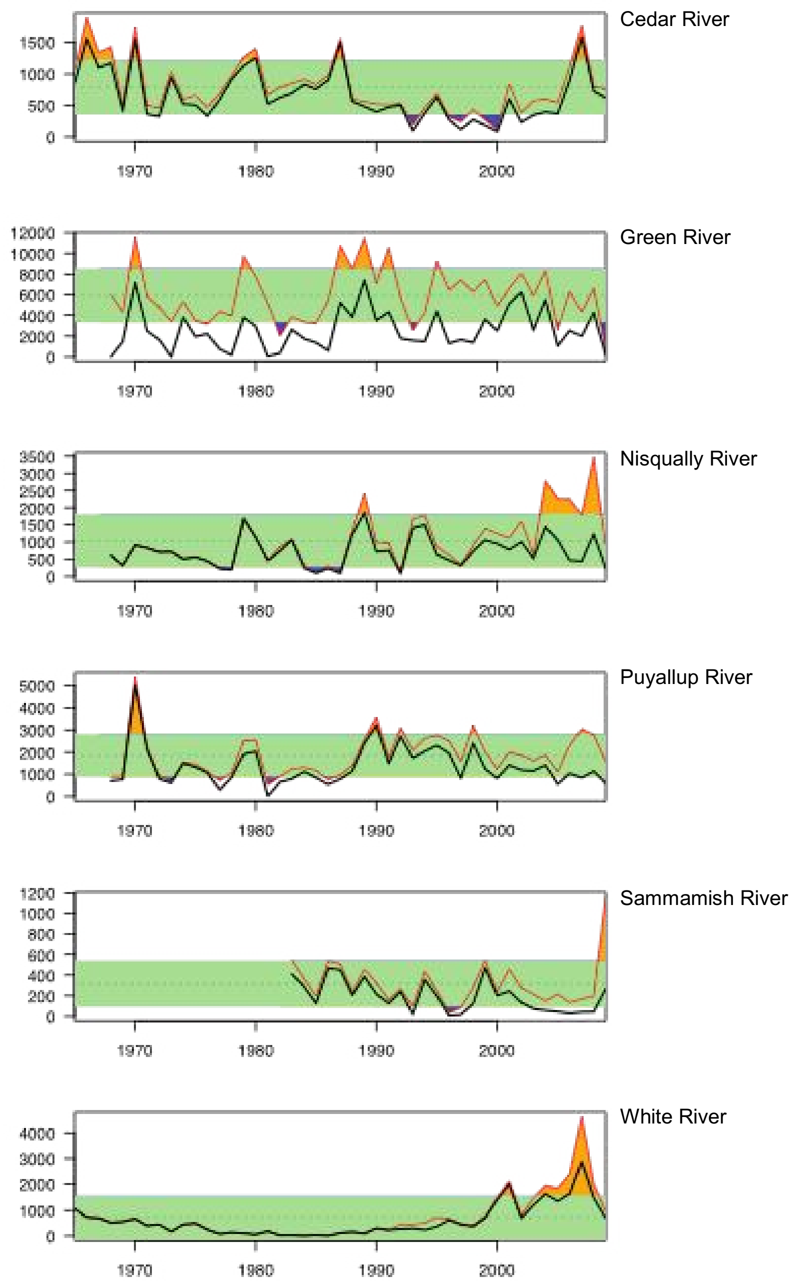

Figure 109. Spawning abundance by year for the central/south MPG in the Puget Sound Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

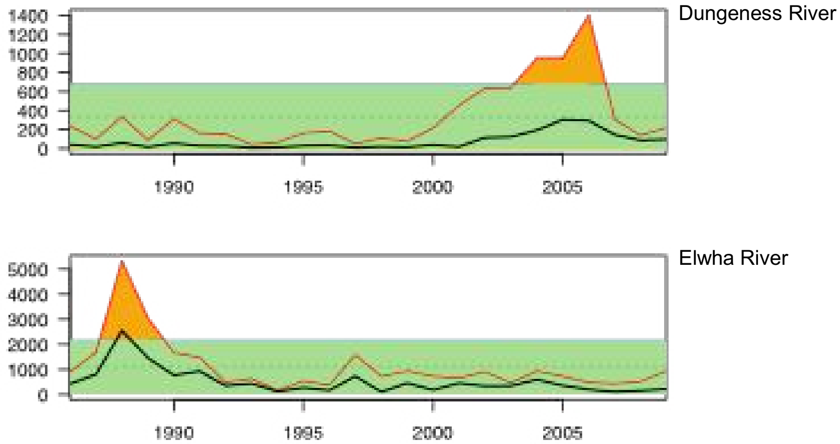

Figure 110. Spawning abundance by year for the northwest or Strait of Juan de Fuca MPG in the Puget Sound Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

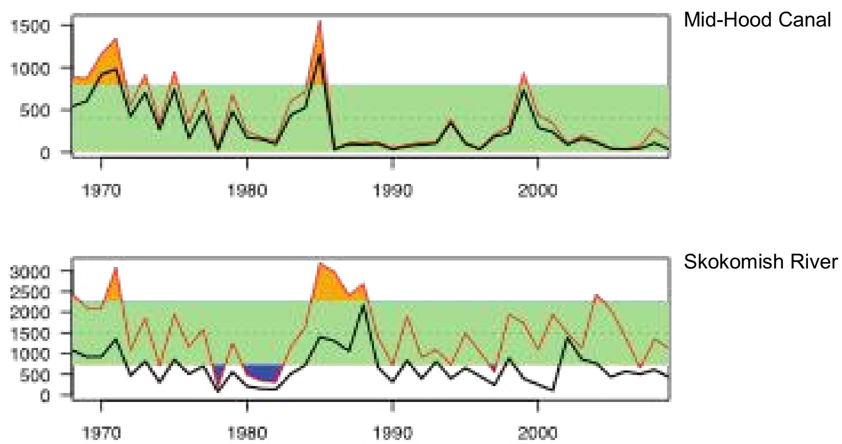

Figure 111. Spawning abundance by year for the central west or Hood Canal MPG in the Puget Sound Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

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 was used to determine changes in distributions of abundance among the 22 populations and among the 5 geographic regions. In particular, the Shannon H diversity index was used to measure diversity of spatial distribution and the results are summarized over 5-year intervals in Table 54. For distribution among populations and

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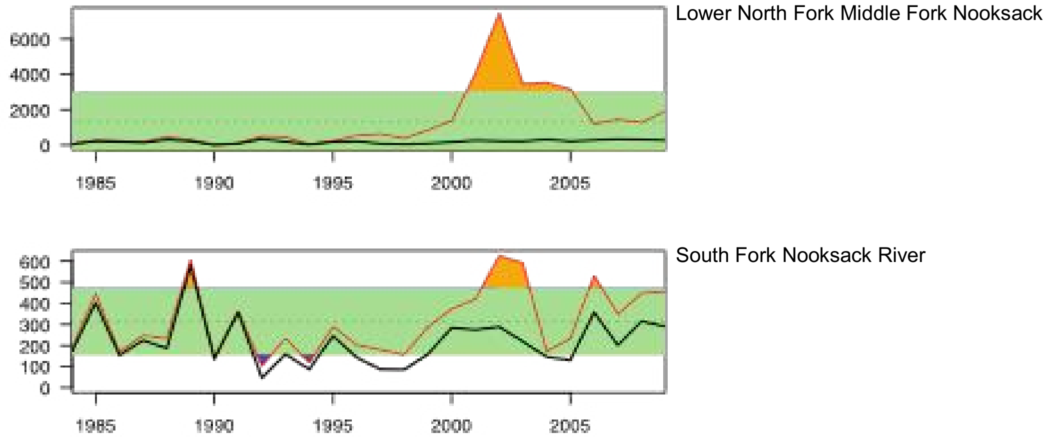

Figure 112. Spawning abundance by year for the northeast or Strait of Georgia MPG in the Puget Sound Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

regions, the diversity is declining, due primarily to the increased abundance of returns to the Whidbey region.

Population viability

The Puget Sound TRT provided planning range spawner abundance levels for 16 of the 22 populations in its viability report (PSTRT 2002). The lower end of the range was the minimum of a level of 17,000 spawners derived from a population viability analysis that leads to a 95% chance of persistence over 100 years and a population-specific estimate of spawner capacity derived from a Beverton-Holt spawner-recruit function assuming properly functioning habitat.[19] This later estimate was calculated by the state and tribal comanagers for each watershed using the Ecosystem Diagnosis and Treatment (EDT) model. The EDT model was also run under assumed historical conditions and this provided an upper end of the TRT planning range (Table 48). EDT runs also produce estimates for the MSY spawning level and productivity (R/S), as reported in the final Puget Sound Salmon Recovery Plan (Shared Strategy 2007).

EDT estimated spawner-recruit functions were based on survival patterns experienced in the early 1990s. 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-1980s. Recovery spawner-recruit curves have been constructed for each population with observed recruit per spawner points superimposed on the same graphs (Figure 116 through Figure 121).

[19] PFC for habitat as described in NMFS 4(d) rule. Minimum thresholds for the PFC for freshwater habitat were compiled in the Matrix of Pathways and Indicators (NMFS 1996) for a number of key indicators, including water temperature, streambed sediments, chemical contaminants, large woody debris, and hydrology. PFC guidance for estuarine and nearshore was not yet available for these analyses; estuarine and nearshore habitats were set at historical conditions for these assessments.

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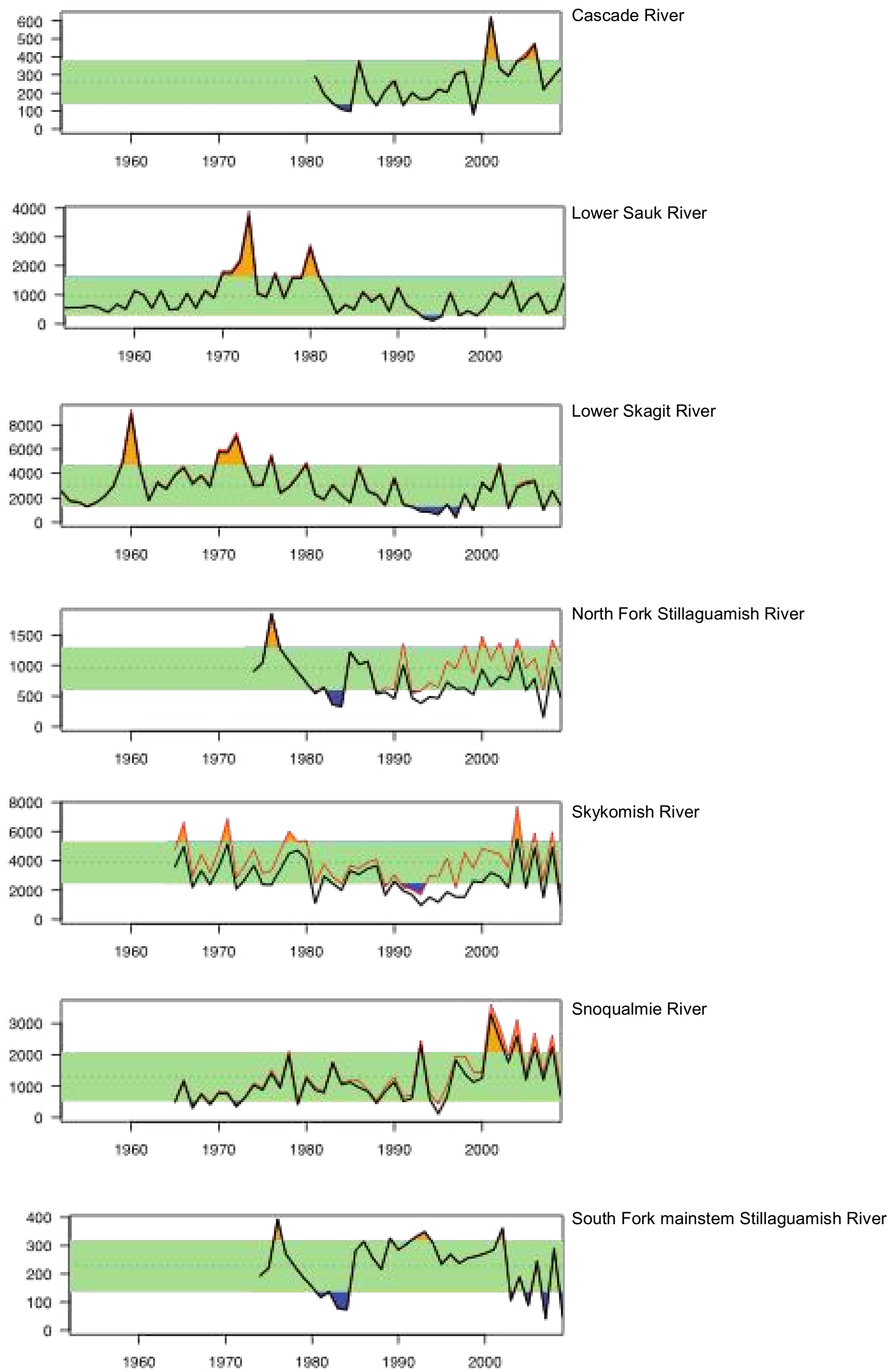

Figure 113. Spawning abundance by year for the central east or Whidbey Basin MPG in the Puget Sound Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

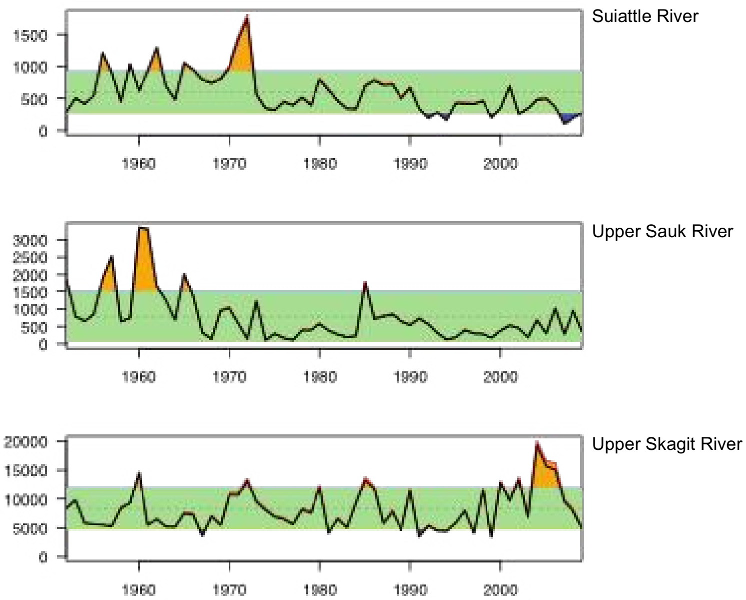

Figure 114. Spawning abundance by year for the central east or Whidbey Basin MPG in the Puget Sound Chinook Salmon ESU. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

Harvest expressed as adult equivalent exploitation rate

Puget Sound Chinook salmon are harvested in Pacific Ocean fisheries, in Puget Sound fisheries, and in terminal fisheries within rivers. They generally migrate to the north as juveniles, so nearly all ocean fishery impacts occur off the coasts of Canada and Alaska, where they are managed according to the Pacific Salmon Treaty. Within Puget Sound, fisheries are managed by the state and tribal comanagers. 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.

Cohort exploitation rates, expressed as the adult equivalent exploitation rate (AEQ ER), were estimated separately for each population based on harvest of hatchery indicator stocks and using population-specific age estimates. ESU-level AEQ ER summary data are provided in Table 55 and population specific data are found in Table 56. Estimated trends in exploitation rates from broodyears 1982−2006 decline when measured over the five 5-year intervals. Exploitation rates were lowest for the 1992−1996 broodyears and have been increasing over the past 10 years for both ocean and terminal fisheries.

Exploitation rate estimates were based on cohort analysis using harvest rate estimates of hatchery indicator stocks from the Chinook Technical Committee (CTC) of the PSC and applied using the appropriate indicator stock or stocks to each natural population.

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Table 51. Short-term and long-term population trend and growth rate estimates for the Puget Sound Chinook Salmon ESU populations.

Region and population	Years	Trend natural spawner w/CI	Hatchery fish success = 0 Lambda w/CI	*P* >1	Hatchery fish success = 1 Lambda w/CI	*P* > 1
Strait of Georgia region						
Lower North Fork-Middle Fork	1995–2009	1.092 (1.023–1.165)	1.082 (0.622–1.884)	0.84	0.607 (0.232–1.589)	0.05
Nooksack early run	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	1.0006 (0.976–1.038)	1.009 (0.883–1.154)	0.57	0.927 (0.825–1.041)	0.07
Whidbey 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

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Table 51 continued. Short-term and long-term population trend and growth rate estimates for the Puget Sound Chinook Salmon ESU populations.

Region and population	Years	Trend natural spawner w/CI	Hatchery fish success = 0 Lambda w/CI	*P* >1	Hatchery fish success = 1 Lambda w/CI	*P* > 1
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

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Table 51 continued. Short-term and long-term population trend and growth rate estimates for the Puget Sound Chinook Salmon ESU populations.

Region and population	Years	Trend natural spawner w/CI	Hatchery fish success = 0 Lambda w/CI	*P* >1	Hatchery fish success = 1 Lambda w/CI	*P* > 1
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 (0.936–1.108)	0.995 (0.408–2.424)	0.48	0.76 (0.345–1.674)	0.07
	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

Table 52. Productivity range and median for the populations for the 5-year ranges.

	Recruits per spawner		Spawners per spawner	
Broodyear	Population range	Population median	Population range	Population 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	0.3–15.0	2.20	0.2–3.4	1.04
1997–2001	0.5–5.2	2.65	0.3–3.0	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

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Table 53. Puget Sound Chinook population average productivity for 5-year intervals measured as spawners per spawner (S/S). Trend over the five intervals is also given.

	Broodyear											
	1982–1986		1987–1991		1992–1996		1997–2001		2002–2006		Trend	
Population	**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 natural 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

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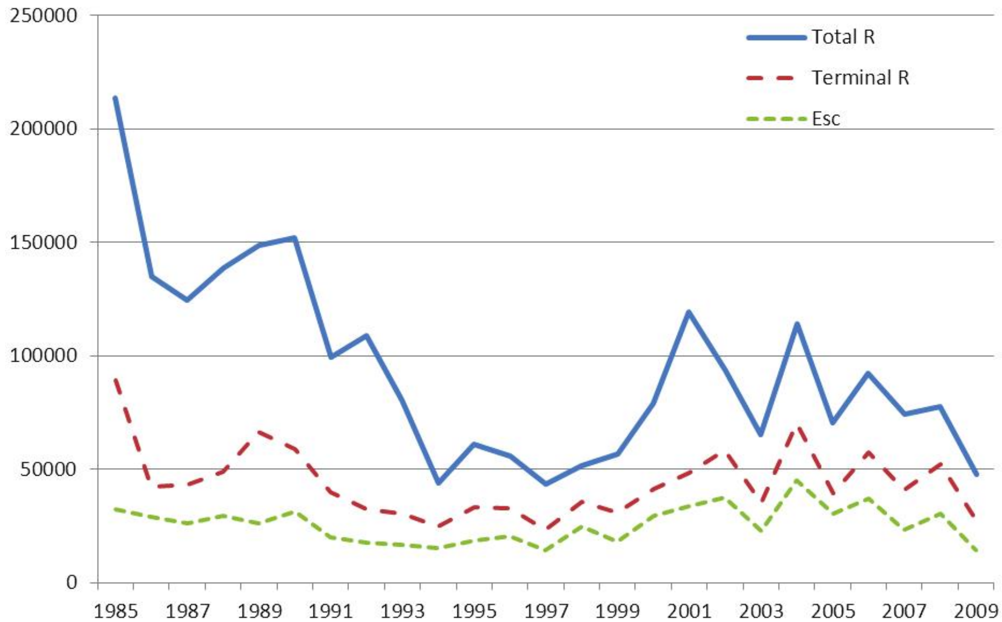

Figure 115. Total natural-origin returns of Chinook salmon to Puget Sound in return years representing total return (prior to any harvest and broodstock take), terminal return (prior to terminal harvest and broodstock take), and natural-origin spawners to the spawning grounds.

Table 54. Diversity and spatial structure of ESU, Shannon diversity index.

5-year ranges	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
2005–2009	2.232	0.768
Trend	–0.041	–0.061

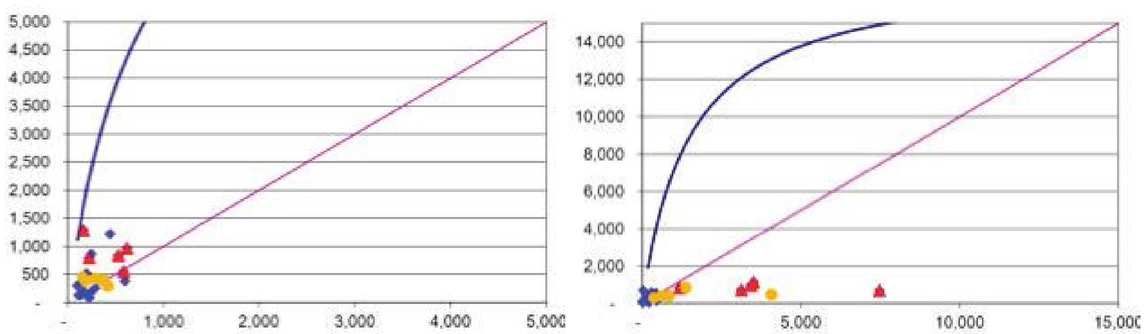
Figure 116. Observed returns (symbols) relative to the estimated recovery spawner (x-axis)–recruit (y-axis) relationship (curved line) for the two populations in the Strait of Georgia region, the South Fork Nooksack (left), and North Fork Nooksack (right). The most recent 5 years are indicated by triangles, the previous 5 years by circles, and remaining years by diamonds. The straight line is replacement (i.e., escapement = recruits).

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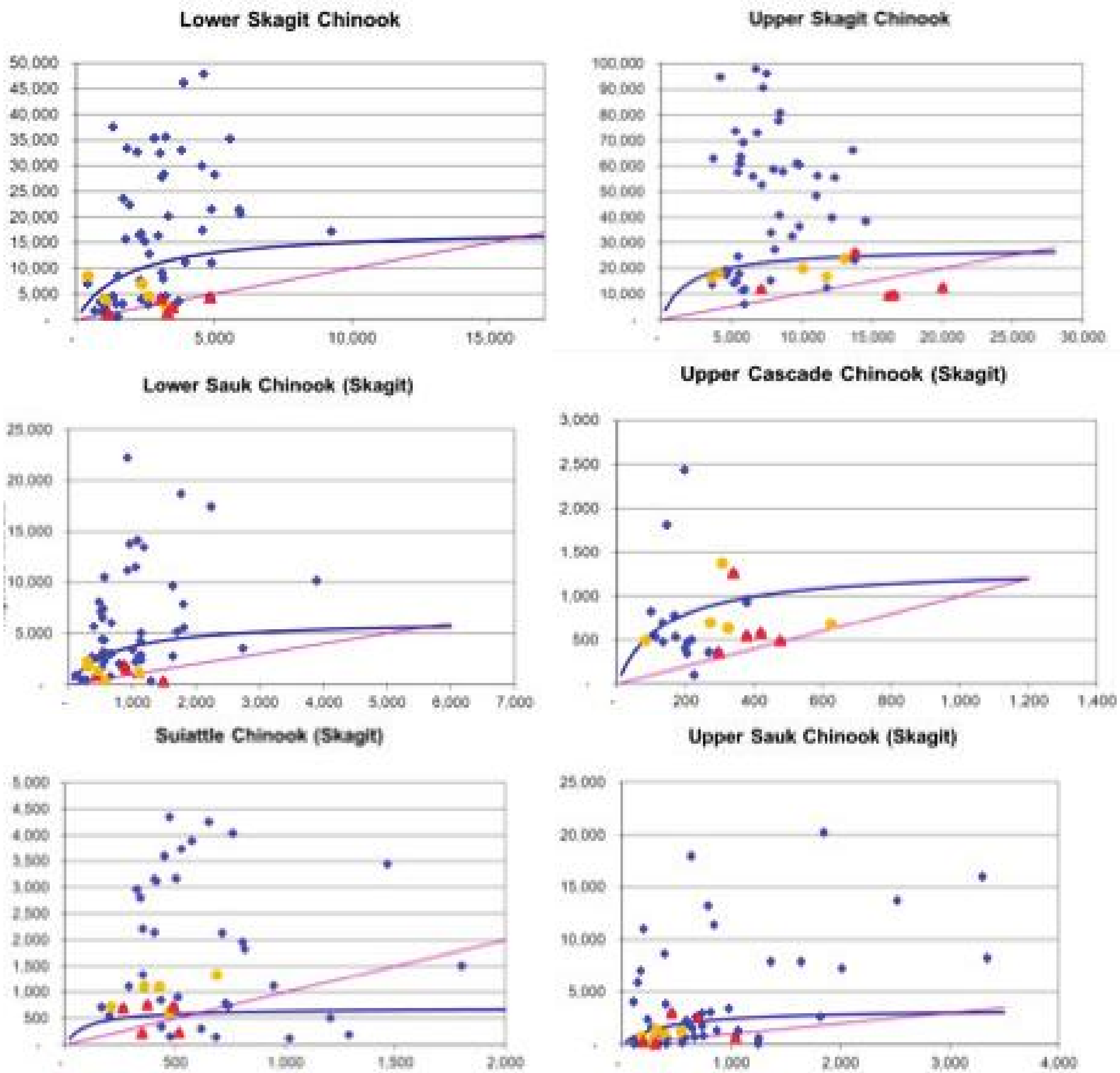

Figure 117. Observed returns (symbols) relative to the estimated recovery spawner (x-axis)–recruit (y-axis) relationship (curved line) for 6 of the 10 populations in the Whidbey Basin region. The top row and left middle graph are the three late-run populations and the right middle graph and bottom row are the three early-run populations in the Skagit River. The most recent 5 years are indicated by triangles, the previous 5 years by circles, and remaining years by diamonds The straight line is replacement (i.e., escapement = recruits). One data point off graph for Upper Sauk (1956 broodyear 1,884 spawners produced 32,337 recruits); nine points off the graph for Suiattle, all occurring prior to 1970.

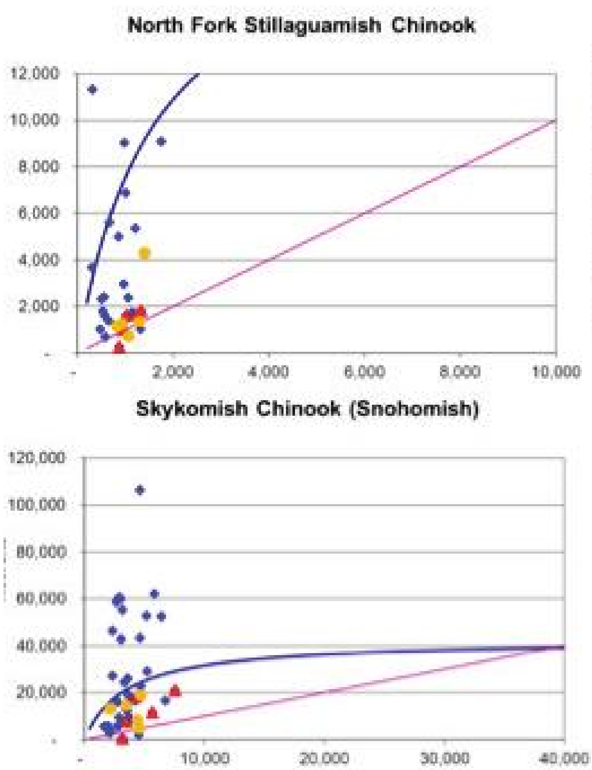

Figure 118. Observed returns (symbols) relative to the estimated recovery spawner (x-axis)–recruit (y-axis) relationship (curved line) for 4 of the 10 populations in the Whidbey Basin region. The most recent 5 years are indicated by triangles, the previous 5 years by circles, and remaining years by diamonds. The straight line is replacement (i.e., escapement = recruits).

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 122 and Figure 123 for total and terminal exploitation rates, respectively. Terminal fisheries are defined as those fishing on the mature portion of the population returning to spawn that year and include net fisheries in Puget Sound as well as in-river fisheries.

Populations from all regions within Puget Sound had a similar pattern of declining exploitation rates in the 1990s and increasing exploitation rates since 2000. 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 contributed a substantial proportion of the total exploitation rate in the late 1980s and early 1990s. The proportion was lowest during 1995−1999 and has been increasing in all areas since then.

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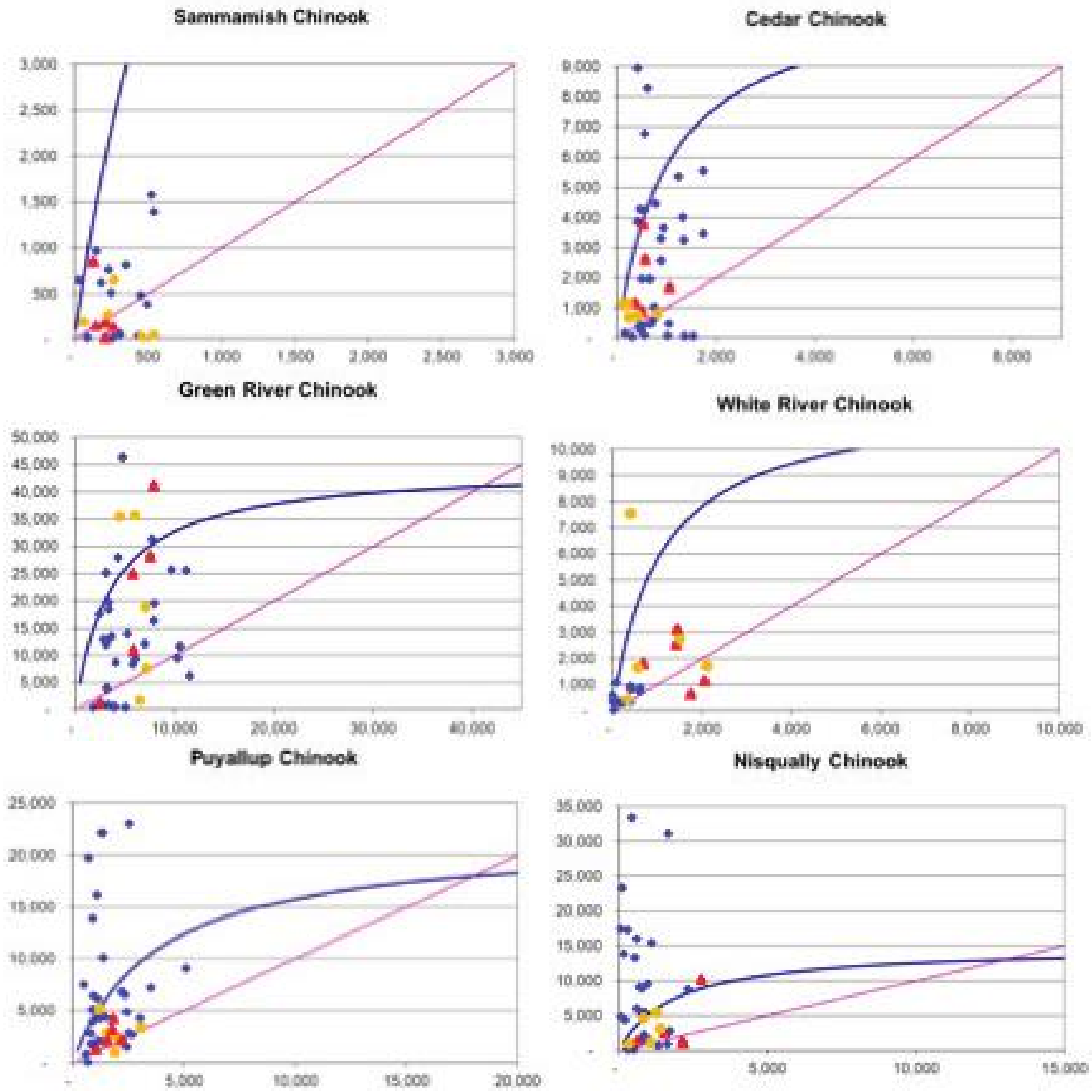

Figure 119. Observed returns (symbols) relative to the estimated recovery spawner (x-axis)–recruit (y-axis) relationship (curved line) for the six populations in the central/south sound region. The most recent 5 years are indicated by triangles, the previous 5 years by circles, and remaining years by diamonds. The straight line is replacement (i.e., escapement = recruits).

Hatchery releases

Hatchery releases of all salmon species except sockeye and steelhead have been trending down in Puget Sound since 1990 (Figure 124).

Puget Sound Chinook Salmon: Updated Risk Summary

All Puget Sound Chinook salmon populations are well below the TRT planning ranges 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

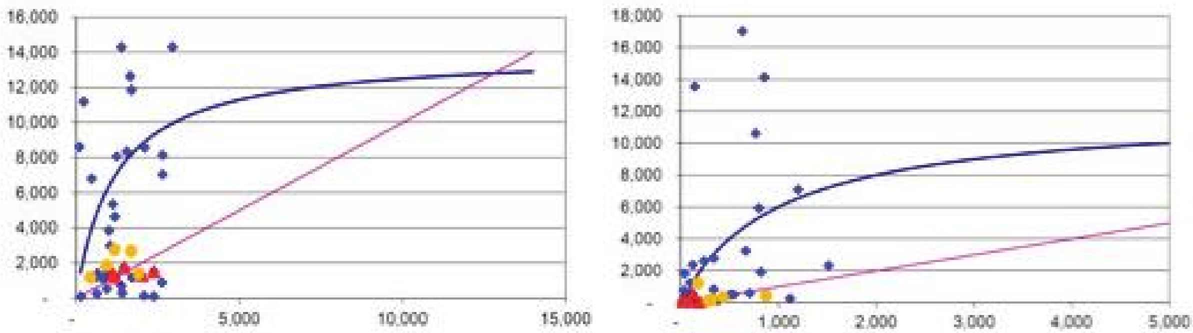

Figure 120. Observed returns (symbols) relative to the estimated recovery spawner (x-axis)–recruit (y-axis) relationship (curved line) for the two Chinook salmon populations in the Hood Canal region, the Skokomish (left), and the mid Hood Canal (right). The most recent 5 years are indicated by triangles, the previous 5 years by circles, and remaining years by diamonds. The straight line is replacement (i.e., escapement = recruits).

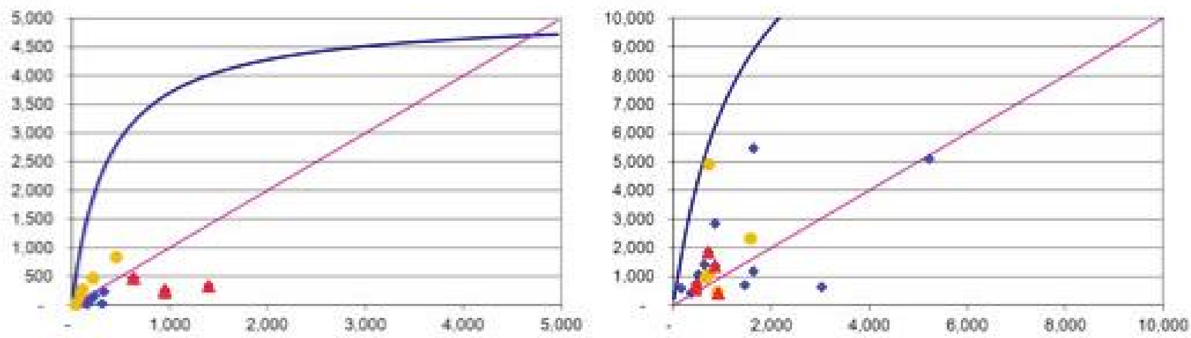

Figure 121. Observed returns (symbols) relative to the estimated recovery spawner (x-axis)–recruit (y-axis) relationship (curved line) for the two populations in the Strait of Juan de Fuca region, the Dungeness (left), and the Elwha (right). The most recent 5 years are indicated by triangles, the previous 5 years by circles, and remaining years by diamonds. The straight line is replacement (i.e., escapement = recruits).

Table 55. Broodyear AEQ ER ranges and medians for 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.

	Mixed-maturity fishery		**Mature fishery**		**Total AEQ ER**	
Broodyear	**Population range**	**Population median**	**Population range**	**Population median**	**Population range**	**Population median**
1982–1986	0.36–0.72	0.58	0.02–0.39	0.15	0.44–0.90	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	0.00–0.32	0.04	0.23–0.80	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

Table 56. Puget Sound Chinook Population average AEQ ERs for 5-year intervals for both mixed-maturity catch fisheries (mix) and mature catch fisheries (mat). Trends calculated over the 5-year intervals are also given.

	Broodyear												
	1982–1986		1987–1991		1992–1996		1997–2001		2002–2006		Trend		
Population	**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 natural 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

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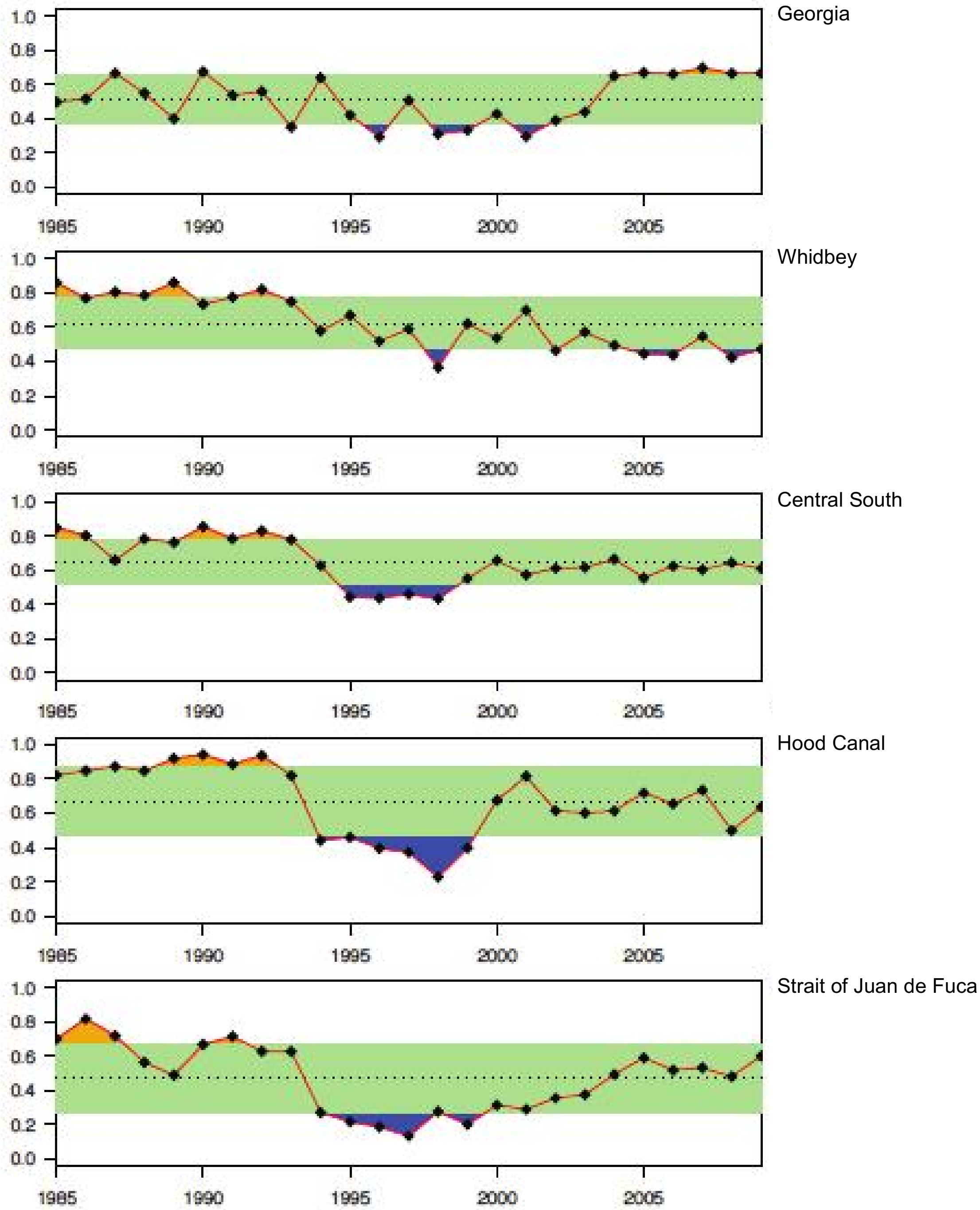

Figure 122. Trends in Puget Sound salmon total exploitation rates (proportion of total return taken by all fisheries in return year) by year for each major population group. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively.

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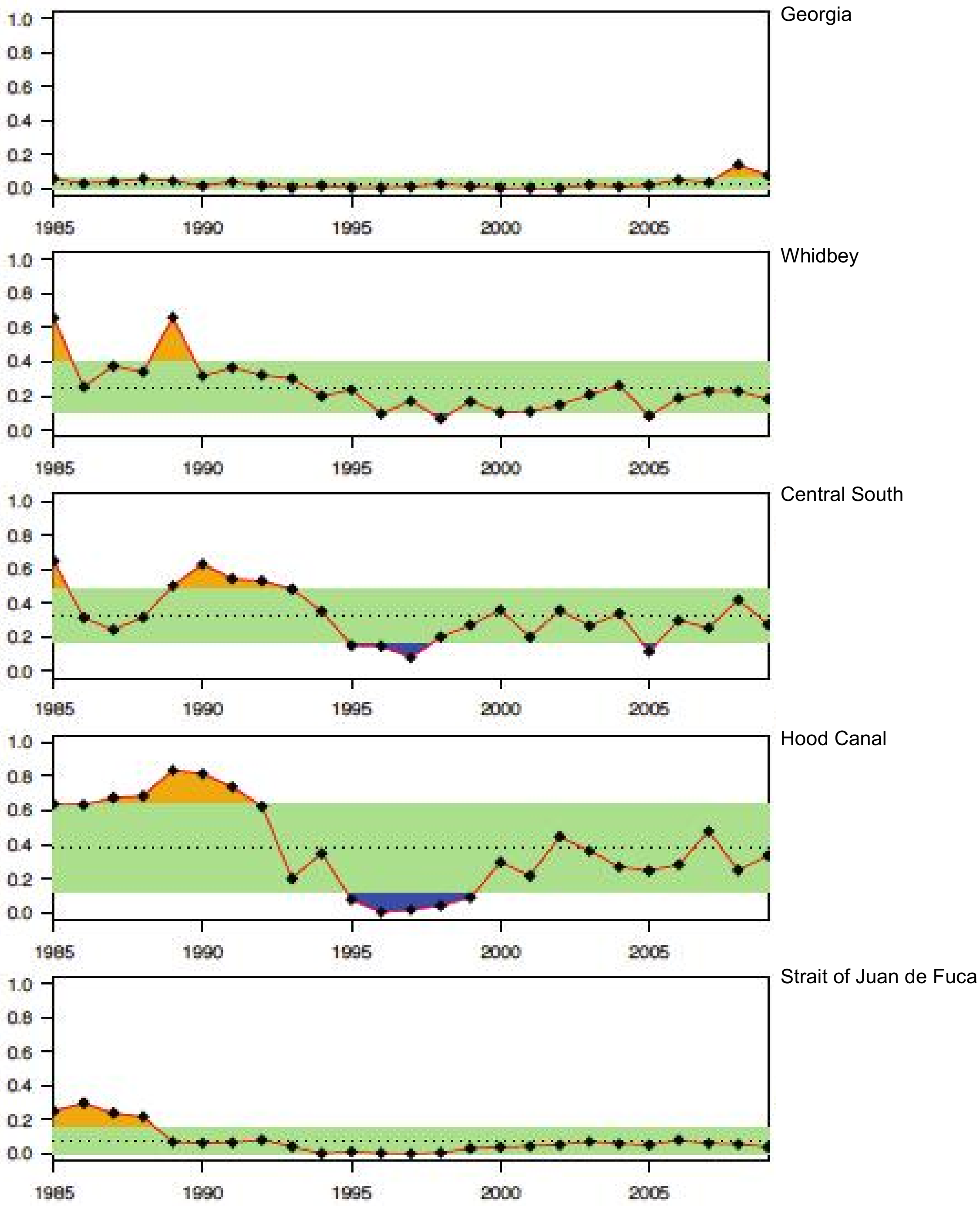

Figure 123. Trends in Puget Sound Chinook salmon terminal harvest rates (proportion of terminal run taken by fisheries) by year for each MPG. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively.

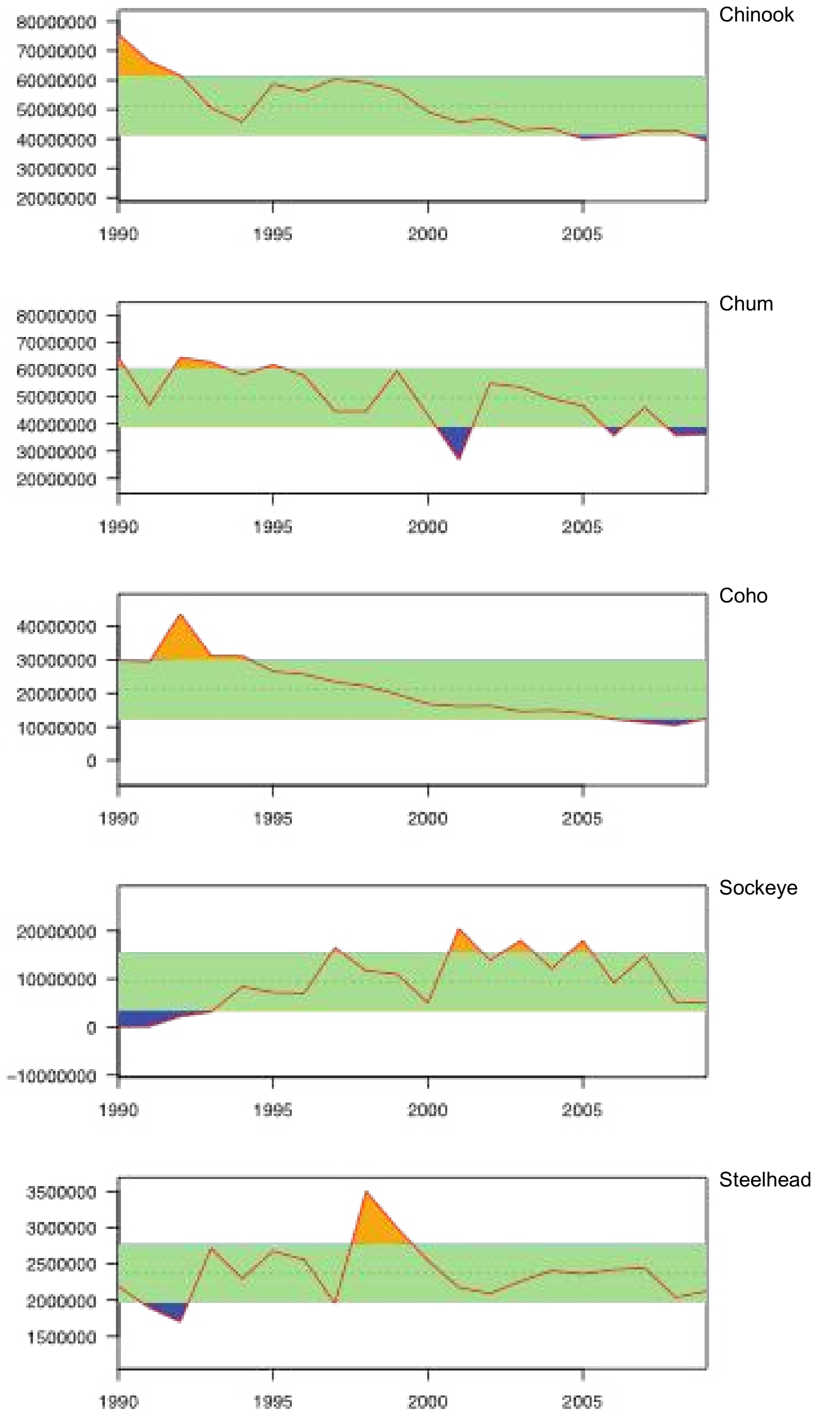

Figure 124. Puget Sound hatchery releases by year. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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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 Salmon Recovery Plan are expected to take years or decades to be implemented and to produce significant improvements in natural population attributes; population trends are consistent with these expectations. Overall, 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.

Hood Canal Summer-run Chum Salmon ESU

Hood Canal summer-run chum salmon were listed as threatened on 25 March 1999; status was reaffirmed 28 June 2005. The ESU includes all naturally spawned populations of summer-run chum in Hood Canal and its tributaries, populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington, and eight artificial propagation programs: 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 programs.

Previous Status Reviews and Recovery Documents

At the time of the last status review (Good et al. 2005), the Puget Sound TRT had not yet finalized its 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 24 May 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	Not available
Historical spawning aggregations	18
Recent peak run size abundance	88,000 (2004)
Recent peak spawning abundance	66,000 NOR, 79,000 total (2004)
Extant populations	2 (1 with 4 extant spawning aggregations and 1 with 10 extant spawning aggregations; some of these are recently reintroduced)
Viable abundance and productivity	Defined by spawner-recruit functions
Viable populations needed for EST	2 with high diversity among spawning aggregations within each population

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ESU Structure

The Puget Sound TRT designated two independent populations for Hood Canal summer chum salmon, one that includes the spawning aggregations from rivers and creeks draining into the Strait of Juan de Fuca and one that includes spawning aggregations within Hood Canal proper (Table 57). Each population consists of several spawning aggregations, and spatial structure and diversity can be measured using a diversity index to measure population distribution among spawning areas.

New Data and Updated Analyses

Escapement data, total natural spawners and hatchery contribution, age distribution of the natural-origin escapement, and hatchery broodstock take are recorded per spawning aggregation, and catch information is available per fishery area from 1971 to 2009 (Sands et al. 2009 and Johnson[20]). Age data from scale samples are available from 1992 to 2009. Each spawning aggregation appears to have its own age distribution, so age distribution for each population is weighted by the relative abundance of the component spawning aggregations. Hatchery

Table 57. Current populations of summer-run chum salmon in the Hood Canal ESU and their associated historical spawning aggregations, updated from Sands et al. (2009). WDFW considers Salmon/Snow one stock and Big and Little Quilcene as one stock.[21] 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, less than 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 River	Extant
Little Quilcene River	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 1990s, 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

[20] T. Johnson, WDFW, Olympia, WA. Pers. commun., 29 October 2010.
[21] See footnote 20.

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contributions to the spawning grounds are estimated to have begun in 1995 with the initiation of several hatchery supplementation programs, and estimates of the proportions of hatchery fish on the spawning grounds were provided by WDFW[22] from 1995 through 2009. Hatchery contribution varies greatly among the spawning aggregations within each population. 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 state and tribal comanagers (WDFW and PNPTT 2003). Cohort run reconstruction was then performed for each population to estimate broodyear-specific R/S as described by Sands (2009).

Relative abundances of subpopulations within each population were used to estimate the Shannon diversity index, which was used as an indicator of spatial structure and diversity.

Abundance

Estimates of spawning abundance are available from 1968 for the Hood Canal population and from 1971 for the Strait of Juan de Fuca population (Figure 125). Escapement estimates prior to 1974 are less precise than those afterwards (WDFW and PNPTC 2000) due to varying sampling procedures.

Average escapements (geometric means) for 5-year intervals are provided in Table 58, which also includes estimates of trends over the intervals for all natural spawners (natural-origin and hatchery-origin) and natural-origin only spawners. In both populations, spawning abundance was relatively high in the 1970s, lowest during 1985−1999, and higher again for the most recent 10 years. The overall trend in spawning abundance was generally stable (close to one) for the Hood Canal population (for all spawners and for natural-origin spawners) and for the Strait of Juan de Fuca population (all spawners). Strait of Juan de Fuca natural-origin spawners have a significant positive trend (1.14).

Short-term and long-term trends and annual population growth rates (lambda) are provided in Table 59. Trends were estimated under two alternative assumptions about the reproductive success of naturally spawning hatchery fish: hatchery fish were assumed to have zero reproductive success or they were assumed to have the same degree of reproductive success as natural-origin spawners. The only positive abundance trend is the short-term trend for the Strait of Juan de Fuca population.

Productivity

Five-year averages of R/S are provided in Table 60. Annual estimates are provided in Table 61 and Table 62. Productivity in the last 5-year period has been low compared to the period from 1992 to 2001.

Spatial structure and diversity

Variance in spatial distribution was measured using the Shannon diversity index (Table 63).

[22] See footnote 20.

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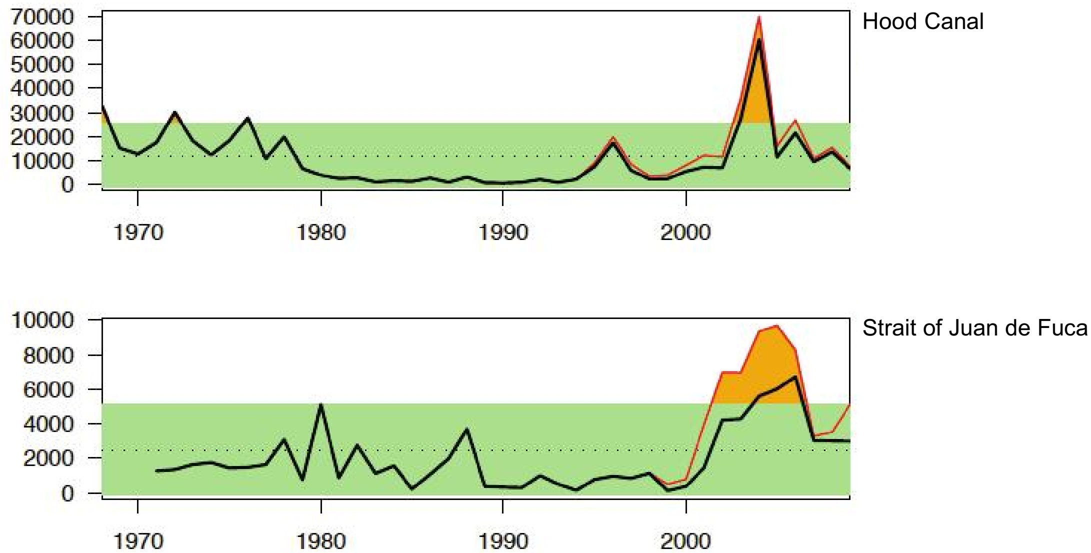

Figure 125. Spawning abundance of summer-run chum salmon by year. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

Table 58. Five geometric means of all spawners and natural-origin spawners only for the two Hood Canal ESU summer-run chum salmon populations. Trend over the 5-year intervals is also given.

	All spawners	Natural-origin spawners
Strait of Juan de Fuca population		
1971–1974	1,502	1,502
1975–1979	1,528	1,528
1980–1984	1,861	1,861
1985–1989	936	936
1990–1994	386	386
1995–1999	822	629
2000–2004	4,279	2,254
2005–2009	5,433	4,057
Trend	1.14	1.06
Hood Canal population		
1971–1974	18,473	18,473
1975–1979	14,757	14,757
1980–1984	1,973	1,973
1985–1989	1,306	1,306
1990–1994	979	979
1995–1999	7,224	5,170
2000–2004	19,407	13,425
2005–2009	13,903	11,513
Trend	1.04	0.99

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Table 59. Short-term and long-term population trend and growth rate estimates for the Hood Canal Summer-run Chum Salmon ESU populations.

		Trend in natural spawners	Lambda hatchery fish success = 0		Lambda hatchery fish success = 1	
Population	**Year**	**Estimate (CI)**	**Estimate (CI)**	***P* > 1**	**Estimate (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
Strait of 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

Table 60. Five-year arithmetic mean of R/S for the populations and ESU.

Broodyear	Strait	Canal	ESU
1971–1976	1.19	3.64	3.45
1977–1981	2.44	2.66	2.33
1982–1986	3.98	9.18	6.20
1987–1991	1.27	7.05	4.70
1992–1996	2.63	14.37	9.54
1997–2001	4.23	10.06	9.41
2002–2006	0.55	2.02	1.49
Trend	0.01	0.54	0.41

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 5 years have the highest average value for both populations. This is partly the result of adding a recently reintroduced spawning aggregation in the Strait of Juan de Fuca population and two reintroduced spawning aggregations in the Hood Canal population. The number and relative abundances of spawning aggregations within each population are shown in Figure 126 and Figure 127.

Viability

The TRT defined the A/P viability criteria for the Hood Canal summer chum salmon populations using the assumption of density independence and replacement growth factor of 1:1 and the assumption of density dependence which provides a series of viable spawner-recruit functions (Sands et al. 2009). Broodyear 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 A/P were also expressed as intrinsic productivity and capacity from Beverton-Holt spawner-recruit

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Table 61. Escapement, catch, and broodstock take data for the Stait of Juan de Fuca summer-run chum salmon population and the estimates of diversity, progeny recruits, and R/S. Recruits and R/S for broodyear 2006 are estimated by forecasting the returns of age-4 fish.

Brood-year	Nat. esc.	% NOR	NOR esc.	Harvest	Broodstock take (NOR)	Diversity	Progeny recruits	Brood-year R/S
1971	1,281	100	1,281	180	0	1.03	1,371	1.07
1972	1,362	100	1,362	159	0	1.09	2,000	1.47
1973	1,648	100	1,648	164	0	1.07	1,490	0.90
1974	1,768	100	1,768	218	0	1.06	2,260	1.28
1975	1,448	100	1,448	299	0	1.02	2,995	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	6,335	3.85
1978	3,080	100	3,080	161	0	1.01	124	0.04
1979	761	100	761	140	0	0.95	4,542	5.97
1980	5,109	100	5,109	465	0	0.93	191	0.04
1981	884	100	884	256	0	1.04	2,055	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	2,066	1.81
1984	1,579	100	1,579	128	0	1.02	2,349	1.49
1985	232	100	232	179	0	0.84	3,827	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	1,739	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	1,346	1.34
1993	521	100	521	71	52	0.61	855	1.64
1994	154	100	154	36	24	0.39	1,395	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	1,087	1.28
1998	1,148	100	1,148	47	121	0.40	1,900	1.65
1999	502	26	131	1	23	0.50	4,628	9.22
2000	801	49	391	2	116	0.46	6,293	7.86
2001	3,955	37	1,473	11	134	0.91	4,594	1.16
2002	6,970	60	4,215	16	88	0.68	7,703	1.11
2003	6,959	62	4,283	36	99	0.68	3,234	0.46
2004	9,341	60	5,597	12	22	1.04	4,475	0.48
2005	9,682	62	6,012	32	24	1.05	2,790	0.29
2006	8,245	81	6,709	29	31	1.06	3,256	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	—	—

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Table 62. Escapement, catch, and broodstock take data for the Hood Canal summer-run chum salmon population and the estimates of diversity, progeny recruits, and R/S. Recruits and R/S for broodyear 2006 are estimated by forecasting the returns of age-4 fish.

Year	Nat. esc.	% NOR	NOR esc.	Harvest	Broodstock take (NOR)	Diversity	Progeny recruits	Brood-year R/S
1971	17,412	100	17,412	10,857	0	1.90	38,312	2.20
1972	30,079	100	30,079	10,859	0	1.66	184,126	6.12
1973	18,107	100	18,107	19,771	0	1.81	89,813	4.96
1974	12,281	100	12,281	1,941	0	1.70	57,375	4.67
1975	18,248	100	18,248	10,866	0	1.91	53,168	2.91
1976	27,715	100	27,715	46,506	0	2.00	26,750	0.97
1977	10,711	100	10,711	5,977	0	1.92	20,208	1.89
1978	19,709	100	19,709	5,635	0	1.80	25,321	1.28
1979	6,554	100	6,554	2,960	0	1.57	13,061	1.99
1980	3,777	100	3,777	9,249	0	1.98	7,438	1.97
1981	2,374	100	2,374	3,501	0	1.78	14,645	6.17
1982	2,623	100	2,623	5,708	0	1.77	18,480	7.05
1983	899	100	899	2,646	0	1.98	9,103	10.13
1984	1,414	100	1,414	1,959	0	2.12	20,181	14.27
1985	1,109	100	1,109	3,314	0	1.77	13,539	12.21
1986	2,552	100	2,552	5,281	0	1.03	5,700	2.23
1987	757	100	757	3,214	0	1.24	819	1.08
1988	2,967	100	2,967	2,713	0	1.95	12,743	4.29
1989	598	100	598	3,877	0	0.93	3,396	5.68
1990	429	100	429	1,135	0	1.06	5,485	12.79
1991	747	100	747	1,452	0	1.70	8,528	11.42
1992	1,945	100	1,945	1,000	432	1.55	53,943	27.73
1993	707	100	707	115	49	1.74	26,950	38.12
1994	2,044	100	2,044	530	385	1.63	8,483	4.15
1995	8,971	83	7,448	429	326	1.37	6,194	0.69
1996	19,707	87	17,202	494	638	1.30	23,165	1.18
1997	8,419	70	5,859	278	381	0.54	18,963	2.25
1998	3,404	63	2,158	171	307	1.19	10,855	3.19
1999	3,884	59	2,279	243	133	0.89	38,507	9.91
2000	7,987	67	5,384	573	390	1.16	252,752	31.65
2001	12,044	60	7,173	789	288	1.55	39,620	3.29
2002	11,454	60	6,852	1,022	350	1.82	72,809	6.36
2003	35,696	77	27,319	249	221	1.53	28,349	0.79
2004	69,995	86	60,328	21,570	236	1.54	47,426	0.68
2005	15,840	72	11,373	293	271	1.85	28,363	1.79
2006	26,754	80	21,385	2,107	209	1.94	12,578	0.47
2007	10,781	87	9,407	1,745	205	2.15	—	—
2008	15,332	88	13,522	1,907	221	2.04	—	—
2009	7,416	88	6,537	1,122	92	1.92	—	—

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Table 63. Five-year Arithmetic Averages of Diversity Index for the Strait of Juan de Fuca and Hood Canal populations and trend measured over the 5-year averages. Note the first average is for 4 years only. Trend is measured as the slope of the linear trend line.

Year	Strait	Hood Canal
1971–1974	1.06	1.77
1975–1979	1.03	1.84
1980–1984	0.98	1.92
1985–1989	0.95	1.38
1990–1994	0.67	1.54
1995–1999	0.55	1.06
2000–2004	0.75	1.52
2005–2009	1.15	1.98
Trend	–0.03	–0.03

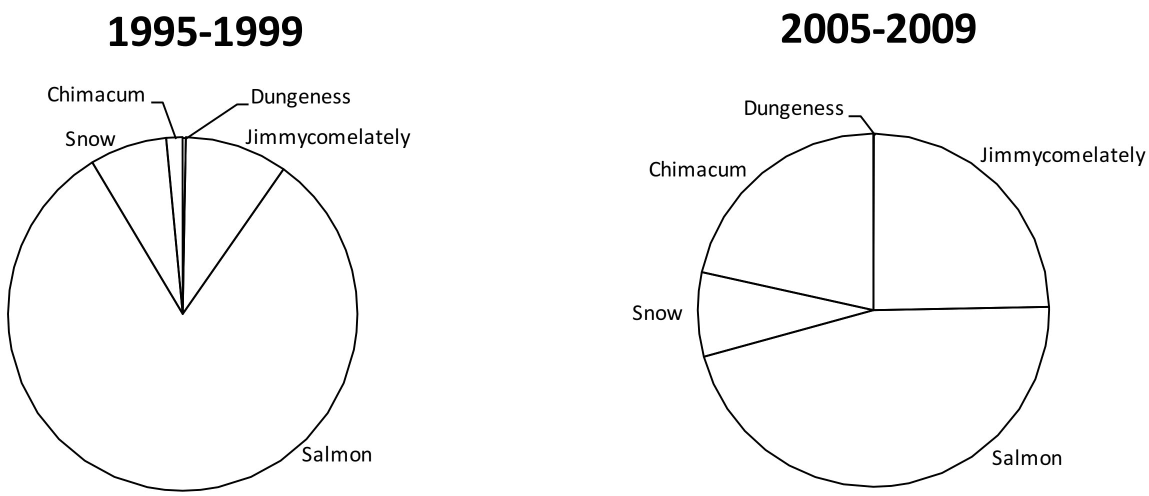

Figure 126. Relative abundance for the natural spawning aggregations of the Strait of Juan de Fuca summer-run chum salmon population for the most recent 5 years of data and the 5 years prior to listing in 1999. In both charts, the percentage for Dungeness is zero.

functions representing a recovered state; different functions were provided for different levels of assumed harvest exploitation after attaining recovery. These two figures from the 2009 report (Sands et al. 2009) are reproduced below (Figure 128 and Figure 129) with current estimates of capacity, intrinsic productivity, and average exploitation rate for three overlapping time periods.

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).

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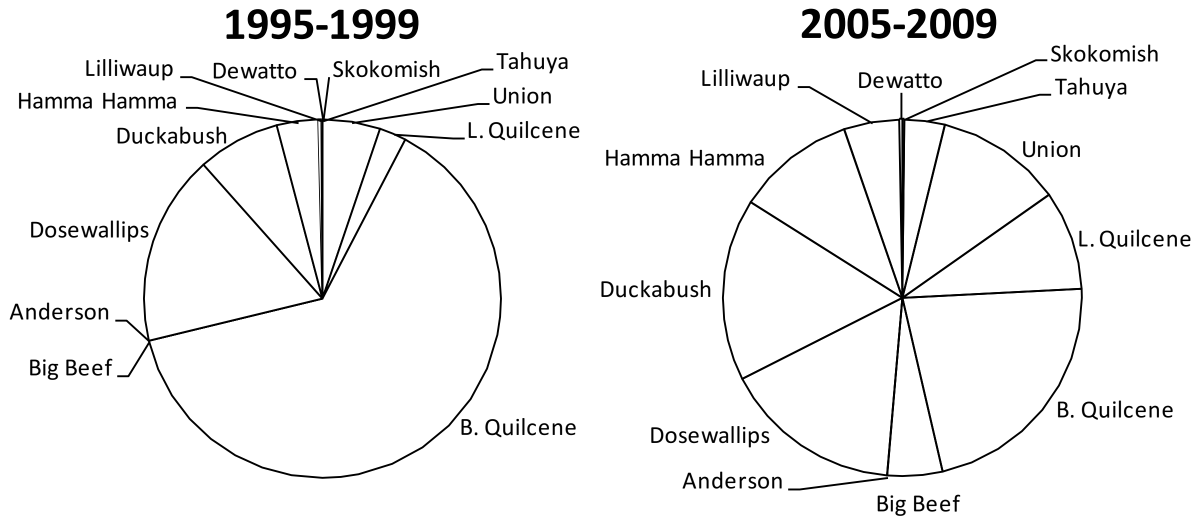

Figure 127. Relative abundance for the natural spawning aggregations of the Hood Canal summer-run chum salmon population for the most recent 5 years of data and the 5 years prior to listing in 1999. In the left chart, the percentages are zero for Skokomish, Tahuya, Big Beef, Anderson, and Dewatto and 1% for Lilliwaup. In the right chart, the percentages are zero for Skokomish, Anderson, and Dewatto.

Harvest

There are no directed fisheries on Hood Canal summer chum salmon. 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 130). The comanagers have continued to constrain harvest impacts as runs have returned to historic levels, leading to escapements that exceed historic levels.

Hatchery releases

Hatchery releases of chum, Chinook, and coho salmon within the Hood Canal Summer-run Chum Salmon 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 131). Chum hatchery releases are primarily fall-run stocks that are not part of the summer-run chum ESU.

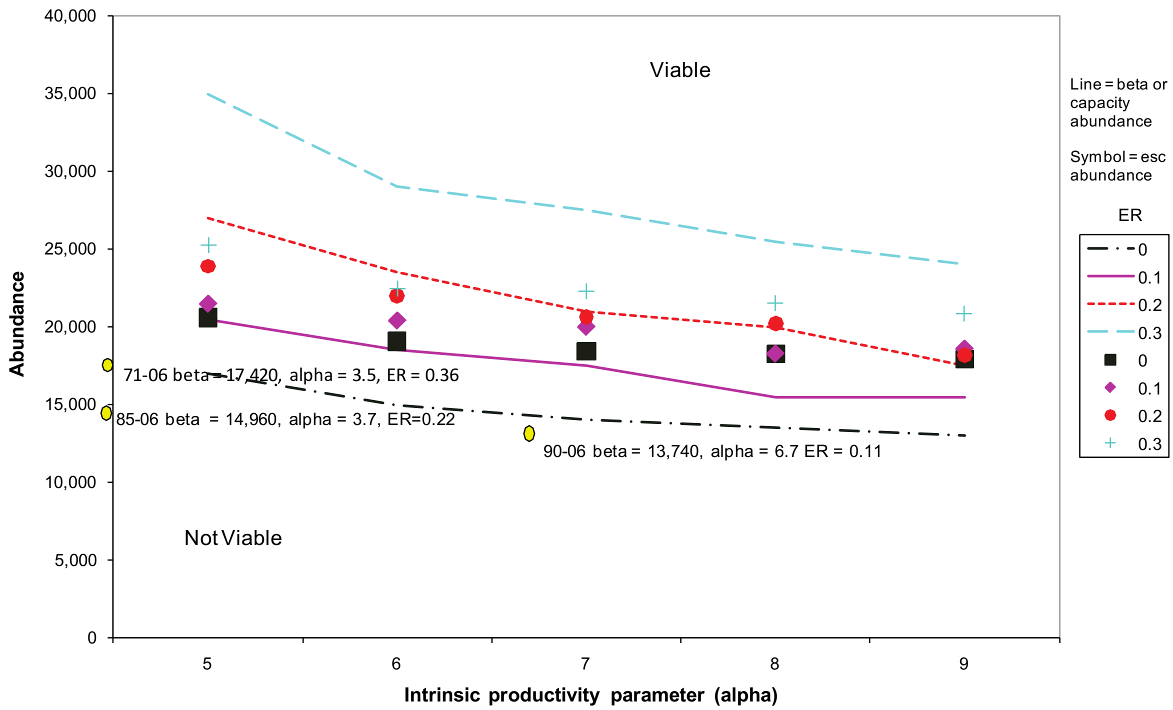

Figure 128. Viability curves for the Hood Canal summer-run chum salmon population for no harvest and three levels of harvest (lines) using the equal to or less than 5% probability of extinction over 100 years. Capacity abundance and intrinsic productivity (beta and alpha parameters of the Beverton-Holt 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 (broodyears 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 1,000 simulated runs). (Adapted from Sands et al. 2009.)

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 lower than it was 5 years ago. While spawning abundances have remained relatively high compared to the low levels in the early 1990s, productivity has decreased for the last 5 broodyears and was lower than any previous 5-year average since 1971. Diversity has increased from the low values seen in the 1990s, due to the reintroduction of spawning aggregates and the more uniform abundance between populations. Overall, however, the new information considered does not indicate a change in the biological risk category since the time of the last BRT status review.

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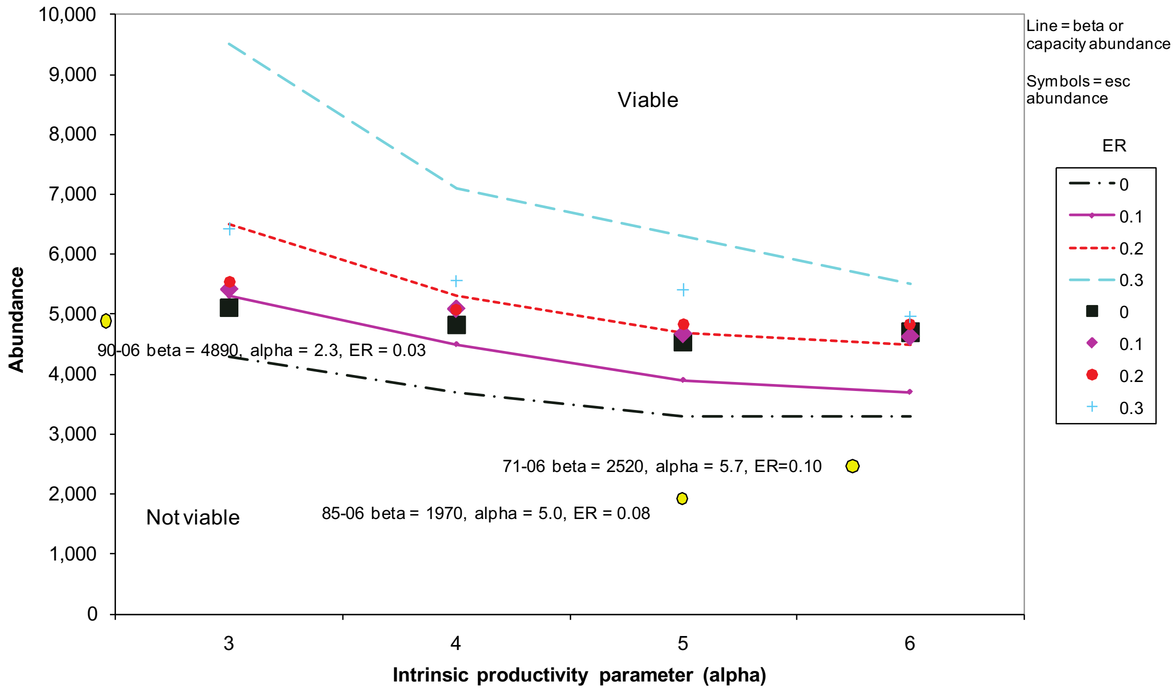

Figure 129. Viability curves for the Strait of Juan de Fuca summer-run chum salmon population for no harvest and three levels of harvest (lines) using the equal to or less than 5% probability of extinction over 100 years. Capacity abundance and intrinsic productivity (beta and alpha parameters of the 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 (broodyears 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 1,000 simulated runs). (Adapted from Sands et al. 2009.)

Puget Sound/Strait of Georgia Coho Salmon ESU

Description of ESU

The Puget Sound/Strait of Georgia Coho Salmon ESU was originally designated in 1994 during the West Coast coho salmon status review (Weitkamp et al. 1995); other than in the earlier subsection 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), the eastern side of Vancouver Island (north to and including Campbell River), and the British Columbia mainland (north to and including Powell River), excluding the upper Fraser River above Hope (Figure 1).

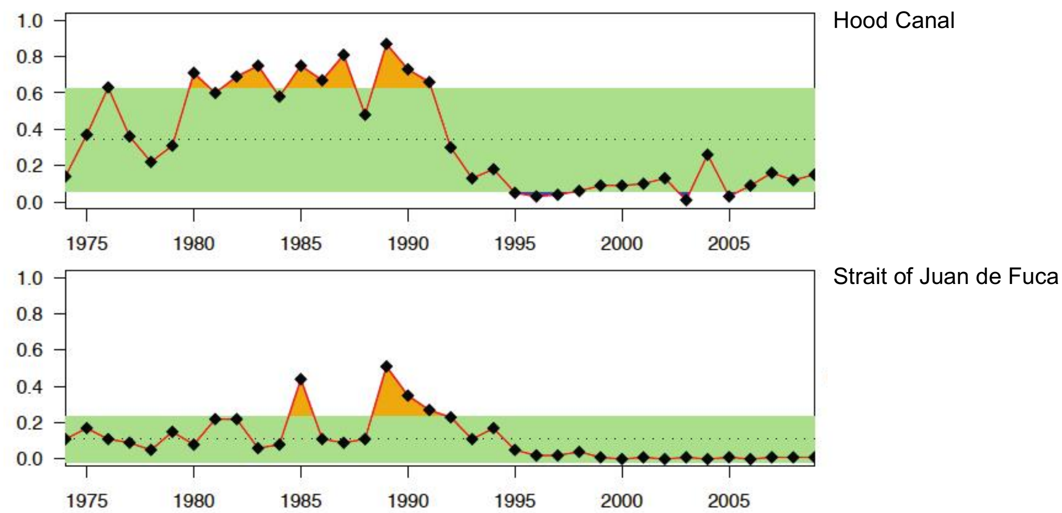

Figure 130. Total exploitation rate by year for summer-run chum salmon. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from WDFW run reconstruction, 1974–2007 data from http://wdfw.wa.gov/fish/chum/chum-5e.htm, 2008 and 2009 data from WDFW.[23]

Summary of Previous BRT Conclusions

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 coho salmon, 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).

[23] V. Tribble, WDFW, Olympia, WA. Pers. commun., 13 July 2010.

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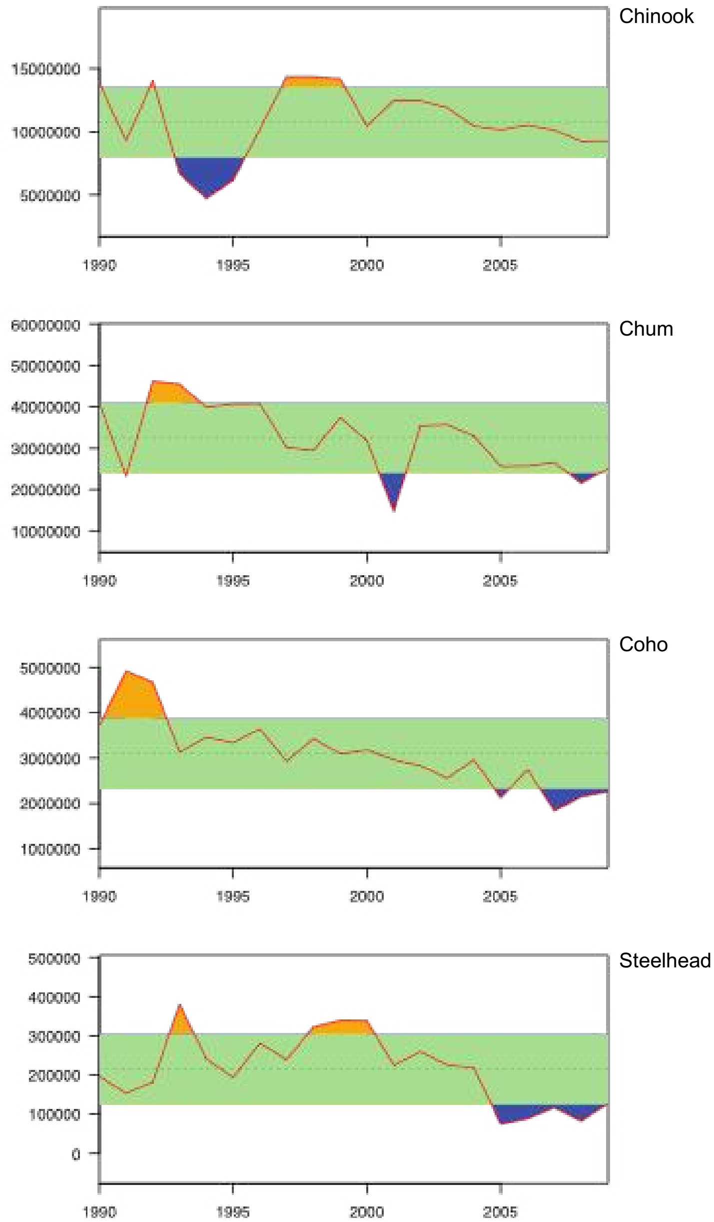

Figure 131. Summary of total hatchery releases by year per species within the spawning and rearing areas of the Hood Canal Summer-run Chum Salmon ESU (note that most chum releases are fall-run chum). The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

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,

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Stillaguamish, and Snohomish rivers and south and central Hood 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.

The 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 the 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 500,000 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 more than 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, but available data indicated that natural populations in British Columbia declined substantially during the early 1990s. 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 comanagers 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 Coho Salmon 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, in order to address whether the ESU's 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 2000−2008 (PFMC 2010). The single largest natural population (Snohomish River) had 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 132, Table 64). Current spawning escapement is similar to levels in the 1990s.

Harvest

Puget Sound coho salmon are taken primarily in Puget Sound fisheries. Historically, Canadian coho fisheries off WCVI and in the Strait of Georgia had very high impacts on Puget Sound coho as well and members of the ESU are taken in northern British Columbia, 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 133). 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 critically depressed upper Fraser River coho salmon. U.S. 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.

Artificial propagation (hatcheries)

In the 1994 and 1995 status reviews, 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, although it has declined substantially since 1995 (Figure 134) 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 to 2008 (Figure 135, 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%

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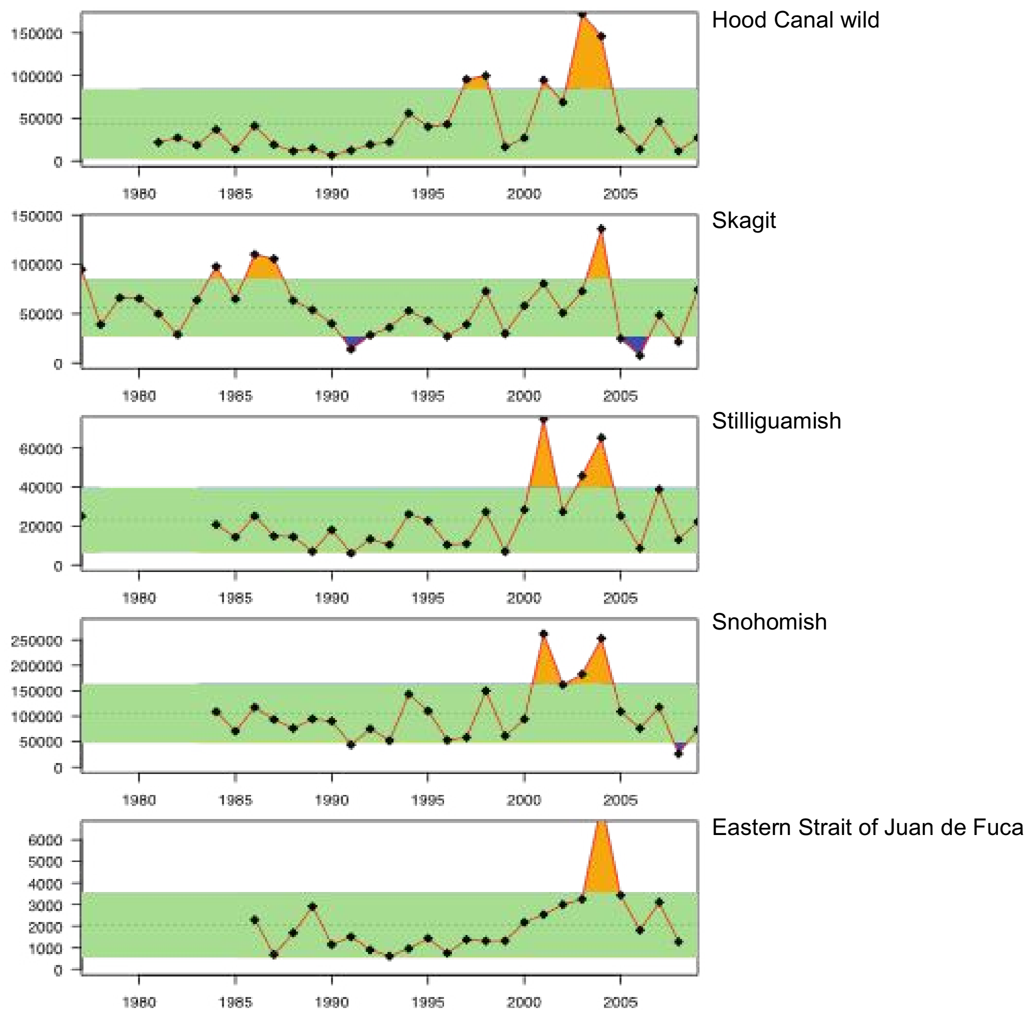

Figure 132. Spawning escapement trends by year in the major wild population areas of Puget Sound coho salmon. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data compiled from WDFW.

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 1980s to approximately 12 million annually during 2005−2009.

Other factors

Marine survival—Marine survival rates are estimated annually for four wild Puget Sound coho salmon populations based on CWTs: Big Beef Creek, Deschutes River, South Fork Skykomish, and Baker (Table 65, Figure 136) (Zimmerman 2009). Big Beef Creek has consistently had the highest marine survival rate (16.0% during 1978−2008), Deschutes and South Fork 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

Table 64. Short-term and long-term trends for the major natural production stocks of Puget Sound coho salmon.

Stock	**Geometric mean spawners**[a]	**Short-term trend (95% CI)**[b]	**Long-term trend (95% CI)**[c]
Hood Canal	23,490	0.946 (0.849–1.052)	1.036 (0.999–1.074)
Skagit	27,074	0.984 (0.897–1.08)	0.983 (0.962–1.006)
Snohomish	71,800	0.99 (0.911–1.076)	1.007 (0.978–1.037)
Stillaguamish	18,864	1.028 (0.936–1.13)	1.029 (0.995–1.066)
East Strait of Juan de Fuca	2,859	1.077 (0.999–1.161)	1.044 (1.007–1.082)

[a]2005–2009 for all except eastern Strait of Juan de Fuca, which is 2004–2008.
[b]Trend from 1995.
[c]Trend from 1981 (Hood Canal), 1977 (Skagit), 1984 (Snohomish, Stillaguamish), and 1986 (east Strait of Juan de Fuca), based on data compiled from WDFW.

populations, trends in marine survival rates have been declining at rates of −0.25%/year (South Fork 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).

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 the Dungeness, Skagit, Cedar, Green, and Deschutes rivers and Big Beef Creek, with a single (2009) estimate for the Nisqually River (135,512) (Zimmerman unpubl. data). Of these systems, the Skagit River 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) (Figure 137).

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 −2,842 smolts/year (Table 66). 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 137).

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

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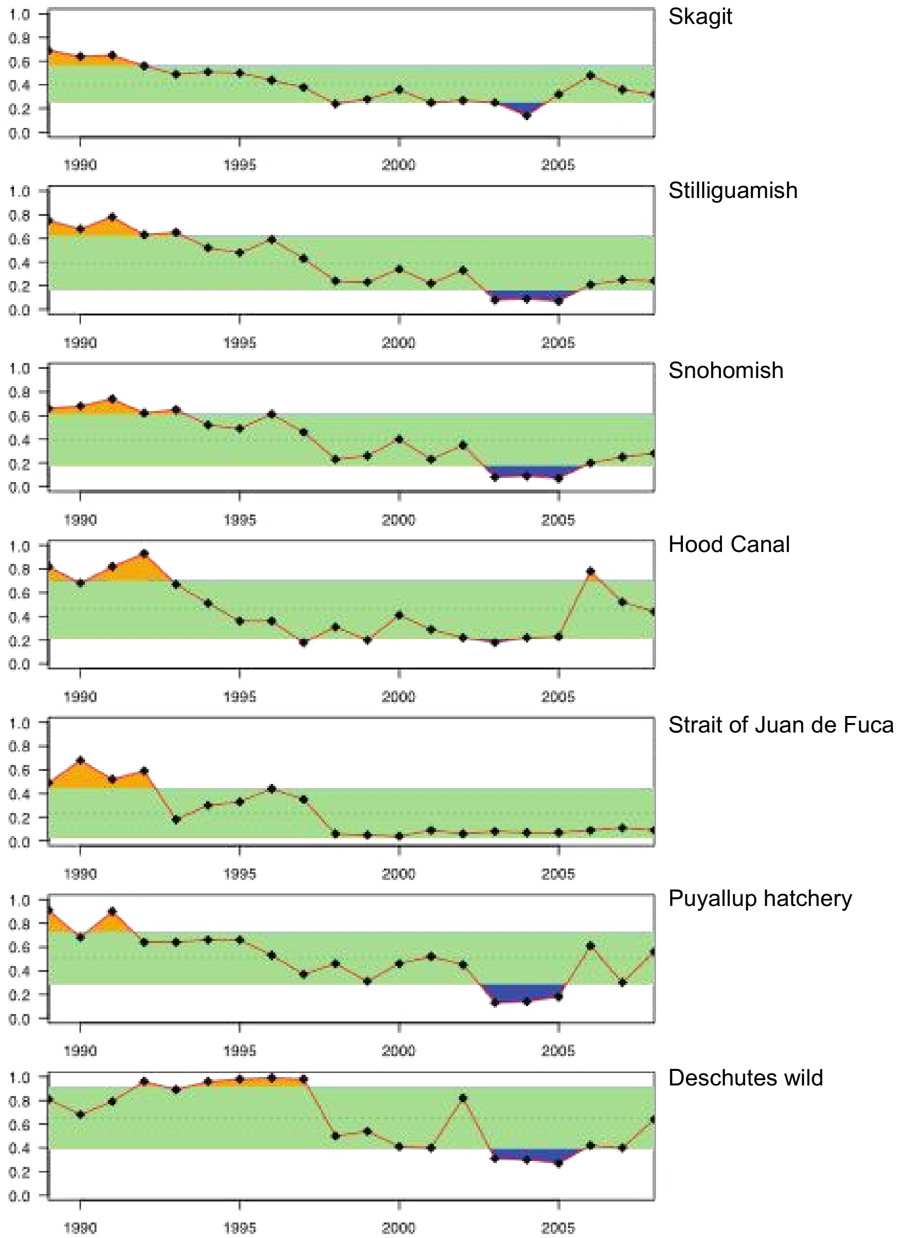

Figure 133. Total exploitation rates by year on Puget Sound coho salmon stocks. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data 1989−1997 based on CWT analysis and 1998−2008 from Fishery Regulation Assessment Model validation runs.[24]

[24] L. LaVoy, NMFS, Lacey, WA. Pers. commun., 13 July 2010.

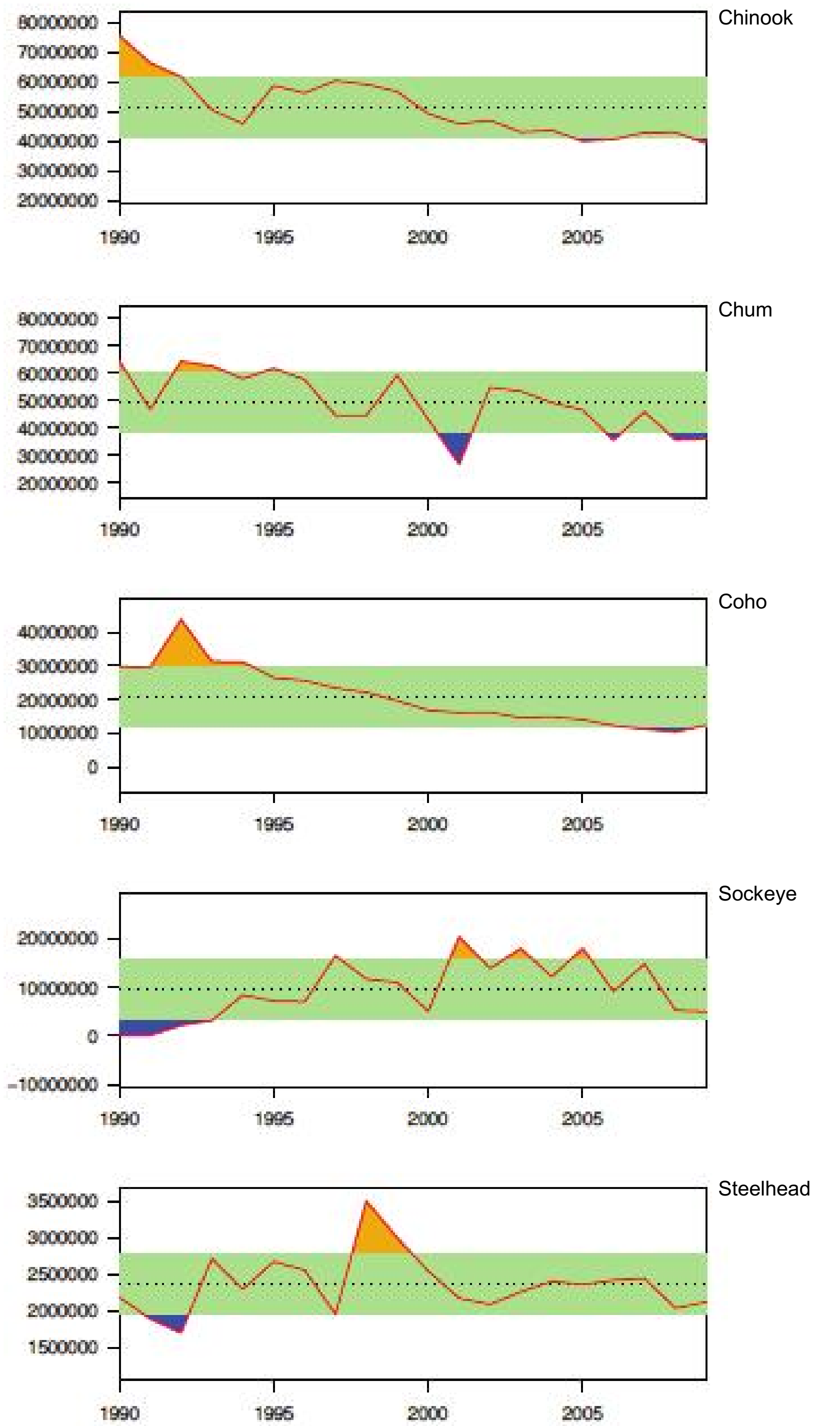

Figure 134. Summary of hatchery releases by year within the Puget Sound/Strait of Georgia Coho Salmon ESU spawning and rearing areas. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

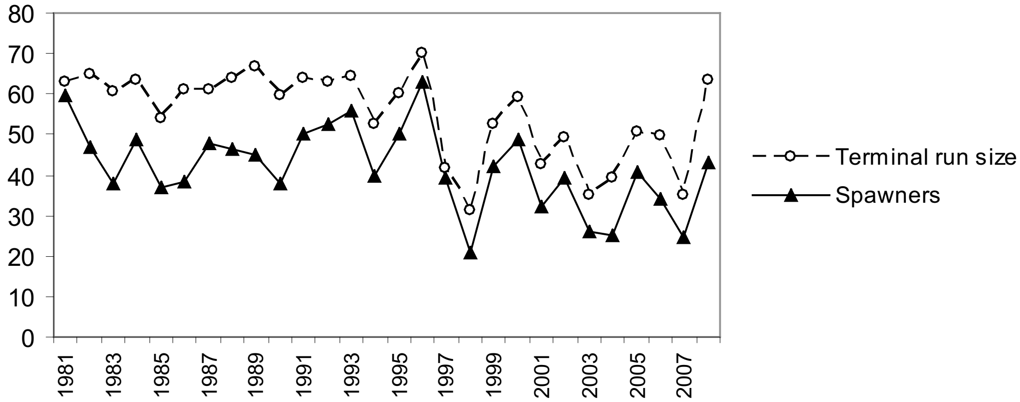

Figure 135. Percent of Puget Sound coho salmon of hatchery origin by year estimated for terminal run size (before terminal harvest) and for spawners. Data from PFMC 2010.

Table 65. Marine survival rate information for wild Puget Sound coho salmon populations. Regression slopes are statistically significant at $P \leq 0.05$. Data from Zimmerman 2009.

		Attribute		
Population	**Year 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
South Fork Skykomish	1979–2008	13.50	–0.25	0.155
Baker River	1992–2008	8.10	–0.34	0.298

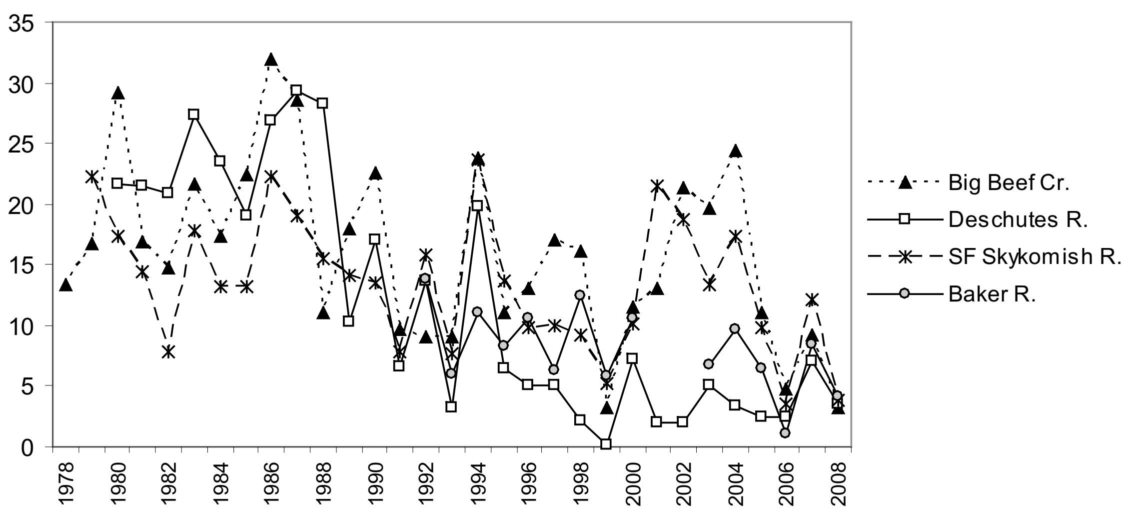

Figure 136. Percent of marine survival rates by year for wild coho salmon populations in Puget Sound. Data from WDFW 2010.

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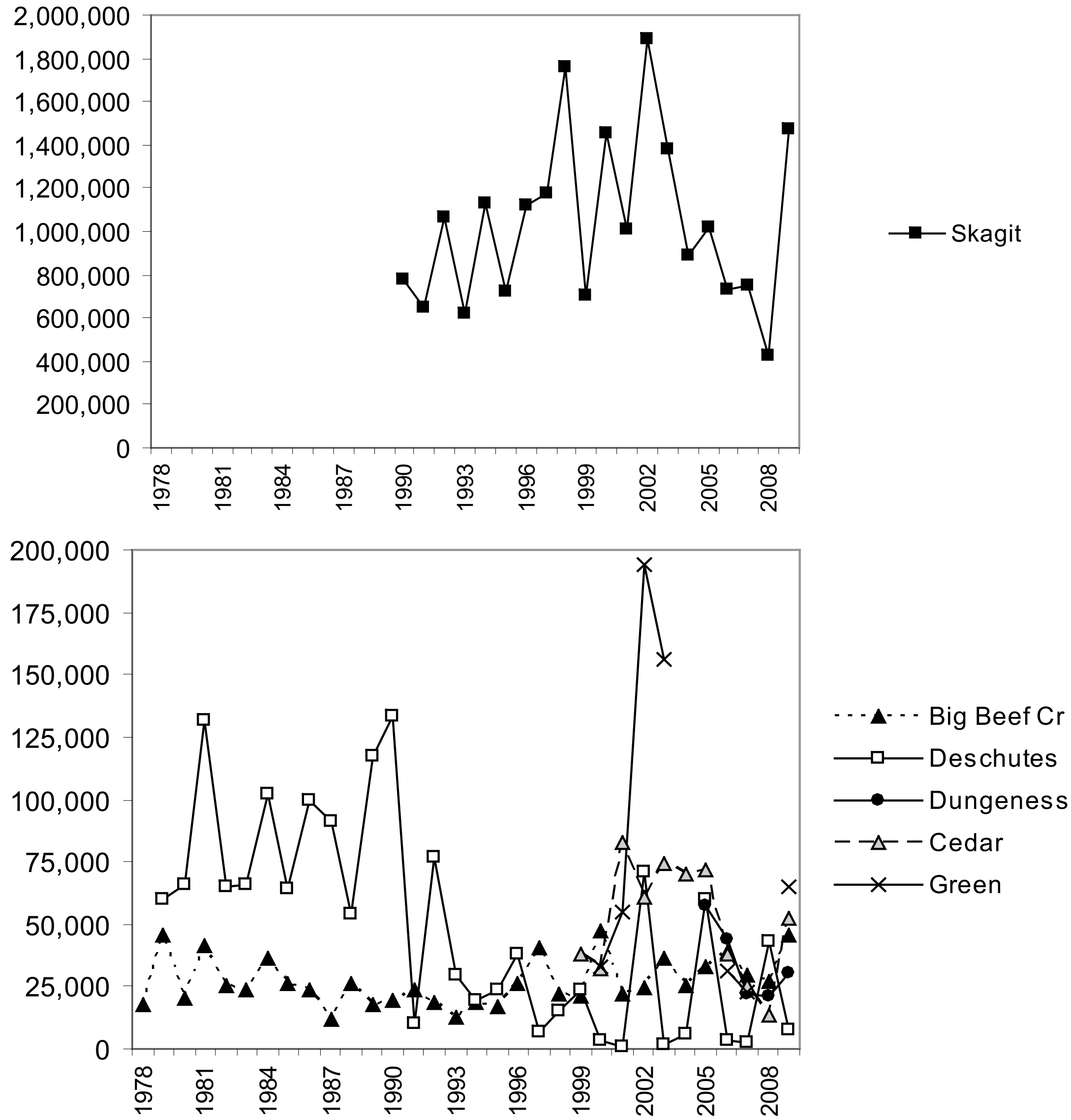

Figure 137. Estimated smolt abundances by year for various Puget Sound coho salmon populations.

at weirs, all indicate that adult size reached minimum levels in the mid-1990s and has since increased (Figure 138 through Figure 140). 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 the 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 fewer negative slopes (only 10 of 26 time series examined), of which only 4 were statistically significant, while most trends were positive (16 of 26), including three statistically significant positive trends (Table 67).

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.

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Table 66. Smolt production estimates for Puget Sound populations (Zimmerman unpubl. data).

Population	Years	Average smolt production	Slope of smolts over time[a]	Regression r^2
Dungeness	2005–2009	35,038	–7,522	0.60
Skagit	1990–2009	1,037,119	+7,826	0.01
Cedar River	1999–2009	50,759	–1,994	0.08
Big Beef Creek	1978–2009	27,015	231	0.05
Green River	2000–2009	79,701[b]	–5,651	0.08
Nisqually	2009	135,512	—	—
Deschutes	1979–2009	48,144	**–2,943**	0.43

[a]Slope that is statistically significantly at $P < 0.05$ is indicated in boldface.
[b]Smolt production estimates were not available for smolt outmigration years 2004, 2005, and 2008.

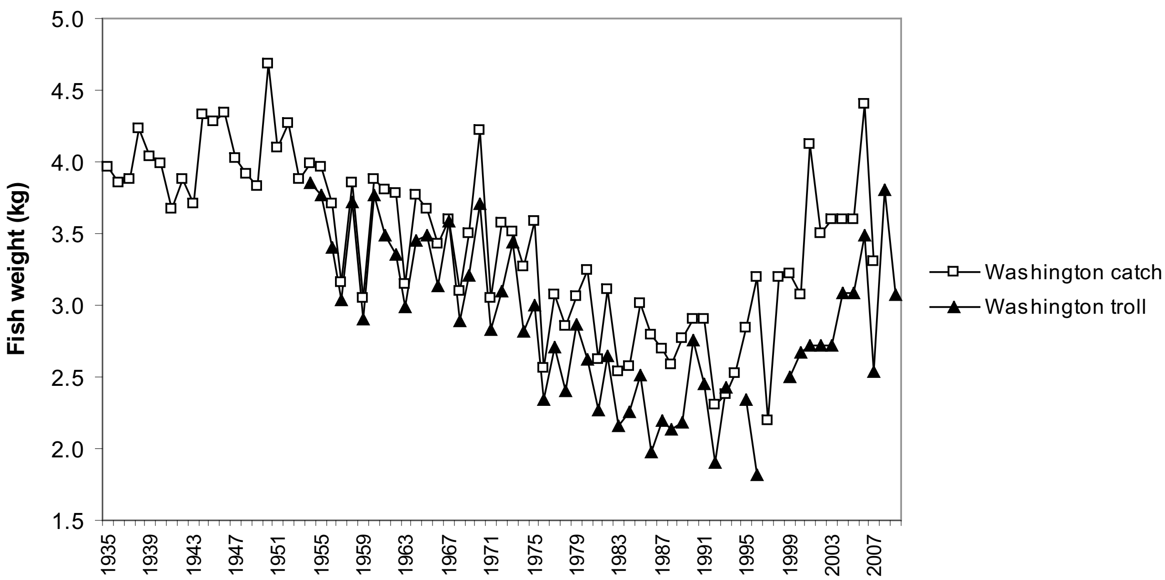

Figure 138. Long-term trends in estimated weight of coho salmon by year caught in Washington commercial fisheries (Washington catch) or Washington commercial troll fisheries (Washington troll). Data from Wright 1970, WDF 1985, Hoines 1998, and PFMC 2010.

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.

Puget Sound Coho Salmon: Updated Risk Summary

Available information suggests that the status of the Puget Sound/Strait of Georgia Coho Salmon ESU is similar to, or perhaps somewhat 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

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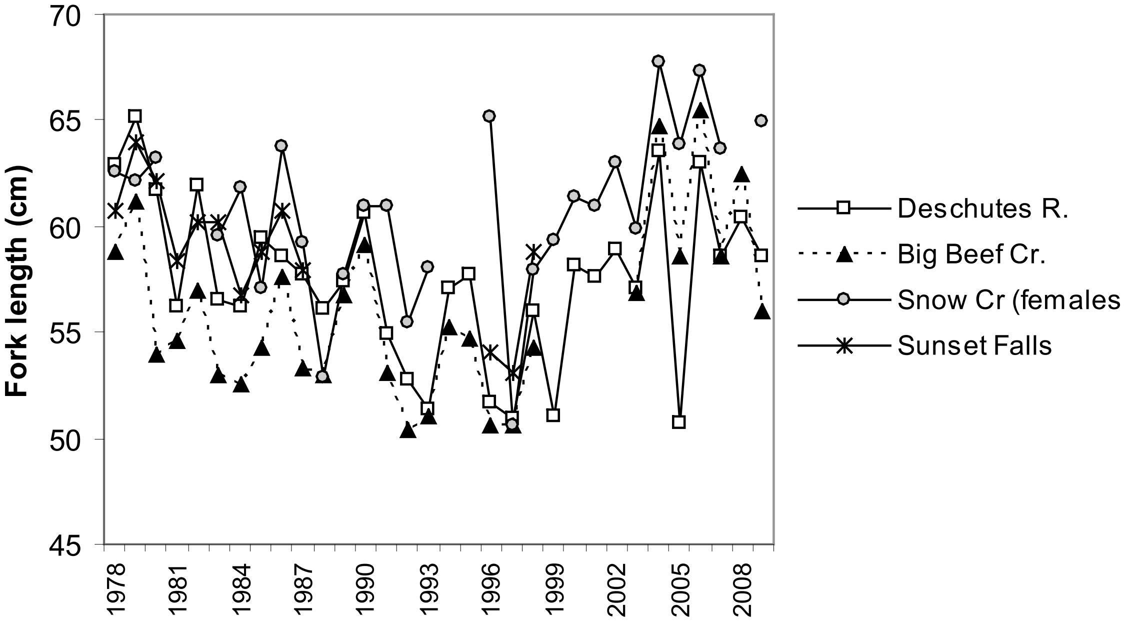

Figure 139. Trends of adult coho salmon size by return year from monitored wild populations in Puget Sound (Zimmerman unpubl. data).

populations that are managed for natural escapement remains as high as 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 salmon 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.

Lake Ozette Sockeye Salmon ESU

Lake Ozette sockeye salmon were listed as a threatened species on 25 March 1999 and the status was reaffirmed 28 June 2005. The ESU includes all naturally spawning populations of sockeye salmon in Lake Ozette, Washington, and streams and tributaries flowing into Lake Ozette as well as two artificial propagation programs: the Umbrella Creek and Big River sockeye hatchery programs. The ESA salmon recovery plan was finalized for Lake Ozette sockeye 29 May 2009 and the Puget Sound TRT completed analyses on population identification (Currens et al. 2009) and population/ESU viability (Rawson et al. 2009). The Lake Ozette sockeye salmon ESU was determined to consist of only one population with 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 twentieth century. Harvest records are our best indicators of population abundance in past years. Estimates of the Makah Tribe's annual harvest of Lake Ozette sockeye peaked at approximately 17,000–18,000 in 1949; harvest then declined sharply in

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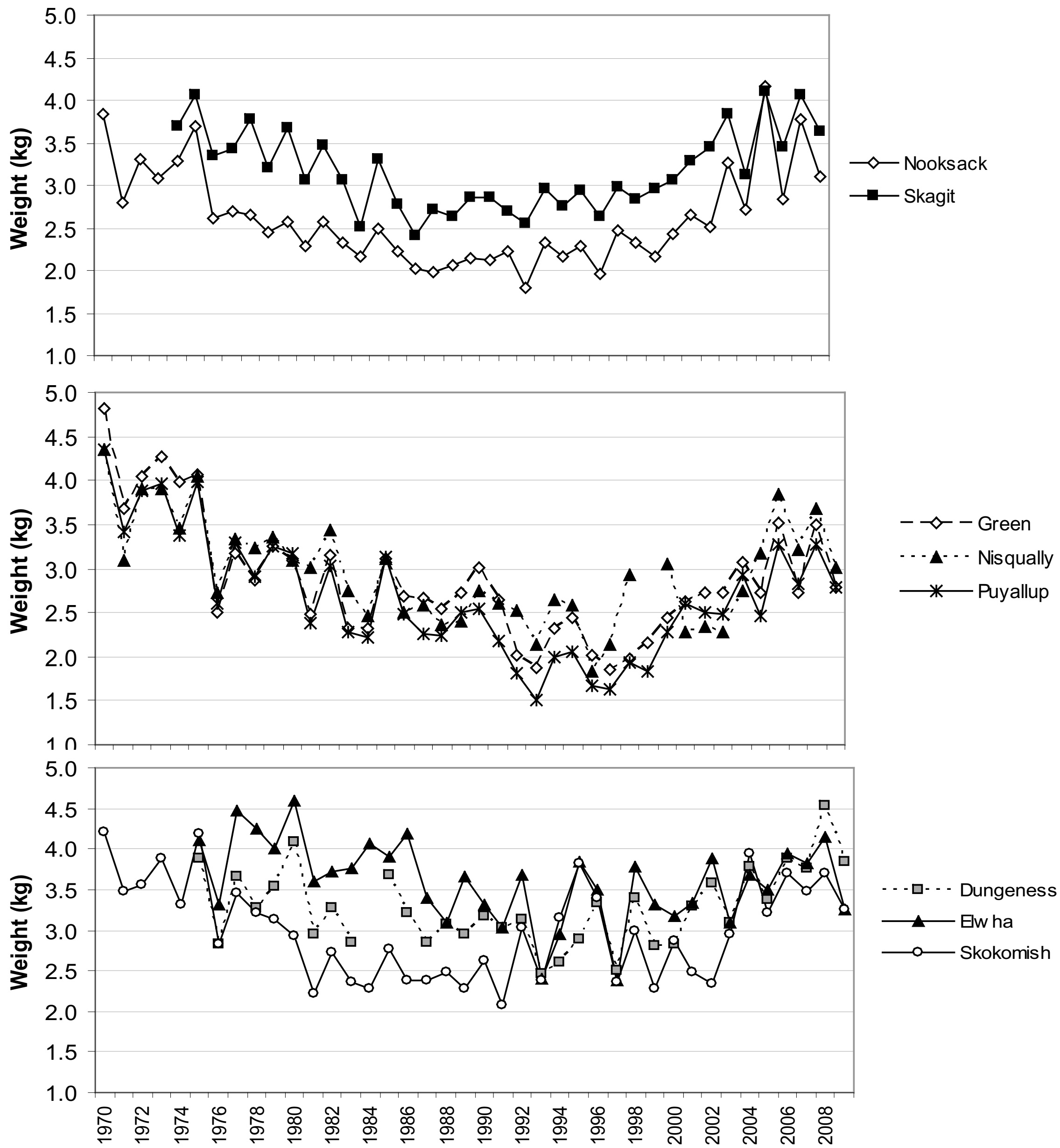

Figure 140. Trends by year of adult size for salmon caught in in-river fisheries in north (top), central (middle) Puget Sound and Hood Canal, and the Strait of Juan de Fuca (bottom). Data from WDFW 2010.

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Table 67. 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 boldface.

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: 1 is WDF 1985 and PFMC 2010; 2 is Wright 1970, WDF 1985, and PFMC 2010; 3 is Zimmerman unpubl. data; 4 is WDFW 2010; and 5 is Hayman (Skagit Cooperative) unpubl. data.

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the 1960s due to declining returns. Commercial harvest ended in 1974 and all harvest ceased in 1982. Estimations of returns to the lake are currently made using a weir at the mouth of the Ozette River.

Previous Status Reviews and Recovery Documents

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

Five-year geometric mean spawning abundance from the three prior 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 1998c).
- 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 and Big creeks with the intent of starting spawning aggregations in the tributaries to augment the existing beach spawning 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 at least temporarily 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 reevaluated.

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

ESU Status at a Glance

Historical peak catch levels	15,000–18,000 (1949−1951)
Historical populations	1
Extant populations	1
Current 5-year average escapement	2,679 (natural origin)
Viable population structure	1 (with multiple beach and tributary spawners)
Viable minimum 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).

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New Data and Updated Analyses

New data for Lake Ozette sockeye salmon are from annual resource management reports from the Makah Tribe (Peterschmidt and Hinton 2005, 2006, 2008, Peterschmidt et al. 2007). Escapement data are available from 1977 to 2007, although the escapement weir data from 2004 was not expanded for sampling effort 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 prespawning mortality. Estimation of returns and spawners has been difficult; weir operation have 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.

All beach spawners are assumed to be 4-year-olds, and the age distribution of tributary spawners is estimated at a weir at the mouth of Umbrella Creek and provided in the resource management reports. Cohort run reconstruction was performed as described by 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 its 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 68 and Figure 141. Escapement numbers that are italic in the table are missing values that have been estimated using the method described by Sands (2009), or in the case of years 2004 to 2007, expanded weir counts based on average expansions, not year specific expansions. These numbers are highly uncertain and we expect these estimates to be updated by tribal biologists in the future.

Average escapement over 5-year intervals is given in Table 69 as well as estimates of trends over the intervals. There is no notable trend; the years 1993−1997 have relatively low abundances and 1998−2002 have relatively high abundances.

Short-term and long-term trends and annual population growth rates (lambda) are provided in Table 70. Neither the trend nor growth rate shows any indication of increasing population growth.

Productivity was 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 age-3 and age-5 spawners returning to the tributaries. Using the age data, cohort run reconstruction was performed to provide R/S estimates for broodyears 1977−2003. Productivity varies greatly from year to year, and the most recent broodyears (1999−2003) have the lowest average R/S (Table 71).

Table 68. Natural spawning escapement (includes natural-origin and hatchery-origin fish), natural-origin fish, the percent of natural escapement that is hatchery origin, and the percent of natural spawners that occur in the tributaries.

Year	Total*	Natural origin	Hatchery percent	Percent tributary spawners	Harvest	Broodstock take
1977	2,752	2,752	0	0	84	0
1978	2,398	2,398	0	0	30	0
1979	1,335	1,335	0	0	30	0
1980	1,054	1,054	0	0	30	0
1981	858	858	0	0	0	0
1982	4,131	4,131	0	0	29	0
1983	*814*	814	0	0	0	14
1984	2,447	2,447	0	0	0	0
1985	*2,014*	2,014	0	0	0	40
1986	*1,592*	1,592	0	0	0	43
1987	*5,579*	5,579	0	0	0	123
1988	9,577	9,098	5	5	0	193
1989	1,671	1,587	5	5	0	6
1990	699	664	5	5	0	33
1991	1,780	1,691	5	5	0	175
1992	4,058	3,873	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	4,063	5	9	0	200
1997	1,346	1,052	22	47	0	263
1998	1,882	1,714	9	24	0	88
1999	2,620	2,248	16	55	0	29
2000	4,851	4,208	13	71	0	213
2001	4,151	3,846	7	85	0	164
2002	3,822	3,344	12	45	0	168
2003	4,876	4,830	1	36	0	199
2004	*4,917*	4,368	11	90	0	218
2005	*2,260*	1,753	22	98	0	192
2006	*2,288*	1,934	15	43	0	86
2007	*510*	509	0	10	0	45

*Total natural spawning estimates are taken from the Limiting Factors Analysis (LFA) 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, and 1995, values were given in an earlier version of the LFA report. All estimates given in the later report were expanded numbers; these 4 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.

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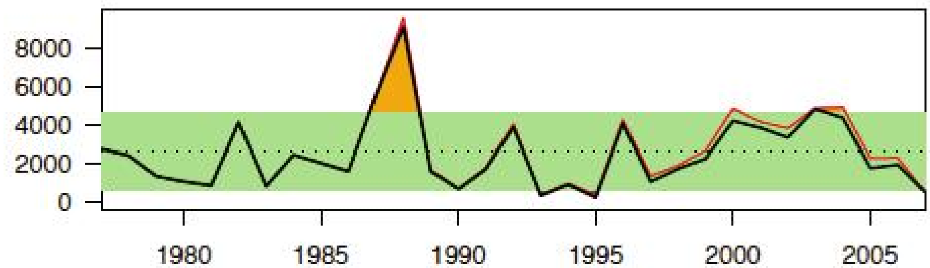

Figure 141. Trend in spawning abundance of Lake Ozette sockeye salmon by year. The dark line indicates natural-origin spawner numbers and the light line indicates total natural spawners (including naturally spawning hatchery fish). The dotted line is the long-term (whole time series) mean of the total spawners and the shaded area indicates ±1 SD around the mean.

Table 69. Five-year geometric mean escapements for natural-origin spawners and natural spawners (natural and hatchery origin) for Lake Ozette sockeye salmon 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
1977–1982	1,790	1,790
1983–1987	2,044	2,044
1988–1992	2,289	2,407
1993–1997	766	921
1998–2002	2,899	3,280
2003–2007	2,052	2,291
Trend	1.05	1.02

Table 70. Short-term and long-term population trend and growth rate estimates for the Lake Ozette sockeye salmon population.

Years	Trend in natural spawners w/CI	Hatchery fish success = 0		Hatchery fish success = 1	
		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

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 monitor 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 program to monitor beach spawning or spawning at other tributaries.

Table 71. R/S for Lake Ozette sockeye salmon broodyears 1977–2003 and 5-year arithmetic averages.

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
Five-year arithmetic averages	
1979–1983	2.57
1984–1988	1.15
1989–1993	1.27
1994–1998	2.81
1999–2003	0.79
Trend	–0.19

Hatchery releases

Hatchery releases started in 1983 into Umbrella Creek with the purpose of introducing tributary spawners into this sockeye ESU (Table 72). The hatchery program will be reevaluated in 2012 to see if it has accomplished its purpose. The program does appear to have produced natural spawners returning to these two creeks and to a lesser extent 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.

AR054669

Table 72. 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. 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 salmon remain highly variable and uncertain. This makes it impossible to accurately detect changes in abundance trends or in productivity in recent years. It is obvious, though, that population levels remain low compared to historical levels. 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 in 2005.

Puget Sound Steelhead ESU

Listed ESU/DPS

This report covers the DPS of Puget Sound steelhead. 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 BRT 2007 status review (Hard et al. 2007). The Puget Sound TRT considered genetic and life history information from steelhead on the Olympic Peninsula and Washington coast and concluded that there is no compelling evidence to alter the DPS boundaries described above.

AR054670

Summary of Previous BRT Conclusions

The initial review of this DPS—then called the Puget Sound 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, NMFS issued a determination that listing 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, NMFS 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 TRT Documents and Findings

The Puget Sound Steelhead 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 MPGs within the DPS. 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 basic analyses of abundance and trend followed by 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

The data considered in this report include estimates of steelhead natural escapement or total run size, as calculated from redd count and catch statistics obtained from WDFW. 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 TRT 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 73 and Table 74 below; these analyses focus on 1) data from the entire time series, 2) data since 1995, and 3) data from the most recent 5 years.

Data from the entire time series—Since 1985 Puget Sound winter-run steelhead abundance has shown a widespread declining trend over much of the DPS (Table 37). Only 4 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, 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.

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Table 73. 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) and since 1995 (1995–2009).

	Exponential trend ln (natural spawners) (95% CI)	
Population	**1985–2009**	**1995–2009**
South sound tributaries winter run	Not calculated	Not calculated
Dungeness River winter run	0.926 (0.909–0.943)	0.919 (0.786–1.075)
East Hood Canal winter run	1.022 (0.997–1.048)	1.033 (0.976–1.092)
Elwha River winter run	0.840 (0.749–0.943)	0.750 (0.020–28.503)
Green River winter run	0.992 (0.969–1.016)	0.953 (0.892–1.019)
Lake Washington winter run	0.807 (0.770–0.845)	0.731 (0.656–0.815)
Nisqually River winter run	0.914 (0.890–0.940)	0.935 (0.876–0.997)
Port Angeles winter run	1.016 (0.983–1.050)	0.964 (0.899–1.031)
Puyallup River winter run	0.919 (0.899–0.938)	0.902 (0.850–0.957)
Samish River winter run	1.008 (0.972–1.045)	0.966 (0.934–0.998)
Skagit River winter run	0.969 (0.954–0.985)	0.978 (0.931–1.029)
Skokomish River winter run	0.956 (0.932–0.979)	1.006 (0.958–1.057)
Snohomish River winter run	0.963 (0.941–0.985)	0.961 (0.878–1.050)
Stillaguamish River winter run	0.910 (0.887–0.934)	0.879 (0.820–0.943)
West Hood Canal winter run	1.101 (1.046–1.160)	1.101 (1.046–1.160)
White River winter run	0.938 (0.923–0.952)	0.933 (0.905–0.963)

Table 74. Geometric means of natural spawners for several winter-run populations of steelhead in the Puget Sound DPS over the most recent 5 years (2005–2009).

Population	Geometric mean (95% CI)
South sound tributaries winter run	Not calculated
East Hood Canal winter run	213 (122–372)
Elwha River winter run	Not calculated
Green River winter run	986 (401–2,428)
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	4,648 (2,827–7,642)
Skokomish River winter run	355 (183–686)
Snohomish River winter run	4,573 (500–41,865)
Stillaguamish River winter run	327 (100–1,067)
West Hood Canal winter run	208 (118–366)
White River winter run	265 (206–342)

Data since 1995—Since 1995 Puget Sound winter-run steelhead abundance has also shown a widespread declining trend over much of the DPS (Table 74). Only 3 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 1 of these is significantly greater ($P < 0.05$) than 1 (positive population growth): west Hood Canal. These four populations are all small. The

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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.

Data from the most recent 5 years—Over the most recent 5 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 8 populations of the 15 evaluated (Table 74). 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 3 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 Puget Sound tributaries populations all have very low recent mean abundances (<15 fish).

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 autoregressive 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 nonprocess (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 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 autoregressive 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 (CIs) are computed from the estimates of abundance

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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 limited 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, that is, 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 142 through Figure 144) 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 Puget 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 each population time series follows a single MPG trajectory and is simply scaled up or down relative to it, and variances in the observation errors for each time series are multivariate normal but allowed to be unique for each population. The estimate of the log(total MPG count) 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 Puget Sound MPG, and Elwha River for the Olympic MPG). The 95% CI around the total MPG estimate are given by the dashed curves (note: these are not the CIs around the observed data, which are expected to fall outside the CI depending on the degree of population-specific nonprocess 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 142). The average long-term MPG growth rate (u est, equivalent to ln(λ); see Table 65 and Table 74) 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 Puget Sound MPG also shows a clearly declining trend in wild abundance (Figure 143). 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 less than 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 144).

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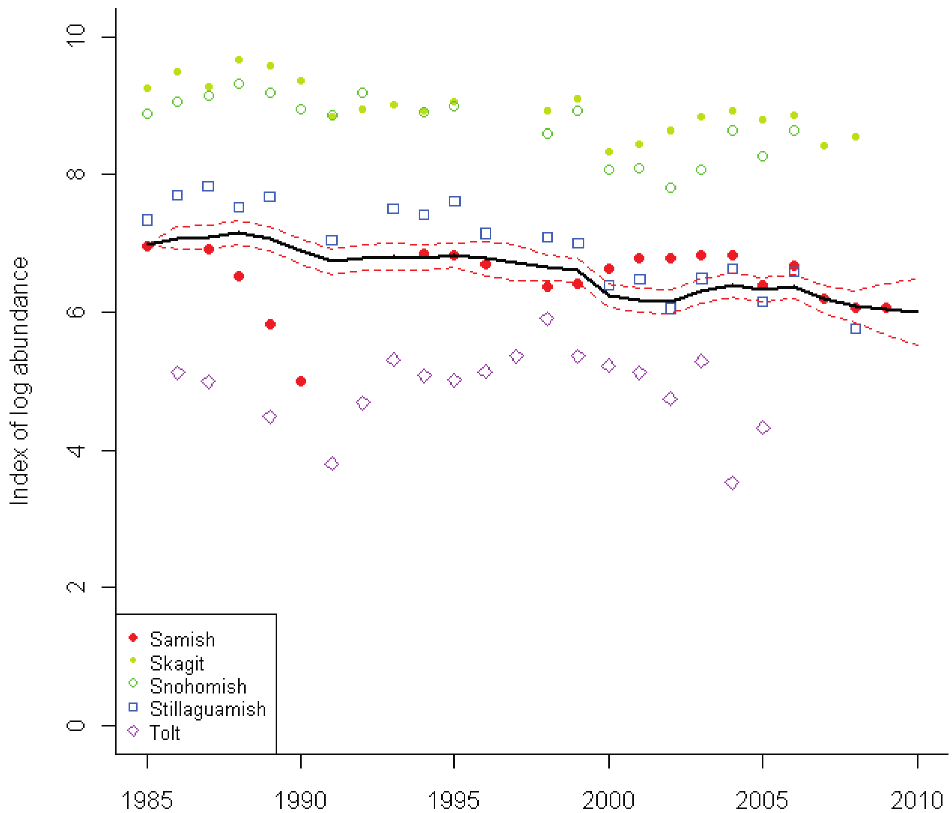

Figure 142. Plot of the observations and total population estimate of Puget Sound winter-run steelhead for a putative Northern Cascades MPG by year. The graph plots the maximum-likelihood estimate of log(total no. steelhead) in the MPG against the observed data, assuming a single-population model for the MPG. The estimate of the log(total MPG count) (solid line) has been scaled relative to the Samish River population. The 95% CIs around the total MPG estimate are given by the dashed lines. (Note that these are not the CIs around the observed data, which are expected to fall outside the CI, depending on population-specific nonprocess error.) No suitable data were available for Nooksack River steelhead.

The next several sets of multiplots (Figure 145 through Figure 160) summarize MARSS analyses that evaluate and project the trends in estimated wild abundance for draft putative DIPs of Puget Sound steelhead over the entire data series (1985−2009, estimates typically taken from a combination of observed redd counts from index reaches and observed catches), 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 PVAs. The top left panel plots the observed counts against year, giving the MARSS maximum-likelihood estimate of fit to the abundance data (curved line), 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% CIs). 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

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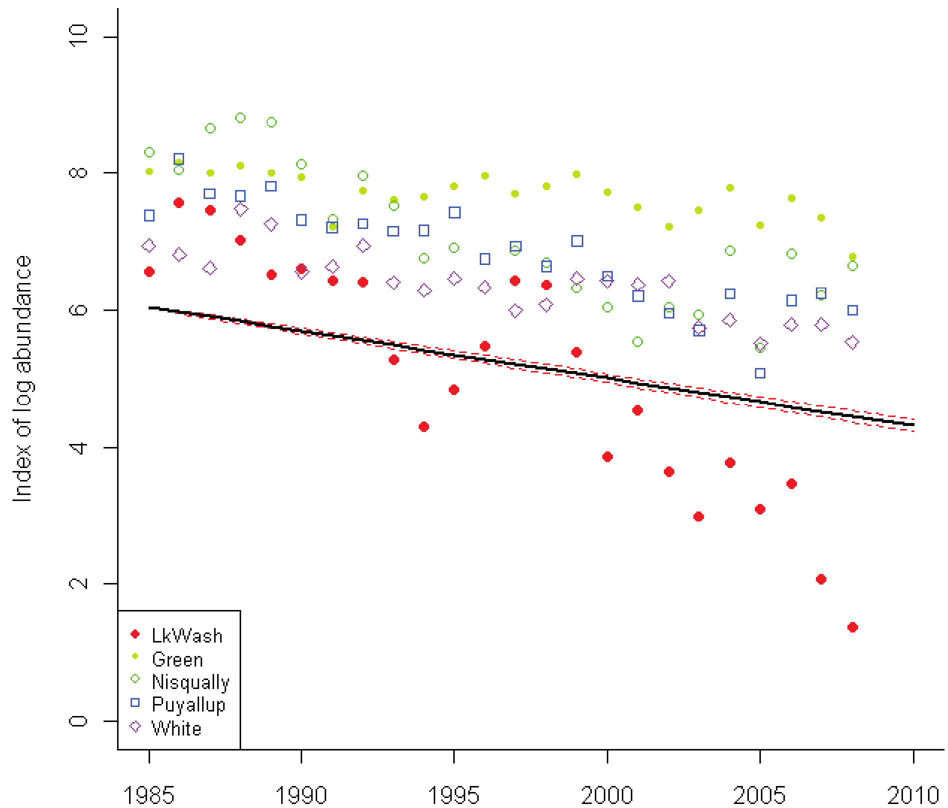

Figure 143. Plot of the observations and total population estimate of Puget Sound winter-run steelhead for a putative South Sound MPG by year. The graph plots the maximum-likelihood estimate of log(total no. steelhead) in the MPG against the observed data. The estimate of the log(total MPG count) (solid line) has been scaled relative to the Lake Washington population. The 95% CIs around the total MPG estimate are given by the dashed lines. (Note that these are not the CIs around the observed data, which are expected to fall outside the CI, depending on population-specific nonprocess error.) No suitable data were available for South Sound tributaries steelhead.

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 lined left-side and lower region is where the upper 95% CIs of the projections do not exceed P = 0.05, that is, where the probability of the specified population decline is less than 5%. The lined upper and right-side region is where the lower 95% CIs of the projections exceed P = 0.95, that is, where the probability of the specified population decline is greater than 95%. The gray regions define less certain areas of parameter space between these extremes, with the dark gray 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 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.

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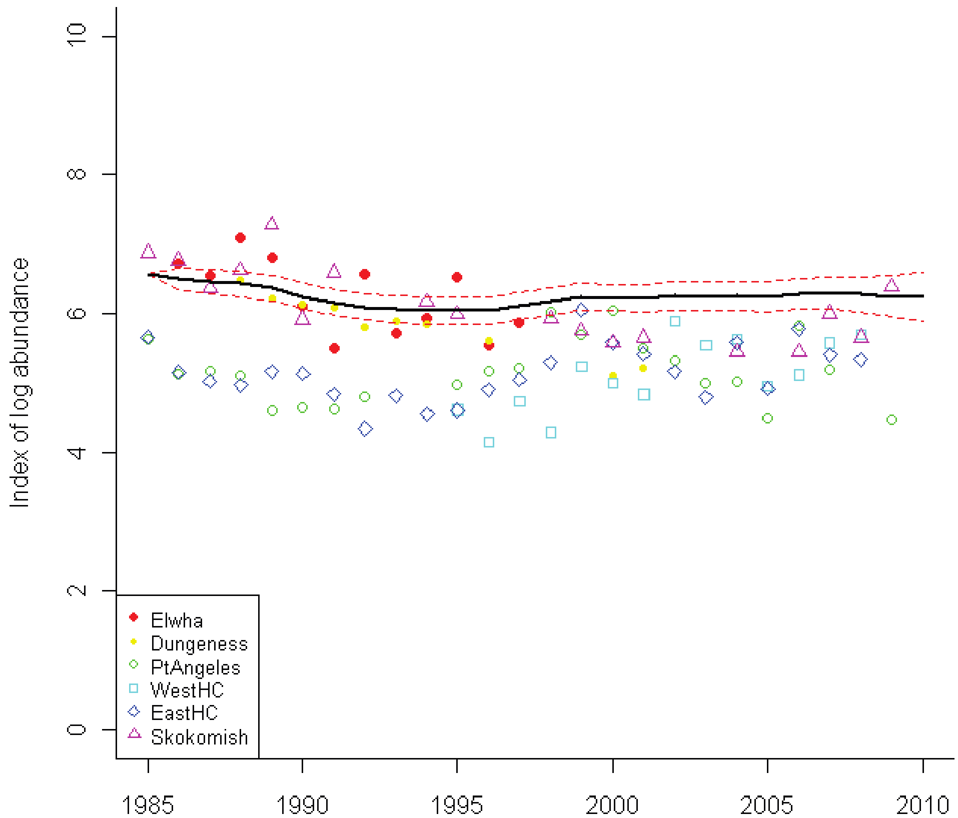

Figure 144. Plot of the observations and total population estimate of Puget Sound winter-run steelhead for a putative Olympic MPG by year. The graph plots the estimate of log(total no. steelhead) in the MPG against the observed data. The estimate of the log(total MPG count) (solid line) has been scaled relative to the Elwha River population. The 95% CIs around the total MPG estimate are given by the dashed lines. (Note that these are not the CIs around the observed data, which are expected to fall outside the CI, depending on population-specific nonprocess error.)

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 Puget 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 the ESU/DPS

The BRT 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 3 years since listing, the status of this threat has not changed appreciably.

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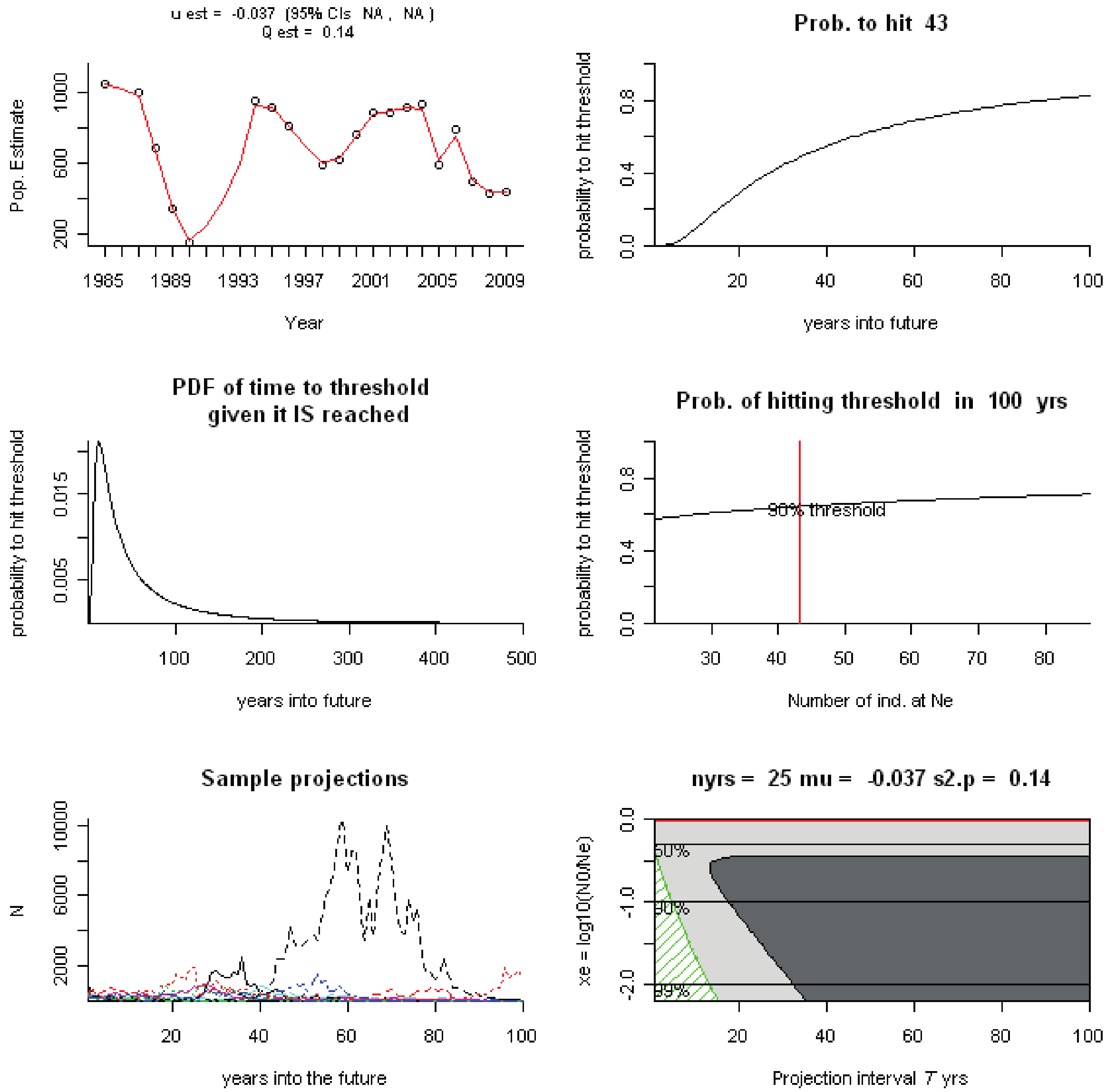

Figure 145. Population trends for Samish River winter-run steelhead. Steelhead counts in the Samish River have declined sharply in recent years. Assuming these counts are a reasonable reflection of spawner abundance, the estimated probability that this steelhead population would decline to 10% of its 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 (λ = 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.

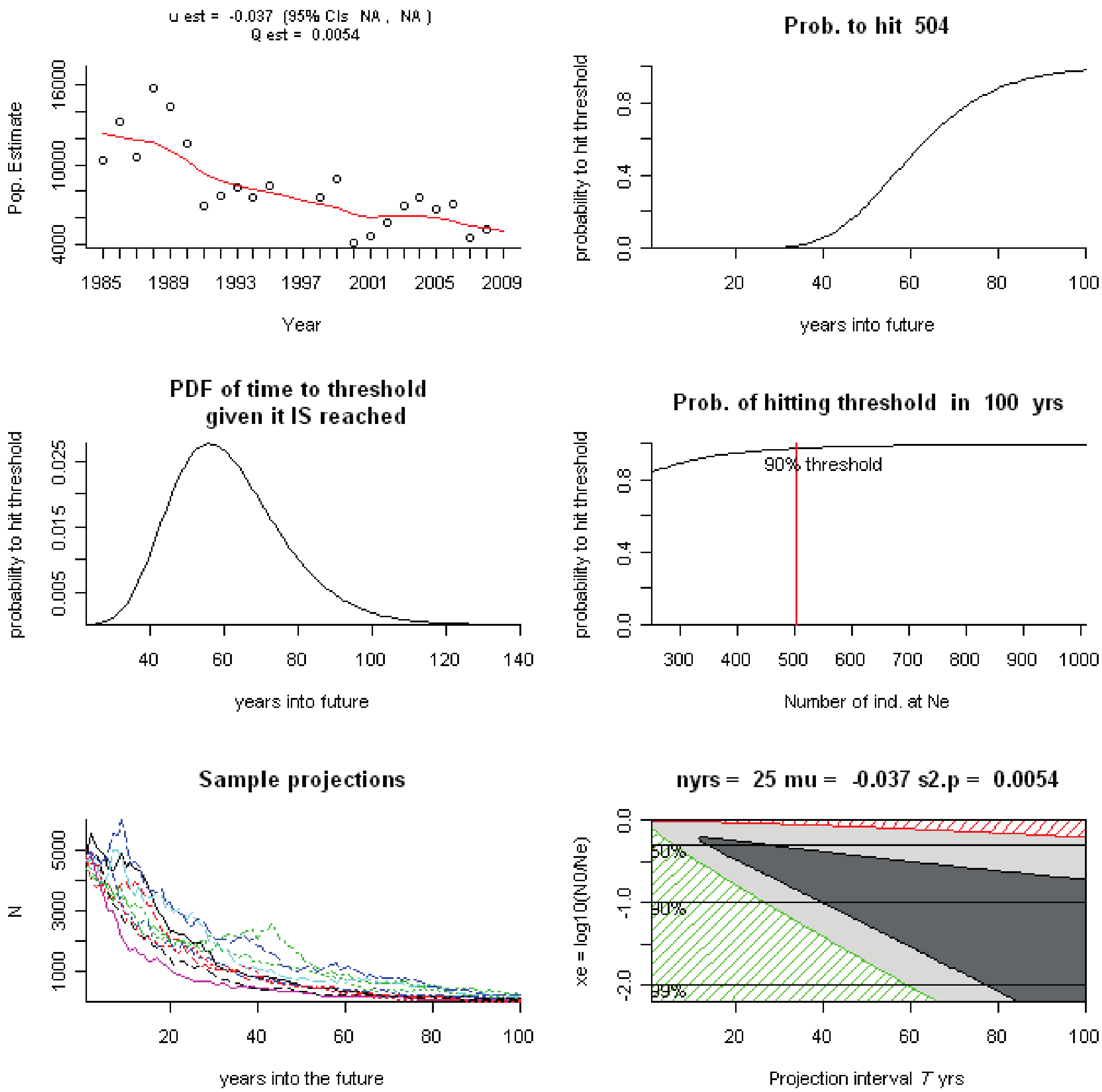

Figure 146. Population trends for Skagit River winter-run steelhead. Steelhead counts in the Skagit River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 504 fish) is high—about 80% within 75 years. With an estimated mean population growth rate of −0.037 (λ = 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.

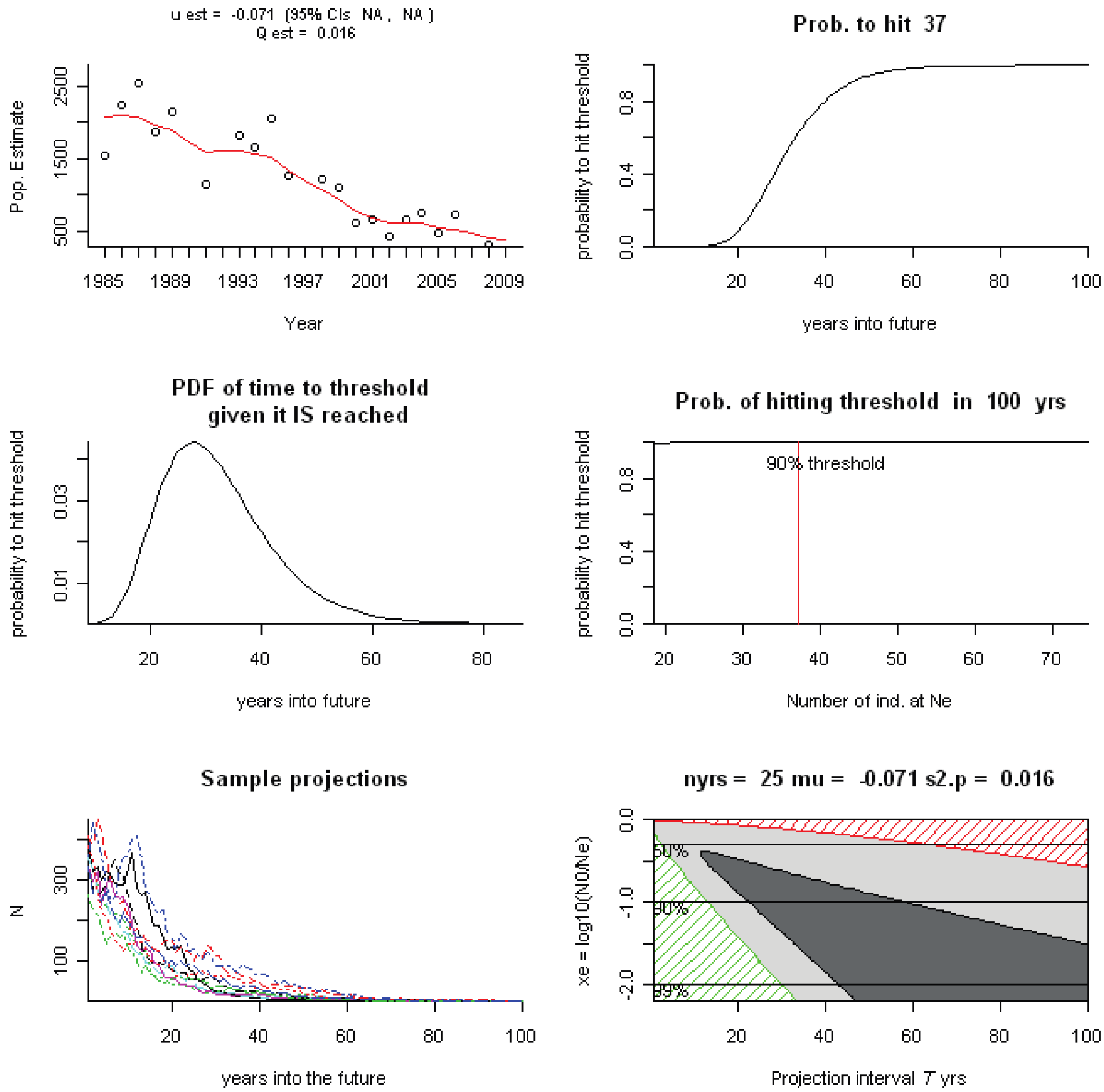

Figure 147. Population trends for Stillaguamish River winter-run steelhead. Steelhead counts in the Stillaguamish River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 37 fish) is high—about 90% within 60 years. With an estimated mean population growth rate of −0.071 (λ = 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.

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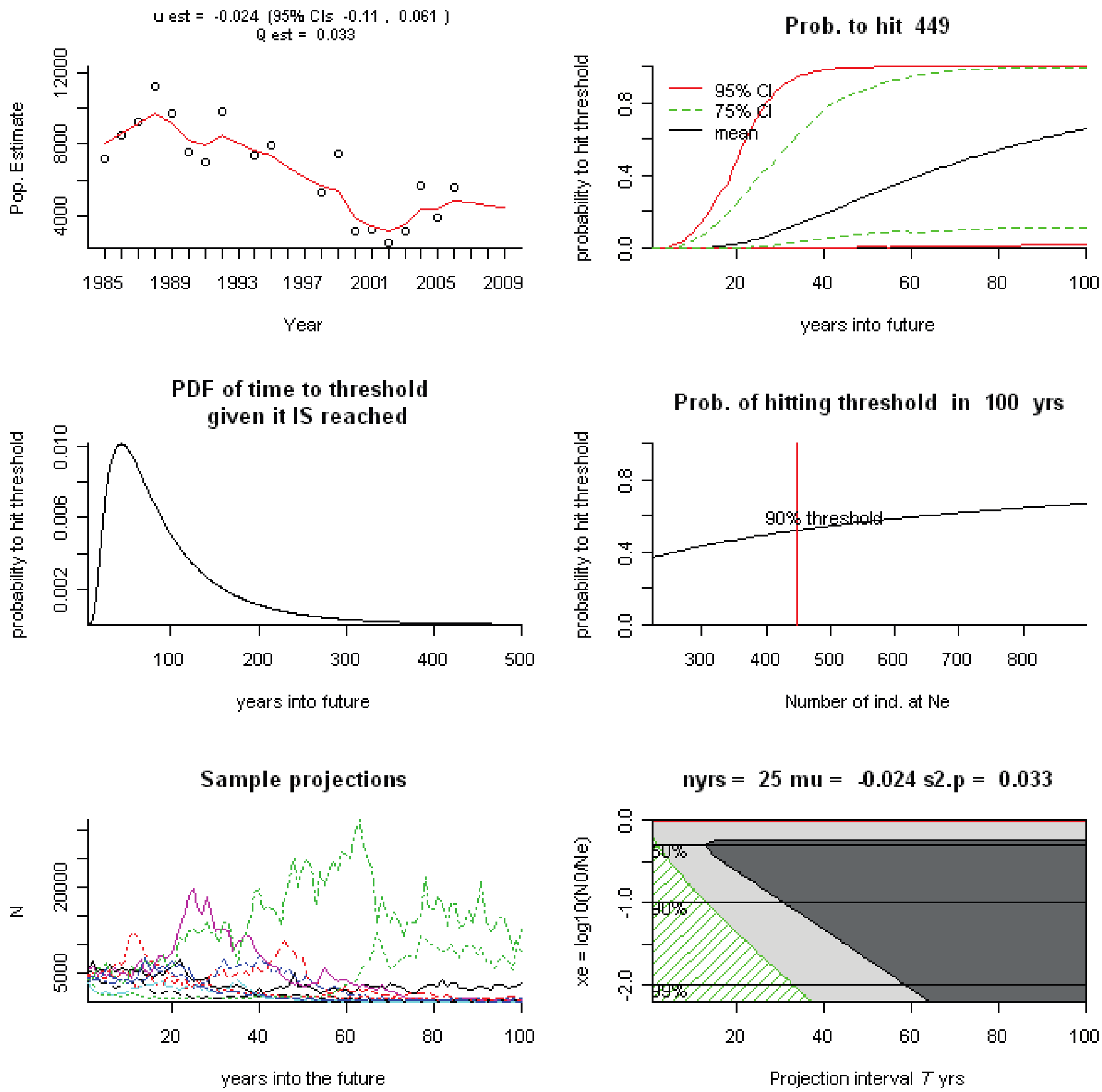

Figure 148. Population trends for Snohomish River winter-run steelhead. Steelhead counts in the Snohomish River have declined since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 445 fish) is moderately high—about 50% within 100 years. With an estimated mean population growth rate of −0.024 ($\lambda = 0.976$) 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.

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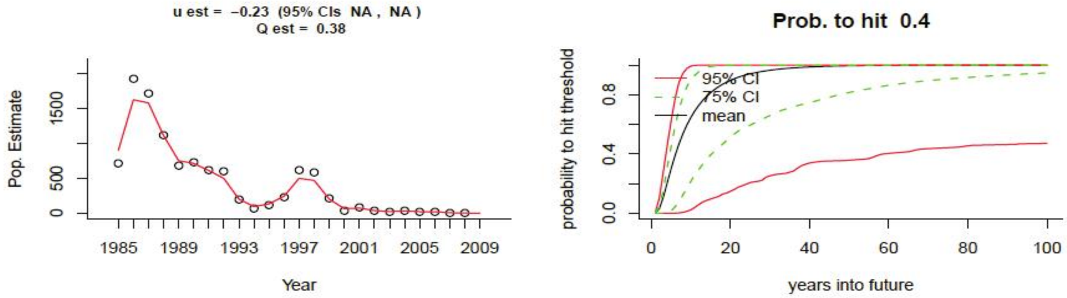

Figure 149. Population trends for Lake Washington winter-run steelhead. The counts have been very low since 2000. The estimated mean population growth rate is −0.23 (λ = 0.794) and process variance is 0.380. The estimated probability that the Lake Washington steelhead population would decline to 10% of its current estimated abundance (<1 fish) is high—approximately 90% within 40 years. An extinction risk envelope could not be calculated for this population from the data.

Hatchery Releases

Hatchery releases of steelhead in Puget Sound have remained relatively constant over the last 20 years, although releases of Chinook and coho salmon have declined (Figure 161).

Harvest

Puget Sound steelhead are impacted in terminal tribal gill net 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 that 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 that 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 noncompliance. In tribal net fisheries, most fishery impacts occur in fisheries directed at salmon and hatchery steelhead.

Most Puget Sound streams have insufficient 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 162). 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%.

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.

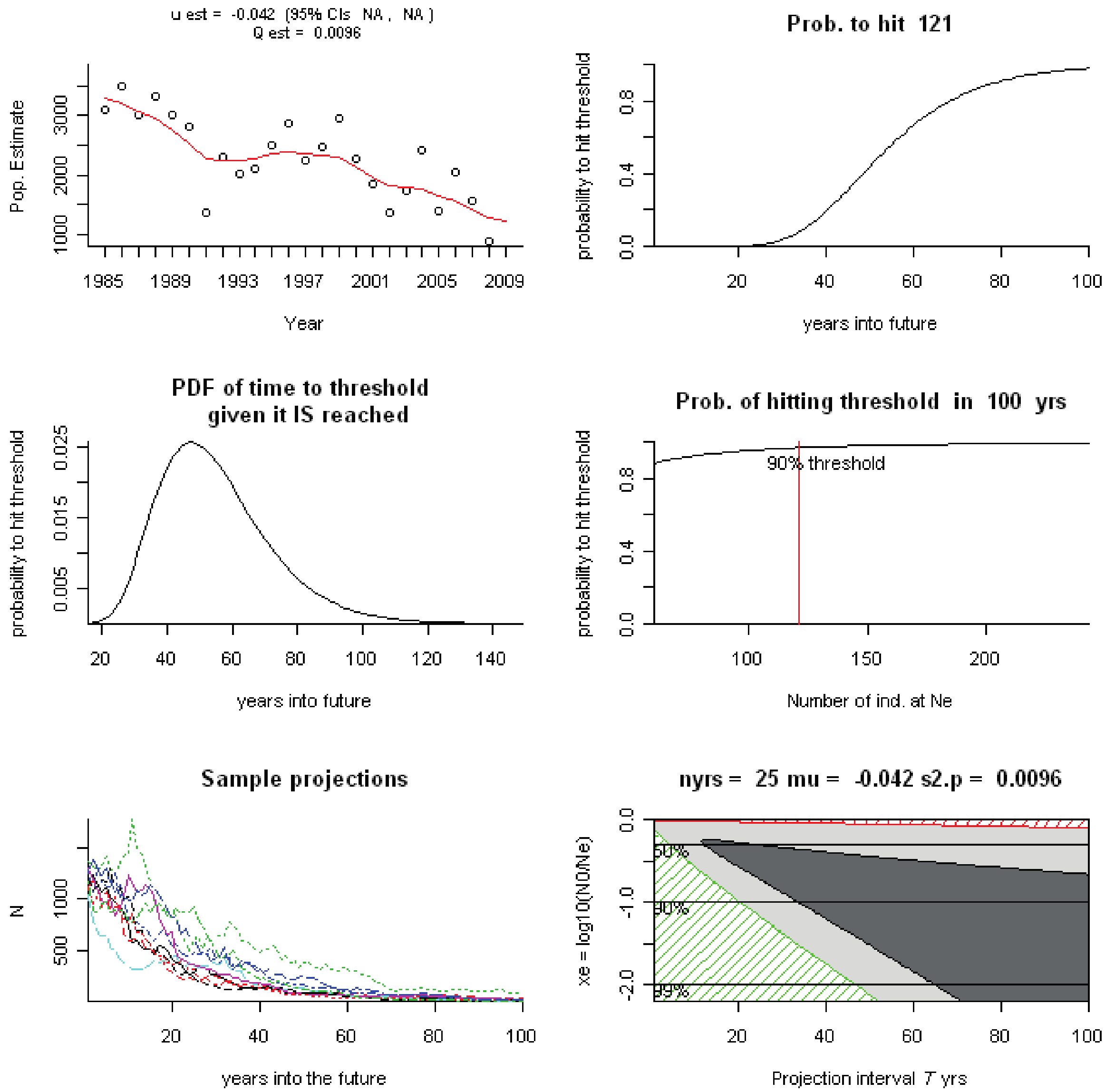

Figure 150. Population trends for Green River winter-run steelhead. Steelhead counts in the Green River have declined steadily since the 1980s and most sharply since 2005. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 45 fish) is high—about 90% within 80 years. With an estimated mean population growth rate of −0.042 ($\lambda = 0.959$) 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.

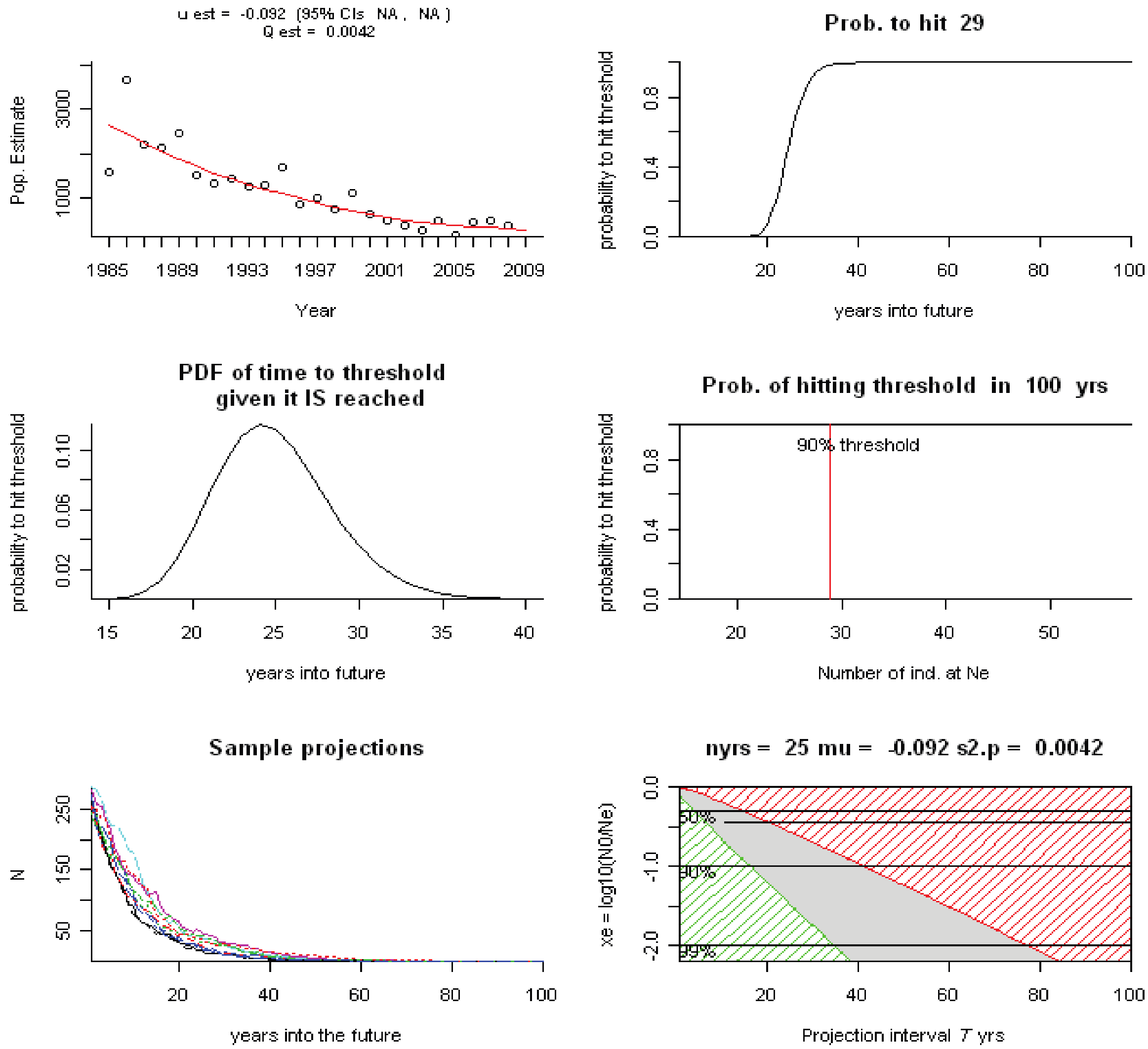

Figure 151. Population trends for Puyallup River winter-run steelhead. Steelhead counts in the Puyallup River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 29 fish) is high—about 90% within 25–30 years. With an estimated mean population growth rate of −0.092 (λ = 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.

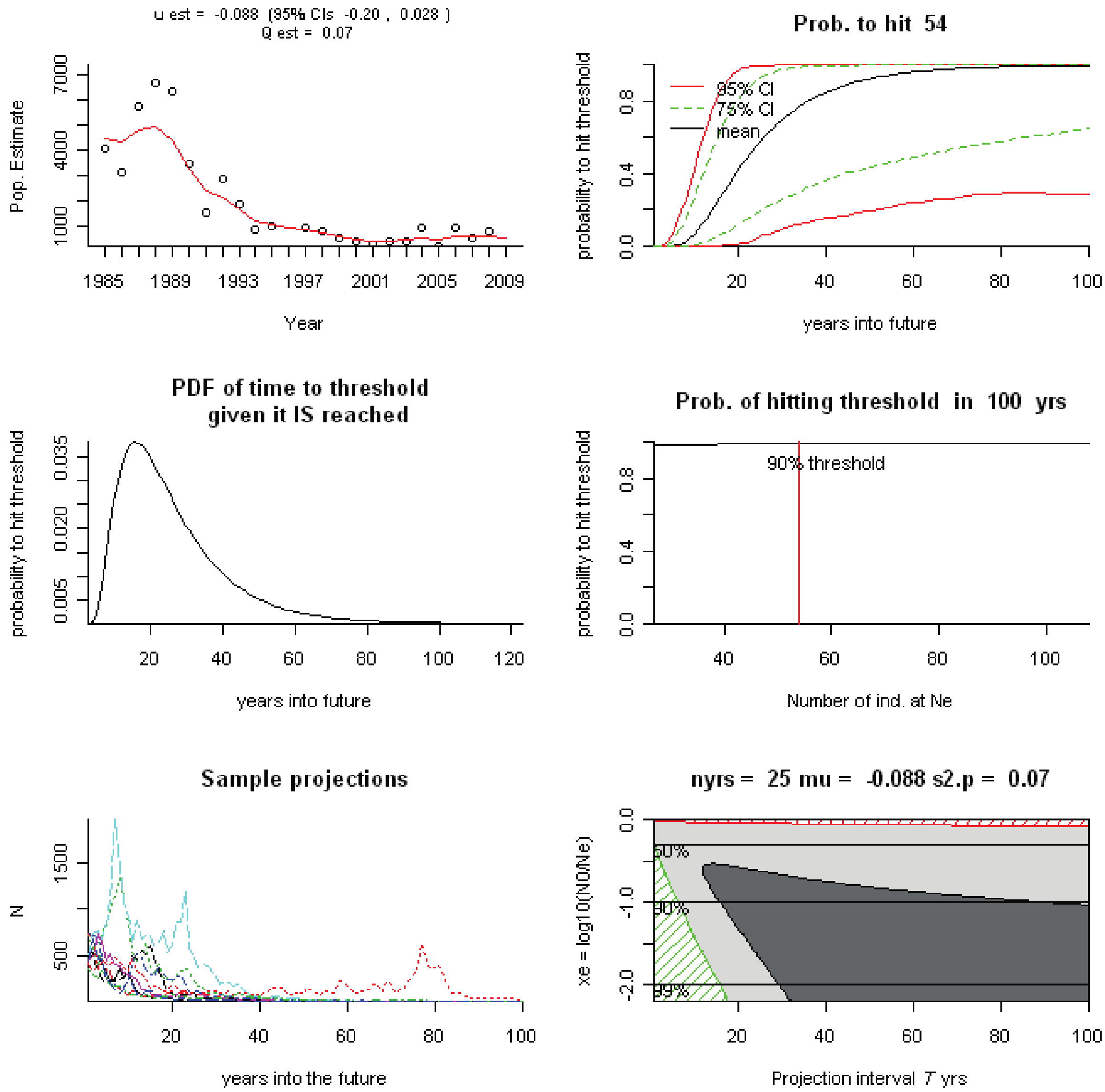

Figure 152. Population trends for Nisqually River winter-run steelhead. Steelhead counts in the Nisqually River declined steeply in the 1980s and 1990s and have remained low since. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 54 fish) is high—about 80% within 40 years. With an estimated mean population growth rate of −0.088 ($\lambda = 0.916$) 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.

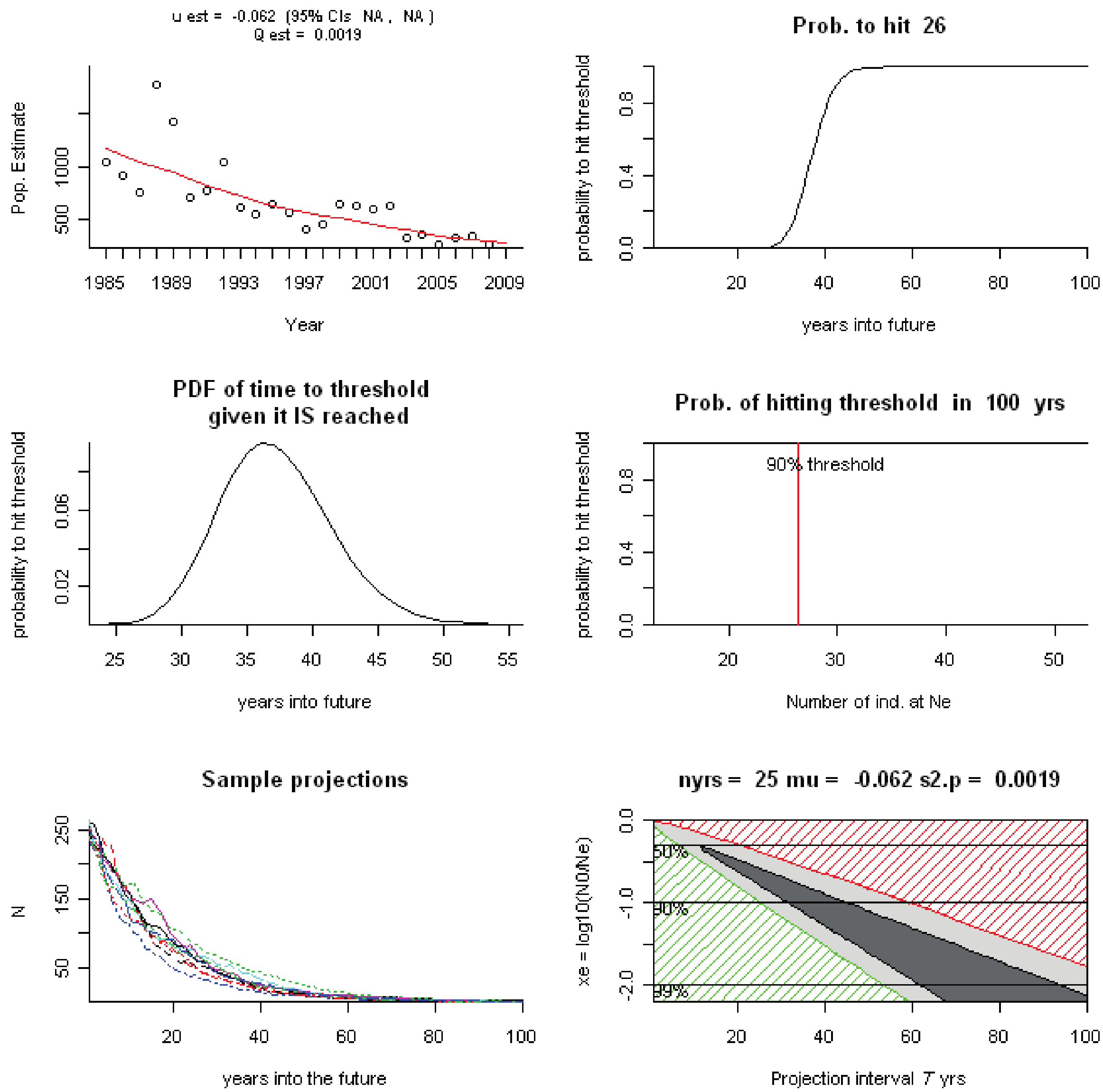

Figure 153. Population trends for White River winter-run steelhead. Steelhead counts in the White River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 26 fish) is high—about 90% within 50 years. With an estimated mean population growth rate of −0.062 ($\lambda = 0.940$) 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.

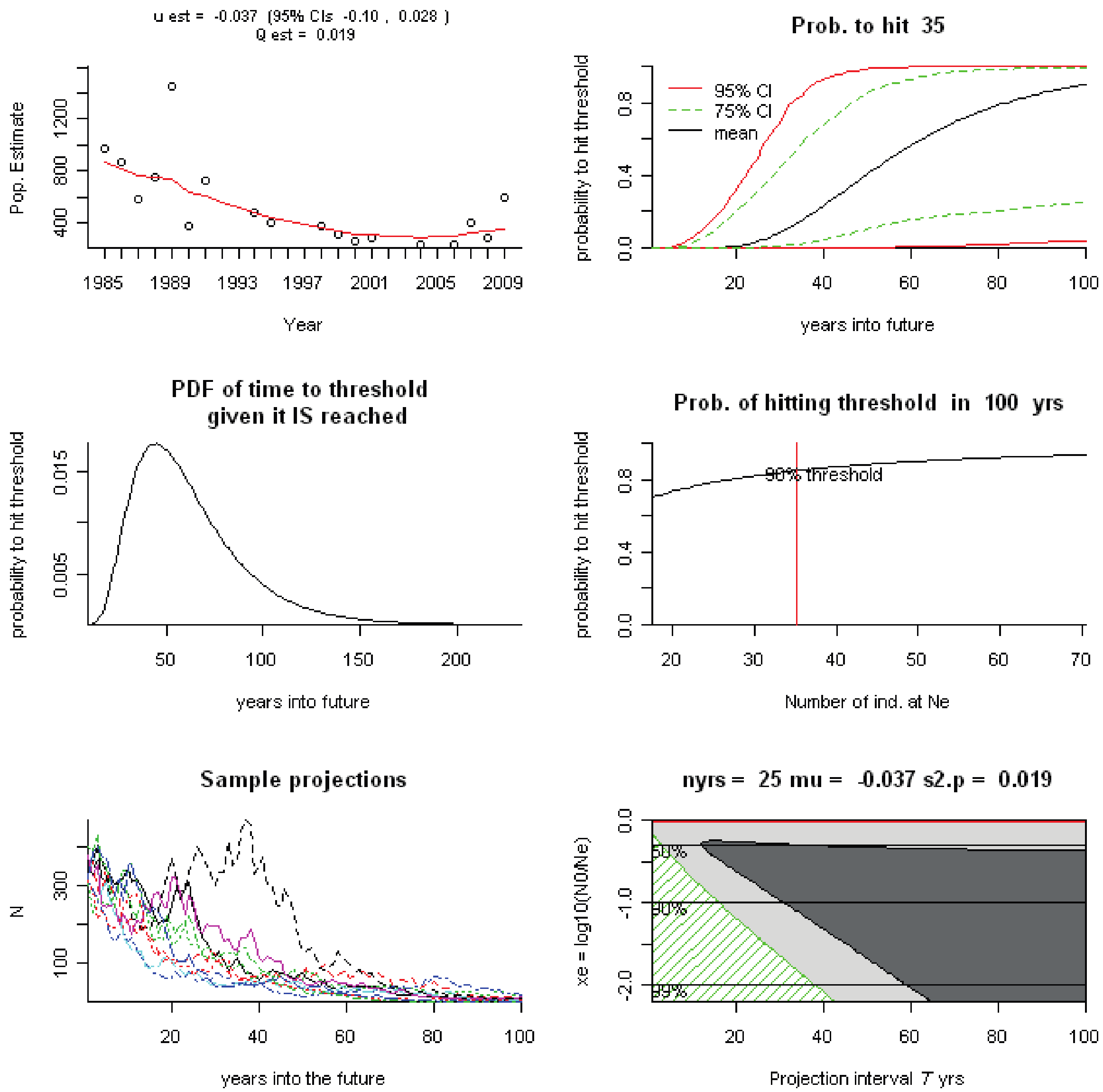

Figure 154. Population trends for Skokomish River winter-run steelhead. The counts have been especially low since the late 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 35 fish) is high—about 80% within 80 years. With an estimated mean population growth rate of −0.037 ($\lambda = 0.964$) 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.

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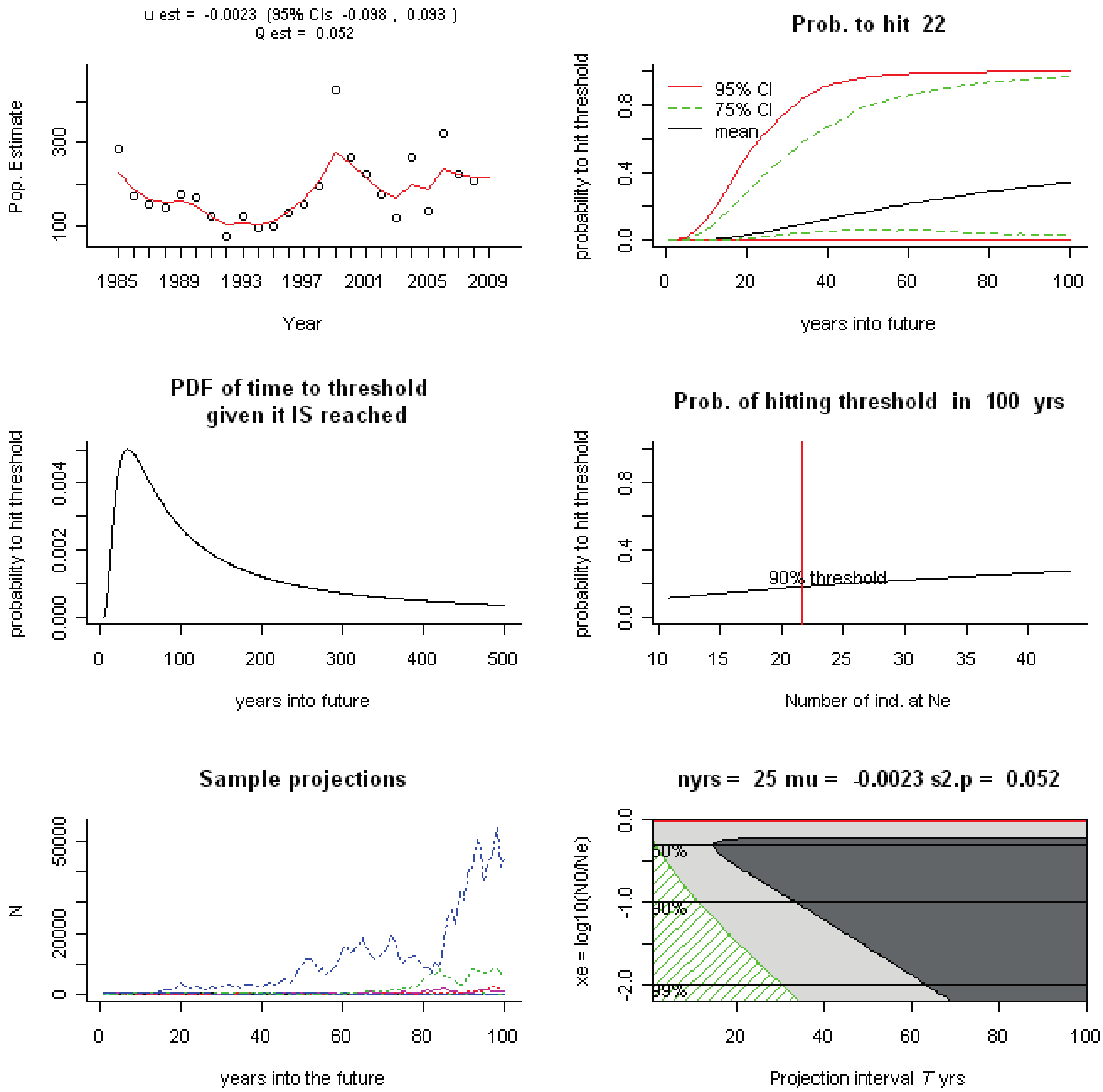

Figure 155. Population trends for east Hood Canal winter-run steelhead. Steelhead counts in east Hood Canal show no clear trend over the time series. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 22 fish) is relatively low—about 30% within 100 years. With an estimated mean population growth rate of −0.002 ($\lambda = 0.998$) 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.

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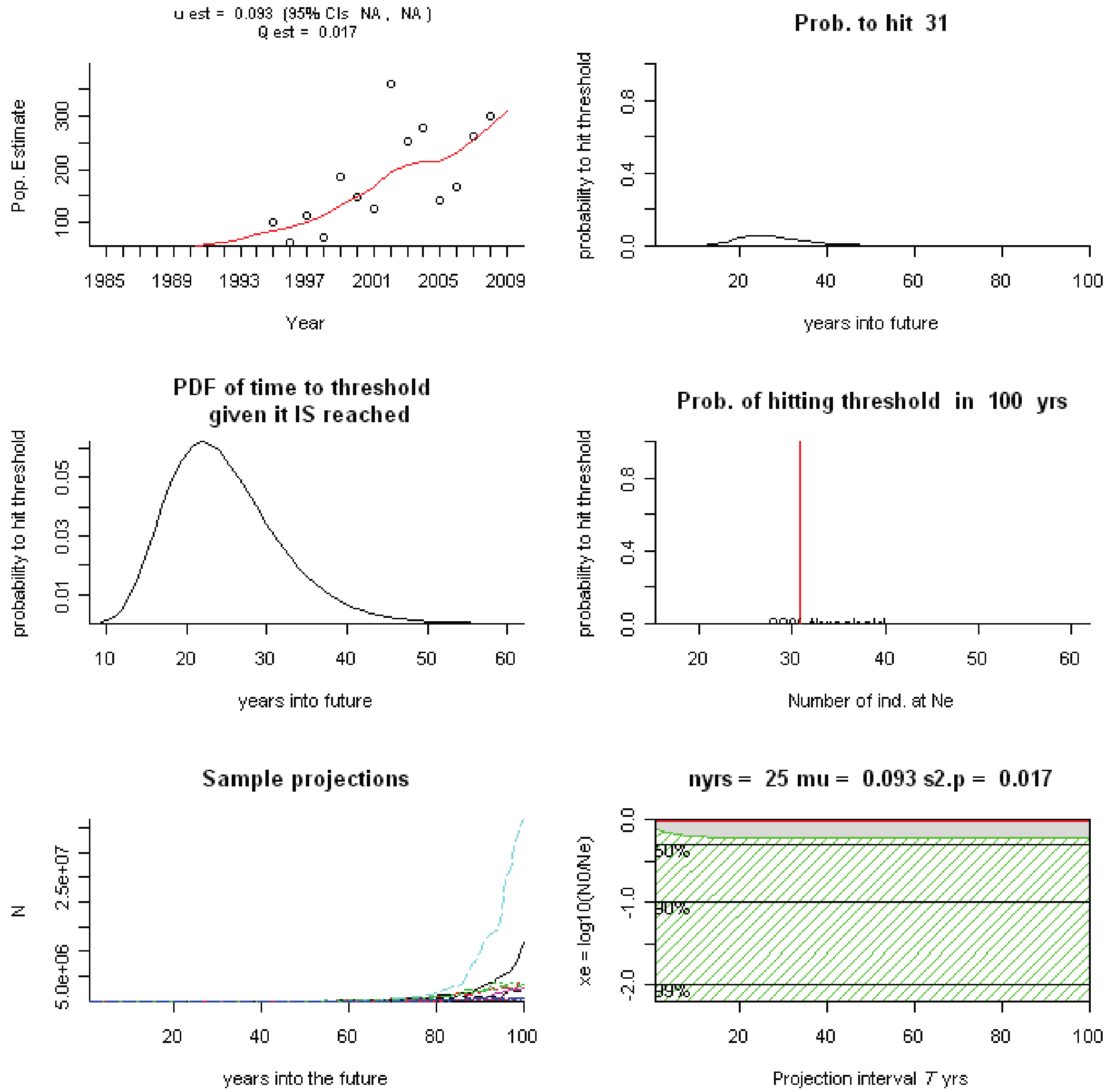

Figure 156. Population trends for west Hood Canal winter-run steelhead. Steelhead counts in west Hood Canal have shown an increasing trend since the mid 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 31 fish) is low—near 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.

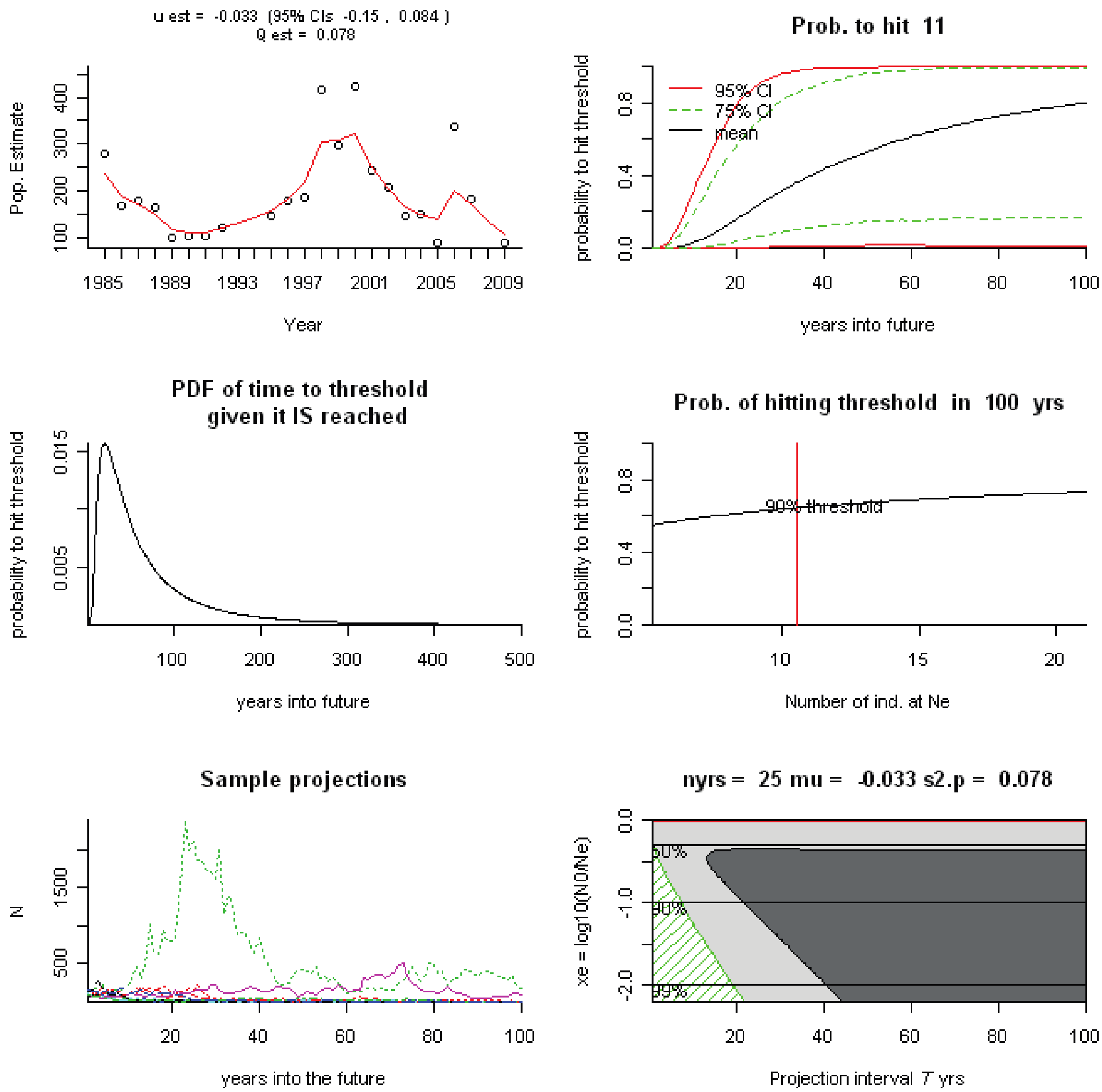

Figure 157. Population trends for Port Angeles winter-run steelhead. Steelhead counts in Port Angeles have declined sharply since the late 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 11 fish) is high—nearly 80% within 100 years. With an estimated mean population growth rate of −0.033 (λ = 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.

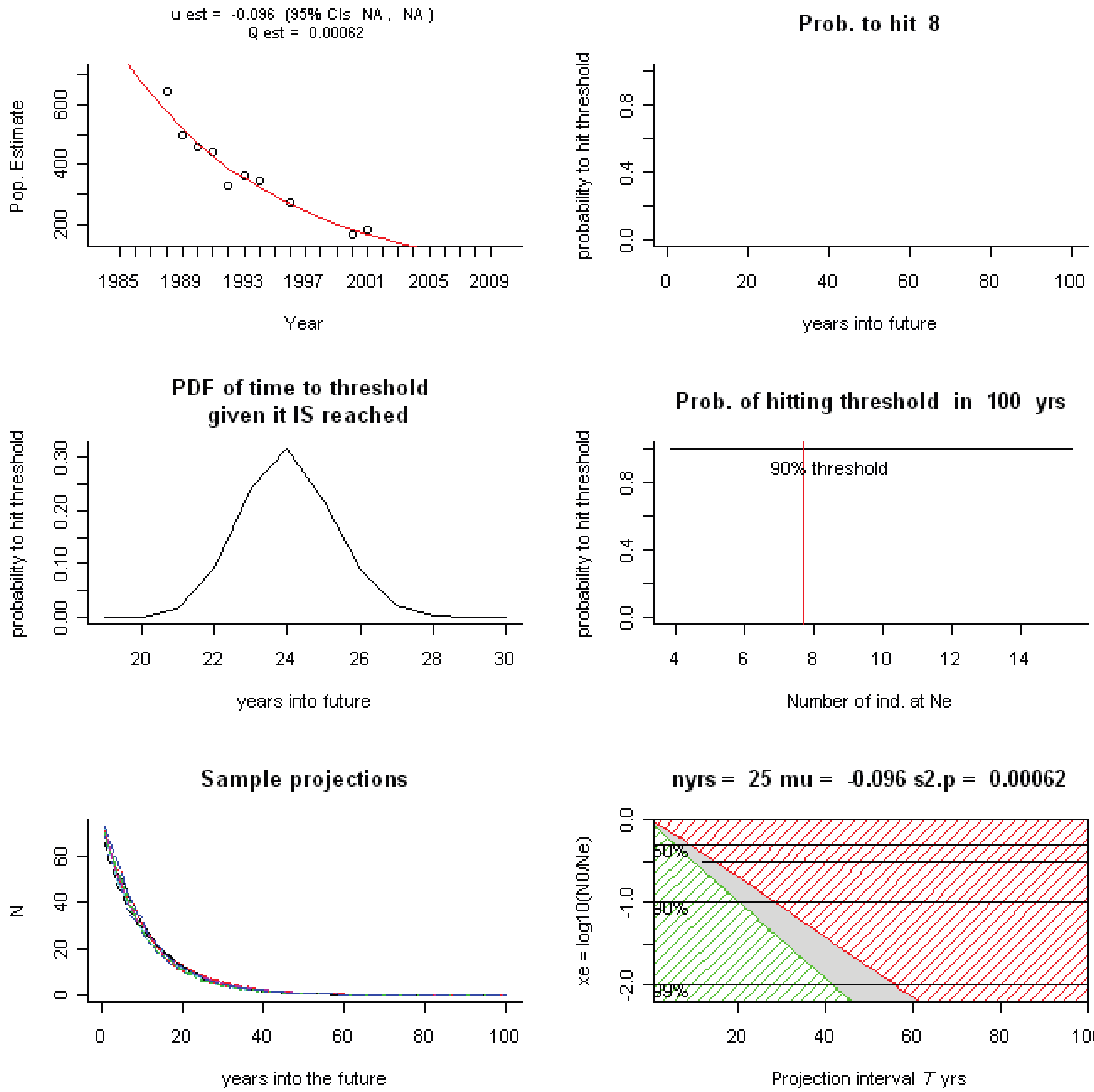

Figure 158. Population trends for Dungeness River winter-run steelhead. The counts have been very low and have steadily declined since the early 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 8 fish) within 100 years is high but could not be calculated. With an estimated mean population growth rate of −0.096 ($\lambda = 0.908$) and process variance of less than 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.

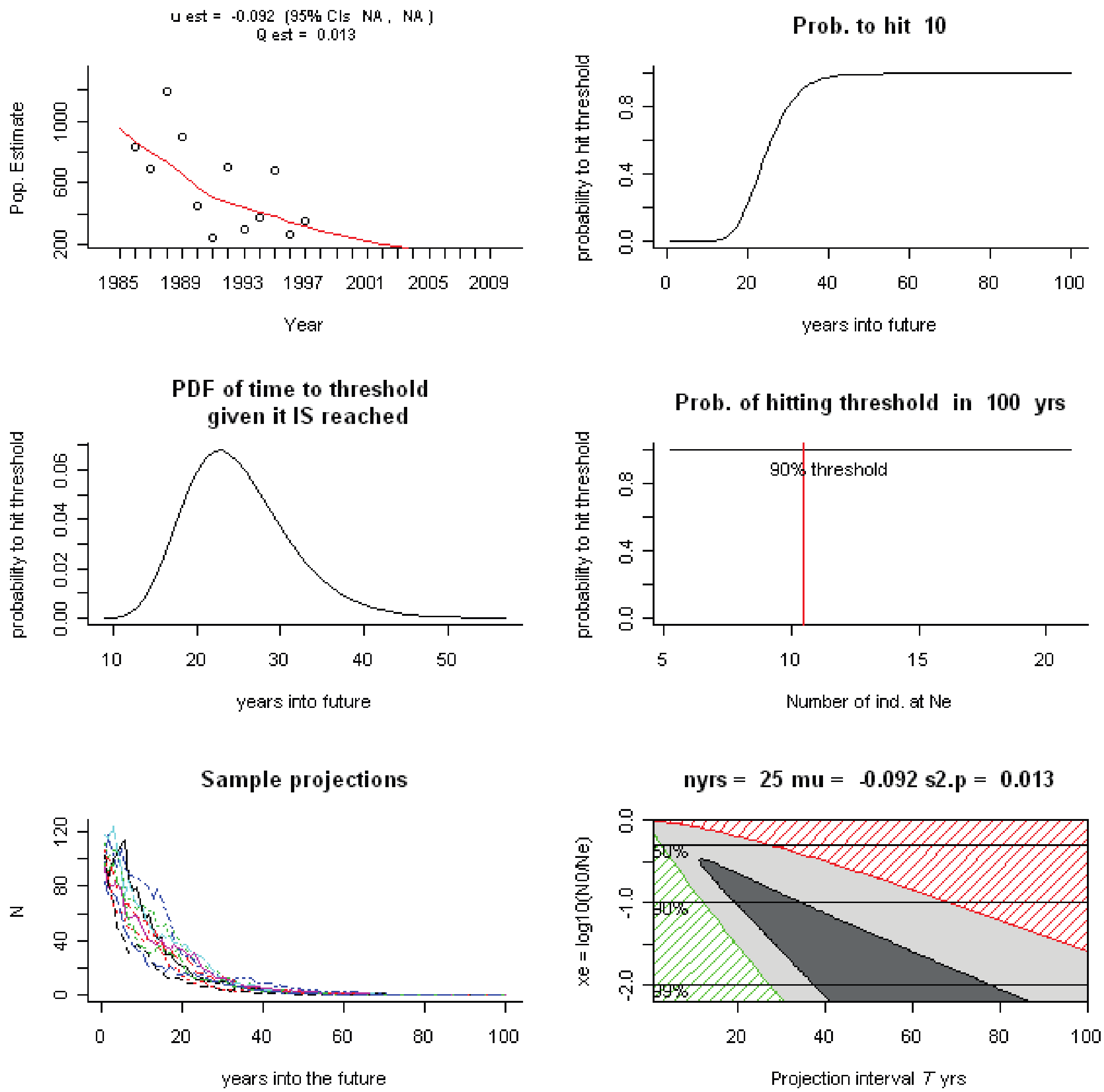

Figure 159. Population trends for Elwha River winter-run steelhead. The counts declined sharply in the late 1980s and early 1990s have been very low in recent years. The estimated probability that the Elwha River steelhead population would decline to 10% of its current estimated abundance (i.e., to 10 fish) is fairly high—approximately 90% within 40 years. With an estimated mean population growth rate of −0.092 ($\lambda = 0.912$) 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.

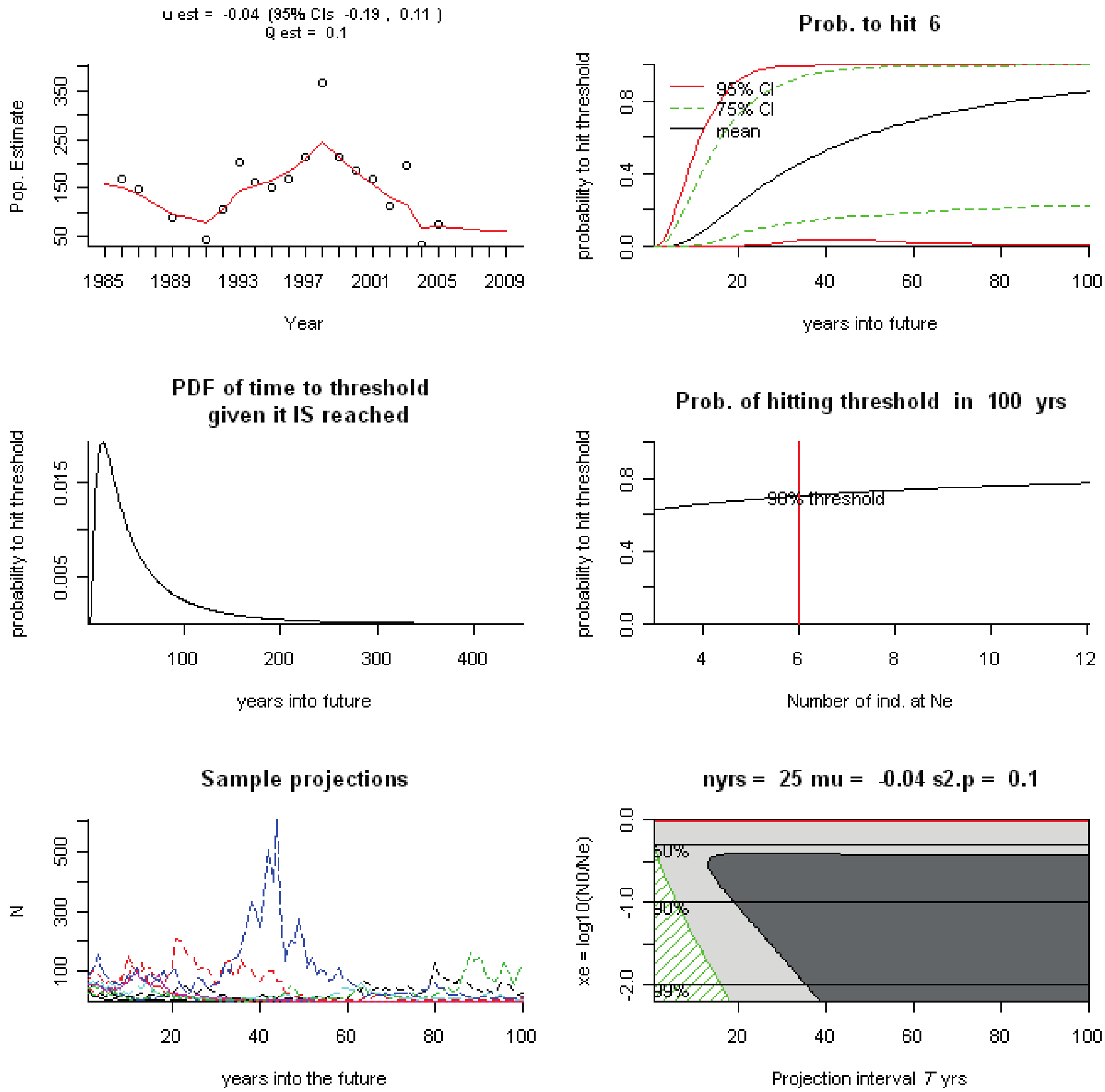

Figure 160. Population trends for Tolt River summer-run steelhead (the only summer-run population for which redd count data are available). Steelhead counts in the Tolt River have declined since the late 1990s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 6 fish) is high—nearly 80% within 100 years. With an estimated mean population growth rate of −0.040 ($\lambda = 0.961$) 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 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.

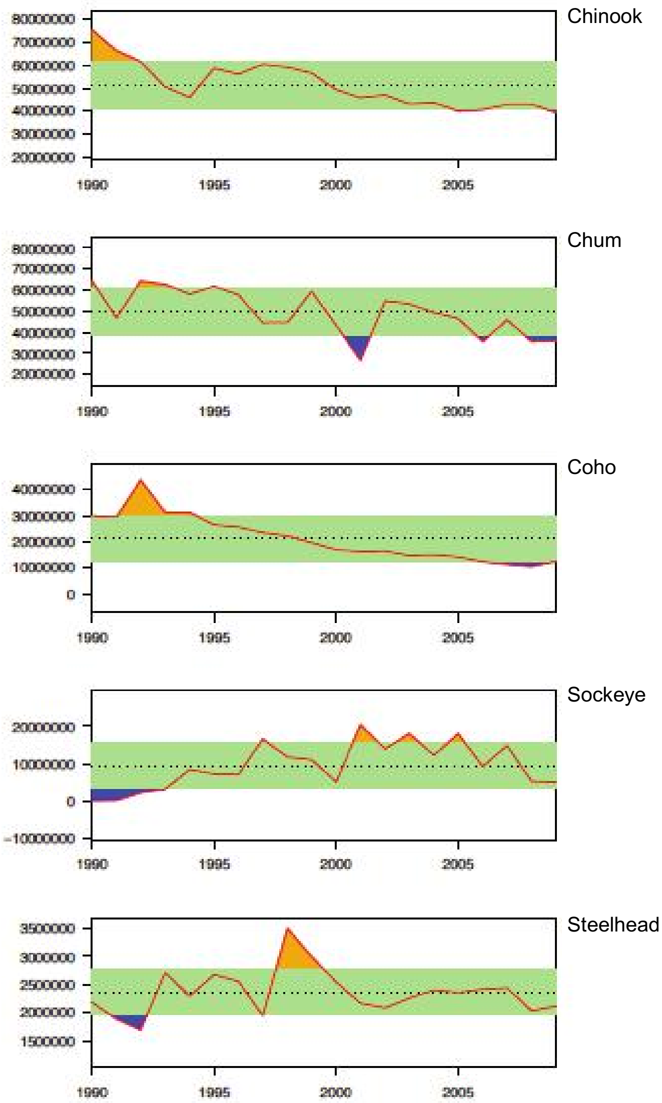

Figure 161. Summary of annual hatchery releases by year within the spawning and rearing areas of the Puget Sound Steelhead DPS. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from RMIS.

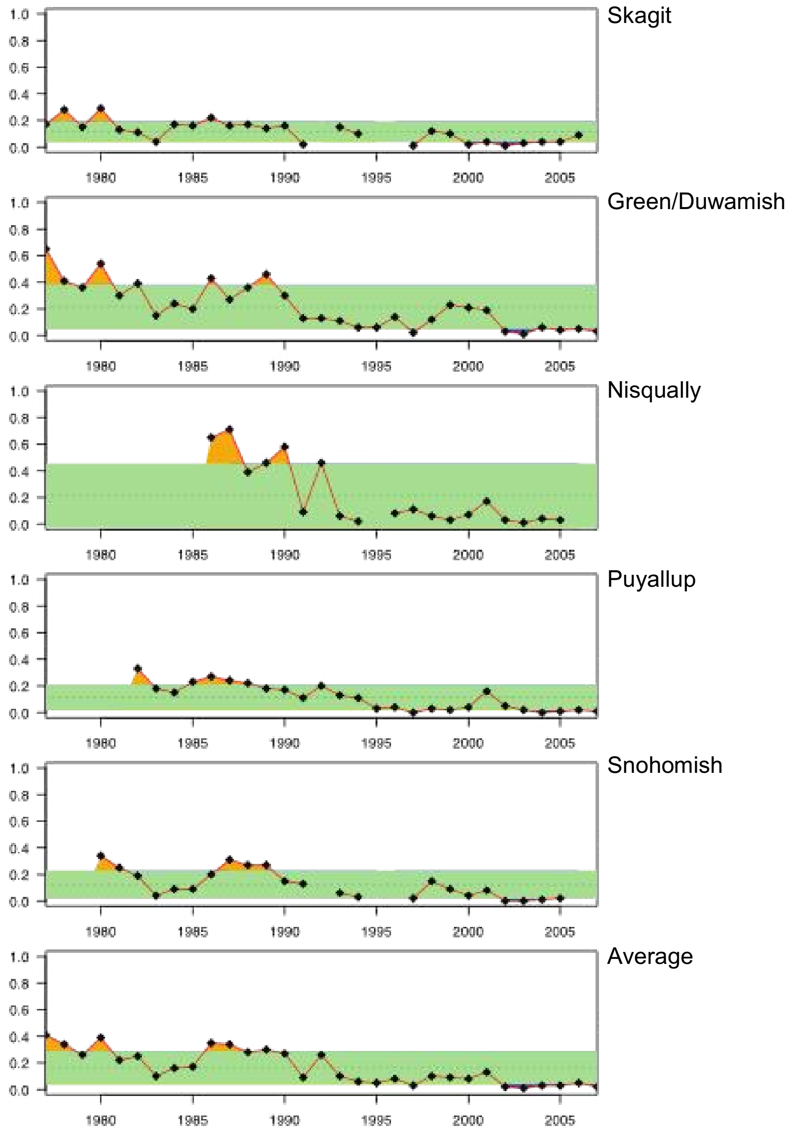

Figure 162. Total exploitation rates by year on natural steelhead from Puget Sound rivers. The dotted line and shaded area indicate the long-term mean and ±1 SD, respectively. Data from the Puget Sound Steelhead Harvest Management Plan, Appendix A.[25]

[25] B. Leland, WDFW, Olympia, WA. Pers. commun., 12 July 2010.

Climate Change

Climatic conditions affect anadromous salmonid A/P, 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 the 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 snowpack, for instance, are likely to be most strongly felt in snowmelt-driven systems, while changes in patterns of freshwater 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. in press, especially Appendix C).

Known Climate-linked Effects on Anadromous Salmonid Populations

Ocean and Estuarine Life Stages

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). Specifically, the Pacific Decadal Oscillation (PDO), 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 (Pearcy 2002, Wing 2006, Cheung et al. 2009).

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 downwelling pattern; this transitions in the spring to a summer upwelling (Checkley and Barth 2009). Upwelling strength is also associated with salmonid productivity (Zabel et al. 2006, Petrosky and Schaller 2010).

Freshwater Life Stages

There are also links between climatic conditions and freshwater survival and productivity. In particular, the warm phases of the El Niño Southern Oscillation or the PDO generally produce warmer, drier years in terrestrial habitats. This in turn leads to below-average

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snowpack and stream flow (Mote et al. 2003), which have effects on salmonid populations; they 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 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 streambeds 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, subsection 11.5). All of these are based on global climate models that were included in assessments by the U.S. Global Change Research Program and the International Panel on Climate Change. 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 75.

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 food web 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 toward 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 and 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 and cold, nutrient-rich waters). Therefore, it is not clear whether the thermocline depth will be sufficiently shallow such that upwelling is able to bring nutrient rich water to the surface, rather than warm, nutrient-poor water.

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Table 75. Summary of expected physical and chemical climate changes in the Pacific Northwest. (Adapted from Table 14 in Stout et al. in press.)

Pattern	Certainty	Sources
Increased air temperature	High	Mote et al. 2003, Mote 2003b, Leung et al. 2004, Mote et al. 2008b, Karl et al. 2009
Increased winter precipitation	Low	Mote et al. 2003, Mote 2003a, 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 and spring snowpack	High	Barnett et al. 2004, Stewart et al. 2004, Hamlet et al. 2005, Mote et al. 2005, Stewart et al. 2005, Mote 2006, Barnett et al. 2008, 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 and intensity	Moderate	Mote et al. 2003, Leung et al. 2004, Hamlet and 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 and 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	Feely et al. 2004, Bindoff et al. 2007, Fabry et al. 2008, Feely et al. 2008

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 PDOs, 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 (Mote et al. 2003, Karl et al. 2009). 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 uncertain) that precipitation will increase in the winter and decrease in the summer (Karl et al. 2009).

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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 and 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 76. 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.

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Table 76. Summary of expected climate effects on Pacific Northwest ESUs. Effect ratings are: + + strongly positive, + positive, 0 neutral, – negative, and – – strongly negative. Certainty level combines the certainty of the physical change with the certainty of the effect. (Adapted from Table 14 in Stout et al. in press.)

Habitat	Physical change	Process affecting salmon	Effect on Pacific Northwest salmonid ESUs	Certainty	Main sources
Terrestrial	Warmer, drier summers	Increased fires, increased tree stress and disease affect large woody debris (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 and 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 and 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 and Zabel 2006, ISAB 2007, Crozier et al. 2008, Mantua et al. 2009
	Earlier peak flow	Potential migration timing mismatch	– – to 0 Largest effects in transition areas that move from a snowmelt-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 snowmelt-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 and 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

Table 76 continued. Summary of expected climate effects on Pacific Northwest ESUs. Effect ratings are: + + strongly positive, + positive, 0 neutral, – negative, and – – strongly negative. Certainty level combines the certainty of the physical change with the certainty of the effect. (Adapted from Table 14 in Stout et al. in press.)

Habitat	Physical change	Process affecting salmon	Effect on Pacific Northwest salmonid ESUs	Certainty	Main sources
	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 and 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 and parasites	– – to – Effects likely to vary by ESU, dependent on ocean distribution	Moderate	Welch et al. 1995, Cole 2000, Marine and 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 and Pearcy 1988
	Delayed spring transition	Food timing mismatch with outmigrants, ecosystem shifts	– – to 0 Effects likely to vary by ESU dependent on correspondence of outmigration with upwelling patterns	Moderate	Brodeur et al. 2005, Emmett et al. 2006, Schwing et al. 2006,
	Increased acidity	Disruption of food supply, ecosystem shifts	– – to – Effects likely to vary by ESU, dependent on 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 on age and size at outmigration and ocean distribution	Low	Peterson and Schwing 2003, Brodeur et al. 2005, Emmett et al. 2006, Fabry et al. 2008, Bograd et al. 2009

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