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Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead

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Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead

Edited by
Thomas P. Good, Robin S. Waples, and Pete Adams*

From contributions by the editors and
Eric P. Bjorkstedt*, David Boughton*, Thomas Cooney,
Richard G. Gustafson, Peter W. Lawson, Steven T. Lindley*,
Paul McElhany, James M. Myers, Orlay Johnson,
Mary H. Ruckelshaus, Norma Jean Sands, Brian C. Spence*,
Sarah Sydor, Thomas C. Wainwright, and Laurie A. Weitkamp

Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112

* Southwest Fisheries Science Center
Santa Cruz Laboratory
110 Shaffer Road
Santa Cruz, California 95060

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U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary

National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr. USN (Ret), Administrator

National Marine Fisheries Service
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Executive Summary

During the 1990s, the National Marine Fisheries Service (NMFS or NOAA Fisheries Service) conducted a series of reviews of the status of West Coast populations of Pacific salmon and steelhead (*Oncorhynchus* spp.) with respect to the U.S. Endangered Species Act (ESA). This technical memorandum summarizes scientific conclusions of the NMFS Biological Review Teams (BRTs) regarding the updated status of 26 ESA-listed ESUs (evolutionarily significant units) of salmon and steelhead (and one candidate species ESU) from Washington, Oregon, Idaho, and California. These ESUs were listed following a series of status reviews conducted during the 1990s. The status review updates were undertaken to allow consideration of new data that accumulated over the various time periods since the last updates and to address issues raised in recent court cases [*Alsea Valley Alliance v. Evans*, 161 F. Supp. 2d 1154, D. Oreg. 2001*,* and *EDC v. Evans,* SACV-00-1212-AHS (EEA); *MID v. Evans,* CIV-F-02-6553 OWW DLB (E.D. Cal)] regarding the ESA status of hatchery fish and resident (nonanadromous) populations.

This technical memorandum represents the first major step in the agency's efforts to review and update the listing determinations for all listed ESUs of salmon and steelhead. By statute, ESA listing determinations must consider not only the best scientific information available but also those efforts being made to protect the species. After receiving the BRT report and considering the conservation benefits of protective efforts, NMFS will determine what changes, if any, to propose to the listing status of the affected ESUs.

As in the past, the BRTs used a risk-matrix method to quantify risks in different categories within each ESU. In the current report, the method was modified to reflect the four major criteria identified in the NMFS viable salmonid populations (VSPs) document (McElhany et al. 2000): abundance, growth rate/productivity, spatial structure, and diversity. These criteria are used as a framework for approaching formal ESA recovery planning for salmon and steelhead. Tabulating mean risk scores for each element allowed the BRTs to identify the most important concerns for each ESU and to compare relative risk across ESUs and species. The BRTs considered these data and other information in making their overall risk assessments. Based on provisions in a draft of the revised NMFS policy on consideration of artificial propagation in salmon listing determinations, each BRT's risk analysis focused on the viability of populations sustained by natural production.

Based on the criterion of self-sustainability, for the following ESUs the majority BRT conclusion was "in danger of extinction:" Upper Columbia River spring-run Chinook (*Oncorhynchus tshawytscha*), Sacramento River winter-run Chinook, Upper Columbia River steelhead (*O. mykiss*), Southern California steelhead, California Central Valley steelhead, Central California Coast coho (*O. kisutch*), Lower Columbia River coho, Snake River sockeye (*O. nerka)*. For the following ESUs, the majority BRT conclusion was "likely to become endangered in the foreseeable future:" Snake River fall-run Chinook, Snake River spring/summer-run Chinook, Puget Sound Chinook, Lower Columbia River Chinook, Upper Willamette River Chinook, California Coastal Chinook, Central Valley spring-run Chinook, Snake River steelhead, Lower Columbia River steelhead, Upper Willamette River steelhead, Northern California steelhead, Central California Coast steelhead, South-Central California Coast steelhead, Oregon Coast coho, Southern Oregon/Northern California Coasts coho, Ozette Lake sockeye, Hood Canal summer-run chum, and Lower Columbia River chum. In one case (Middle Columbia River steelhead), the BRT was nearly evenly split on the question of whether the ESU was likely to become endangered in the foreseeable future (a slight majority concluded that the ESU was likely to become endangered) (Table ES-1).

Table ES-1. BRT conclusions regarding updated status of salmon and steelhead ESUs. X = the majority vote. (X) = a substantial minority (>40% of the vote).

Species	ESU	Danger of extinction	Likely to become endangered	Not likely to become endangered
Chinook	Snake River fall run	–	X	–
	Snake River spring/summer run	–	X	–
	Upper Columbia River spring run	X	(X)	–
	Puget Sound	–	X	–
	Lower Columbia	–	X	–
	Upper Willamette	–	X	–
	California Coastal	–	X	–
	Sacramento River winter run	X	–	–
	Central Valley spring run	–	X	–
Steelhead	Snake River Basin	–	X	–
	Upper Columbia River	X	(X)	–
	Middle Columbia River	–	X	(X)
	Lower Columbia River	–	X	–
	Upper Willamette River	–	X	–
	Northern California	–	X	–
	Central California Coast	–	X	–
	South-Central California Coast	–	X	–
	Southern California	X	–	–
	California Central Valley	X	–	–
Coho	Oregon Coast	–	X	(X)
	Southern Oregon/Northern California Coasts	–	X	–
	Central California	X	–	–
	Lower Columbia	X	–	–
Sockeye	Snake River	X	–	–
	Ozette Lake	–	X	–
Chum	Hood Canal summer run	–	X	–
	Columbia River	–	X	–

Acknowledgments

We are grateful to the large number of regional biologists who provided raw data and information used in this report. This report 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 Andrew Albaugh, Charlene Bergeron, Ronda Carbary, Henry Carson, Kurt Davis, Christopher Donohoe, Tamara Harms, Christine Holt, Andrea Jarvela, Laura Johnston, Jenny Moslemi, Jessica Piasecke, Cory Ruedebusch, Brycen Swart, J. J. Westfall, and Thomas Williams.

Abbreviations and Acronyms

BRT	Biological Review Team
CBD	Center for Biological Diversity
DPS	distinct population segment
ESA	U.S. Endangered Species Act
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
FEMAT	Forest Ecosystem Management Assessment Team
NMFS	National Marine Fisheries Service (also referred to as NOAA Fisheries)
NOAA	National Oceanic and Atmospheric Administration
PDO	Pacific Decadal Oscillation
PVA	population viability analysis
SASSI	Salmon and Steelhead Stock Inventory
SSHAG	Salmon and Steelhead Hatchery Assessment Group
TRT	Technical Recovery Team
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid population

INTRODUCTION AND METHODS

1. Introduction

During the 1990s, the National Marine Fisheries Service (NMFS or NOAA Fisheries Service) conducted a series of reviews of the status of West Coast populations of Pacific salmon and steelhead (*Oncorhynchus* spp.) with respect to the U.S. Endangered Species Act (ESA). Initially, these reviews were in response to petitions for populations of a particular species within a particular geographic area, but in 1994 the agency began a series of proactive, comprehensive ESA status reviews of all populations of anadromous Pacific salmonids from Washington, Idaho, Oregon, and California (NMFS 1994a).

The first step in these reviews is to determine the units that can be considered "species" under the ESA and hence listed as threatened or endangered, if warranted, based on their status. The ESA allows listing not only of full species but also named subspecies and distinct population segments (DPSs) of vertebrates (including fish). The ESA petitions and status reviews for Pacific salmonids have focused primarily on the DPS level. To guide DPS evaluations of Pacific salmonids, NMFS has used the policy developed in 1991 (NMFS 1991a, Waples 1991, 1995), which is described in the next section. As a result of these status reviews, NMFS has identified over 50 evolutionarily significant units (ESUs) of salmon and steelhead from California and the Pacific Northwest, of which 26 are listed as threatened or endangered species under the ESA.[1]

In 2000 NMFS initiated formal ESA recovery planning for listed salmon and steelhead ESUs. Recovery efforts are organized into a series of geographic areas or domains. Within each domain, a Technical Recovery Team (TRT) has been (or is in the process of being) formed to develop a sound scientific basis for recovery planning. Regional planners will use the information the TRTs provide to craft comprehensive recovery plans for all listed ESUs within each domain. For more information about the ESA recovery planning process for salmon and steelhead and the TRTs, see the NMFS Northwest Salmon Recovery Planning Web site (http://www.nwfsc.noaa.gov/trt/).

Recently, several factors led NMFS to conclude that the ESA status of listed salmon and steelhead ESUs should be reviewed at this time. First, a September 2001 court ruling called into question the NMFS decision to not list several hatchery populations considered to be part of the Oregon Coast coho salmon ESU (*Alsea Valley Alliance v. Evans*, 161 F. Supp. 2d 1154, D. Oreg. 2001, hereafter called the Alsea decision). The ruling held that the ESA does not allow listing of any unit smaller than a DPS (or ESU), and that NMFS had violated that provision of the act by listing only part of an ESU. Although this legal case applied directly only to the Oregon Coast coho salmon ESU, the same factual situation (hatchery populations considered part of listed ESUs, but not listed) also applied to most other listed ESUs of salmon and steelhead. Second,

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[1] A complete list of these evaluations can be found online (http://www.nwr.noaa.gov/1salmon/salmesa/fractlist.htm), and the technical documents representing results of the status reviews can be accessed online at Web sites of the Northwest Fisheries Science Center (http://www.nwfsc.noaa.gov/publications/index.cfm), the Southwest Regional Office (http://swr.nmfs.noaa.gov/salmon.htm), the Santa Cruz Laboratory (http://www.pfeg.noaa.gov/), and the Northwest Regional Office (http://www.nwr.noaa.gov/).

two additional lawsuits currently pending that involve California ESUs of steelhead [*EDC v. Evans,* SACV-00-1212-AHS (EEA); *MID v. Evans,* CIV-F-02-6553 OWW DLB (E.D. Cal).] raised a similar issue—NMFS concluded that resident fish were part of the ESU, but only the anadromous steelhead were listed. Again, this same factual situation is found in most, if not all, listed steelhead ESUs. Finally, at least several years of new data are available for most ESUs, and up to a decade has passed since the first populations were listed in the Sacramento and Snake rivers. Furthermore, in some areas, adult returns in the last few years have been considerably higher than have been seen for several decades.

As a result of these factors, NMFS committed to a systematic updating of the ESA status of all listed ESUs of Pacific salmon and steelhead—Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and chum salmon (*O. keta*) (NMFS 2002a). This report summarizes updated biological information for the 26 listed salmon and steelhead ESUs and one candidate ESU (lower Columbia coho salmon), and presents the team's conclusions regarding these ESUs' current risk status. The Biological Review Teams (BRTs) consisted of a core groups of scientists from the NMFS Northwest and Southwest Fisheries Science Centers, supplemented by experts on particular species from NMFS and other federal agencies. BRT membership is indicated in the sections for each species. The BRTs met in January, March, and April 2003 to review information related to the updated status reviews.

ESU Determinations

As amended in 1978, the ESA allows listing of distinct population segments of vertebrates as well as named species and subspecies. However, the ESA provided no specific guidance for determining what constitutes a distinct population segment, and the resulting ambiguity led to the use of a variety of criteria in listing decisions over the past decade. To clarify the issue for Pacific salmonids, NMFS published a policy describing how the agency will apply the definition of "species" in the ESA to anadromous salmonid species, including sea-run cutthroat trout and steelhead (NMFS 1991a). A more detailed description of this topic appeared in the NMFS "Definition of Species" paper (Waples 1991). The NMFS policy stipulates that a salmon population or group of populations is considered "distinct" for purposes of the ESA if it represents an ESU of the biological species. An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations, and 2) represents an important component in the evolutionary legacy of the species. 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 can be provided by data on genetic and life history characteristics, habitat differences, and the effects of stock transfers or supplementation efforts. The BRTs have used a comprehensive approach that used all available scientific information to define ESUs. A discussion of how the NMFS policy was applied in a number of ESA status reviews can be found in Waples (1995).

Geographic Boundaries

The status review updates focused primarily on risk assessments, and (apart from the discussion of resident fish in steelhead ESUs) the BRTs did not consider issues associated with the geographic boundaries of ESUs. If significant new information arises to indicate that specific ESU boundaries should be reconsidered, it will be done at a later time.

Artificial Propagation

Most salmon and steelhead ESUs have hatchery populations associated with them, and it is important for administrative, management, and conservation reasons to determine the biological relationship between these hatchery fish and natural populations within the ESU. The NMFS ESA policy for artificial propagation of Pacific salmon and steelhead (NMFS 1993a) has guided ESA status reviews conducted since 1993. That policy recognizes that “genetic resources important to the species’ evolutionary legacy may reside in hatchery fish as well as in natural fish, in which case, the hatchery fish can be considered part of the biological ESU in question.” As part of the coastwide status reviews (Weitkamp et al. 1995, Busby et al. 1996, Gustafson et al. 1997, Johnson et al. 1997, Myers et al. 1998), the BRTs applied this principle in evaluating the ESU status of hatchery populations associated with all listed salmon and steelhead ESUs, with the result that many hatchery populations are currently considered to be part of the ESUs. However, only a small fraction of these hatchery populations have been listed—generally, those associated with natural populations or ESUs considered at high risk of extinction. NMFS felt that listing other hatchery populations in the ESUs would provide little or no additional conservation benefit beyond that conferred by the listing of natural fish, but would greatly increase the regulatory burden on stakeholders, researchers, and the general public.

As discussed, a recent court decision determined that this approach is inconsistent with the ESA—that is, an ESU must be listed or not listed in its entirety. At the same time that the agency announced the status review updates, NMFS committed to revising the ESA artificial propagation policy for Pacific salmonids and to using the revised policy to guide the hatchery ESU determinations and consideration of artificial propagation in the risk analyses (NMFS 2002a). Although a revised artificial propagation policy has not yet been finalized, a draft has been available on the agency’s Web site (http://www.nwr.noaa.gov/HatcheryListingPolicy/DraftPolicy.pdf) since August 2002. That draft indicates hatchery populations that have “diverged substantially from the evolutionary lineage represented by the ESU” will not be considered part of the ESU. The draft policy is currently under revision, and one issue that remains to be resolved is how “substantial” the divergence must be before a hatchery population should no longer be considered part of a salmon or steelhead ESU, even if it was originally derived from populations within the ESU. Due to the lack of resolution of this issue, the BRTs have not attempted to revisit the ESU determinations for hatchery populations in this report. However, a separate working group, the Salmon and Steelhead Hatchery Assessment Group (SSHAG), updated the stock histories and biological information for every hatchery population associated with each listed ESU (SSHAG 2003) and assigned each hatchery population to one of four categories, as described below. How these categories relate to ESU membership remains to be determined. A table showing the SSHAG categories appears in the appendix for each section of this report for each species. The BRTs reviewed the information in these appendices, along with other hatchery information, to obtain a better understanding of the nature and role of hatcheries associated with each listed ESU.

In the SSHAG document, each hatchery stock was assigned to a category based on variation across three axes (Figure 1): 1) the degree of genetic divergence between the hatchery stock and the natural populations that occupy the watershed into which the hatchery stock is released, 2) the origin of the hatchery stock, and 3) the status of the natural populations in the watershed. There are four categories of divergence: minimal, moderate, substantial, and extreme. Minimal divergence means that, based on the best information available, there is no appreciable genetic divergence between the hatchery stock and the natural populations in the watershed (e.g., because the hatchery and wild populations are well mixed in each generation). Moderate divergence means the level of divergence between the hatchery stocks and the local natural populations is no more than what would be expected between closely related populations within the ESU. Substantial divergence is roughly the level of divergence expected between more distantly related populations within the ESU. Extreme divergence is divergence greater than what would be expected among natural populations in the ESU, such as that caused by deliberate artificial selection or inbreeding. The second axis describes the origin of the hatchery stock, and it can either be local, nonlocal but predominantly from within the ESU, or predominantly from outside of the ESU. The third axis describes the status of the natural populations in the watershed of the same species as the hatchery stock, which can either be native or nonnative.

Category 1 stocks are characterized by no more than minimal divergence between the hatchery stock and the local natural populations and regular, substantial incorporation of natural-origin fish into the hatchery broodstock. Within category 1, category 1a stocks are characterized by the existence of a native natural population of the same species in the watershed, and category 1b stocks are characterized by the lack of such a population (i.e., the local, naturally spawning population was introduced from elsewhere). Note that a category 1a designation can describe a range of biological scenarios, and does not necessarily imply that the hatchery stock and the associated natural population are close to a "pristine" state. For example, a hatchery program that started many years ago with local broodstock and regularly incorporated local natural-origin fish in substantial proportions thereafter would likely be a category 1a, even if both the hatchery stock and the local natural population have diverged from what the natural population was like historically.

Category 2 stocks are no more than moderately diverged from the local, natural populations in the watershed. Category 2a stocks were founded from a local, native population in the watershed in which they are released. Category 2b stocks were founded nonlocally, but from within the ESU, and are released in a watershed that does not contain a native natural population. Category 2c stocks were founded nonlocally, but from within the ESU, and are released in a watershed that contains a native natural population.

Category 3 stocks are substantially diverged from the natural populations in the watershed in which they are released. The a, b, and c designations are the same as described for category 2 above.

	Source of hatchery stock and status of local population			
Relationship to natural population	Local; native natural population	Nonlocal but within ESU; no native local natural population	Nonlocal but within ESU; native local natural population exists	Nonlocal and predominantly from outside of ESU
Substantial natural-origin fish in broodstock and minimal divergence	1a	1b	NA	4
Moderate to few natural-origin fish in broodstock and no more than moderate divergence[a]	2a	2b	2c	
Substantial divergence[b]	3a	3b	3c	
Extreme divergence[c]	4	4	4	4

[a] Moderate divergence = no more than observed between similar populations within ESU.

[b] Substantial divergence = comparable to divergence observed within entire ESU.

[c] Extreme divergence = greater than divergence observed within ESU or substantial artificial selection or manipulation.

Figure 1. Summary of the hatchery categorization system. Source: SSHAG (2003).

Category 4 stocks are characterized either by being founded predominantly from sources that are not considered part of the ESU in question, or by extreme divergence from the natural populations in the watershed in which they are released, regardless of founding source.

Resident Fish

In addition to the anadromous life history, sockeye salmon and steelhead have nonanadromous or resident forms, generally referred to as kokanee (*O. nerka*) and rainbow trout (*O. mykiss*), respectively. (At least one resident population of Chinook salmon also occurs, in Lake Cushman, Washington.) As is the case with hatchery fish, it is important to determine the relationships of these resident fish to anadromous populations in listed ESUs. The complexity of jurisdictional responsibilities complicates this issue—NMFS has ESA responsibility for anadromous Pacific salmonids, but the U.S. Fish and Wildlife Service (USFWS) has ESA jurisdiction for resident fish. At the time this report was prepared, the two agencies had not developed a general policy on how to determine the ESU/DPS status of resident fish or how to make the listing determinations for the overall ESU/DPSs.

Resident (kokanee) populations in the two ESA-listed sockeye salmon ESUs (Redfish Lake and Ozette Lake) have been genetically characterized and determined not to be part of the sockeye salmon ESUs. However, the ESU status of many resident populations of *O. mykiss* remains in doubt. Therefore, for the purposes of this status review update, the BRTs adopted a working framework for determining the ESU/DPS status of *O. mykiss* that is geographically associated with listed steelhead ESUs. These evaluations were guided by the same biological principles used to define ESUs of natural fish and determine ESU membership of hatchery fish: the extent of reproductive isolation from and evidence of biological divergence from other populations within the ESU. These principles are comparable to the "discreteness" and "significance" criteria of the joint DPS policy of the two listing agencies (USFWS and NMFS 1996). Ideally, each resident population would be evaluated individually on a case-by-case basis, using all available biological information. In practice, little or no information is available for most resident salmonid populations.

To facilitate conclusions about the ESU/DPS status of resident fish, NMFS and USFWS identified three different cases, reflecting the range of geographic relationships between resident and anadromous forms within different watersheds:

> Case 1: No obvious physical barriers to interbreeding exist between resident and anadromous forms.
>
> Case 2: Long-standing natural barriers (e.g., a waterfall) separate resident forms upstream from anadromous forms downstream.
>
> Case 3: Relatively recent (e.g., within the last 100 years) human actions or man-made barriers (e.g., construction of a dam without provision for upstream fish passage) separate resident and anadromous forms.

The BRTs reviewed available information about individual resident populations of *O. mykiss* to determine into which case each population fits. The BRTs also adopted, for the purpose of the updated status reviews and extinction risk assessments, the following working assumptions about ESU membership of resident *O. mykiss* falling in each of these categories:

> Case 1: Resident fish were assumed provisionally to be part of the ESU. Rationale: Empirical studies show that resident and anadromous *O. mykiss* are typically very similar genetically when they co-occur in sympatry, with no physical barriers to migration or interbreeding (Chilcote 1976, Currens et al. 1987, Leider et al. 1995, Pearsons et al. 1998). (Note: This assumption is not necessarily applicable to *O. nerka*, because sockeye and kokanee can show substantial divergence, even in sympatry.)
>
> Case 2: Resident fish were assumed provisionally not to be part of the ESU. Rationale: Many populations in this category have been isolated from contact with anadromous populations for thousands of years. Empirical studies (Chilcote 1976, Currens et al. 1990) show that, in these cases, the resident fish typically show substantial genetic and life history divergence from the nearest downstream anadromous populations.
>
> Case 3: No default assumption was made about ESU status of resident fish.

The default assumptions about ESU membership for case 1 and case 2 populations can be overridden by specific information for individual populations. For example, as noted above, anadromous and resident *O. nerka* can diverge substantially in sympatry, and it is possible the same may be true for some *O. mykiss* populations.

The BRTs discussed case 3 populations at some length. Case 3 populations were most likely case 1 populations (and hence presumably part of the ESU) prior to construction of the artificial barrier. Some BRT members felt that, in the absence of information to the contrary, it is reasonable to assume that case 3 populations of *O. mykiss* are still in the ESU, given that the time since erection of the artificial barriers has been relatively short for substantial evolutionary divergence to have occurred. However, the majority of the BRT members preferred to make no particular assumption regarding case 3 populations for two main reasons. First, case 3 populations that historically were part of the ESU may no longer represent the ESU biologically because of 1) bottlenecks or local adaptation and rapid evolutionary divergence in a novel environment; or 2) displacement or introgression from nonnative, hatchery-origin rainbow trout. Notably, releases of hatchery rainbow trout have been widespread in the Pacific Northwest and California, including areas impounded by dams that block access to anadromous fish (Ludwig 1995, Van Vooren 1995). Empirical studies (Wishard et al. 1984, Williams et al. 1997, Utter 2001) have shown that the results of such releases can be quite variable, ranging from replacement of the native gene pool to hybridization to no detectable genetic effect. Therefore, the current relationship between case 3 populations and anadromous populations in the ESU is difficult to evaluate without empirical data and historical stocking records for the population in question. Second, identifying a default assumption for case 3 populations in the face of considerable biological uncertainty requires consideration of other factors that are not entirely scientific: What is the appropriate burden of proof? What are the biological, economic, and political consequences of making a wrong assumption? Therefore, because of these issues, in this report, the BRTs did not suggest a default assumption regarding the ESU status of case 3 populations. Instead, this report summarizes empirical information that does exist for specific case 3 populations and discusses its relevance to ESU determinations. As new biological information relevant to the ESU status of individual case 3 populations is developed as part of the overall recovery planning process for West Coast salmon and steelhead (described in the species subsections titled Background and Introduction) that information will be passed on to NMFS regional office staff for consideration.

Genetic data can provide a powerful means for determining the evolutionary origin of a sampled population, and such data can therefore be useful in evaluating the extent to which native resident *O. mykiss* populations have been affected by releases of nonnative hatchery rainbow trout. The steelhead ESU reports in this technical memorandum summarize this information as it applies to specific case 3 populations. As discussed, rapid genetic changes associated with human impacts can also occur within populations in the absence of stock transfers, and these changes are unlikely to be detected with standard molecular genetic techniques. Evaluating the importance of such effects is very difficult. Phenotypic and life history traits can serve as proxies for genetically based, adaptive differences among populations; however, environmental conditions can affect such traits, which confounds their interpretation. These confounding effects can generally be teased apart only with very detailed experiments. It is therefore likely that the evolutionary relationships of many case 3 populations will remain uncertain for the foreseeable future.

In response to a request for additional information about listed ESUs of steelhead (NMFS 2002b), NMFS received two comments relevant to the ESU status of resident *O. mykiss*. The Center for Biological Diversity (CBD 2003) argued that NMFS erred in referring to *O. mykiss* trapped above dams as "resident" fish and excluding them from the steelhead listings. According to the CBD, the distinction between anadromous and resident populations should be based not on circumstances of geography (i.e., whether the fish are currently above or below a recent man-made barrier), but rather on biological attributes of the populations—specifically, the "genetic trait expressed in smoltification." They argued that resident populations that are genetically (i.e., historically) anadromous but currently trapped above human barriers with no opportunity to express anadromy should be considered part of the listed steelhead ESUs. The conclusions of the BRTs regarding the ESU status of case 3 resident populations (above human barriers) are described in the previous discussion.

Trout Unlimited (2003) argued that, based on substantial ecological and life history differences, anadromous and resident *O. mykiss* should be in separate ESUs, even in cases where there are no appreciable molecular genetic differences between the two forms. They cited studies showing 1) little evidence that transplanted rainbow trout can give rise to anadromous populations, and 2) one study in the Deschutes River, in which all anadromous fish examined were found to have an anadromous female parent and all resident fish examined were found to have a resident female parent, as evidence for a genetic basis for the differences between the two forms. This argument is similar to the arguments the BRTs considered in previous status reviews, that summer- and winter-run steelhead, or spring- and fall-run Chinook in coastal basins, should be in different ESUs (Busby et al. 1996, Myers et al. 1998). As in those status reviews, the BRTs do not dispute that the two forms of *O. mykiss* can exhibit some degree of reproductive isolation, even in areas where they co-occur. However, the strong genetic similarity of the two forms in sympatry in every case where they have been examined indicates that, in general, the two forms are genetically linked on evolutionary time frames. Furthermore, the Deschutes River study (Zimmerman and Reeves 2000) also examined a population in British Columbia, where the authors found that anadromous fish can give rise to resident offspring, and vice versa—a result that has been found in other areas as well. In general, genetic data show that resident and anadromous *O. mykiss* below barriers in the same basin are genetically more similar to each other than either is to the same form in another basin. Therefore, lumping steelhead and resident populations into separate ESUs would create artificial units in which each population had its nearest relative in a different ESU. This problem could be resolved only by considering every population (anadromous or resident) its own ESU—a result that would lead to hundreds of ESUs of *O. mykiss* and would be inconsistent with the approach NMFS has taken in all other status reviews for Pacific salmonid. Therefore, the BRTs continued to consider the evolutionary relationships between resident and anadromous populations in a way that was consistent with the approach used in evaluating alternative life history forms in previous status reviews.

Although resident *O. mykiss* may occasionally produce anadromous offspring, and vice versa, there is (as noted by Trout Unlimited 2003) little empirical evidence to indicate that a population of resident *O. mykiss* can give rise to a self-sustaining anadromous *population*. This issue is relevant to extinction risk analysis for ESUs containing both forms and is discussed in the steelhead report.

Risk Assessments

ESA Definitions

After the composition of an ESA species is determined, the next question to address is "Is the species threatened or endangered?" Section 3 of the ESA defines endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range." The term threatened species is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Neither NMFS nor the USFWS have developed formal policy guidance about how to interpret the ESA definitions of threatened or endangered species.

The BRTs consider a variety of information in evaluating the level of risk an ESU faces. According to Section 4 of the ESA, the determination of whether a species is threatened or endangered should be made "solely on the basis of the best scientific and commercial data available" regarding the species' current status, after taking into account efforts made to protect the species. In their biological status reviews, the BRTs do not evaluate possible future effects of protective efforts, except to the extent the effects are already reflected in metrics of population or ESU viability. The NMFS regional offices take into account protective efforts in a separate process prior to making listing determinations. Therefore, the BRTs do not make recommendations as to whether identified ESUs should be listed as threatened or endangered species because that determination requires evaluation of factors the teams do not consider. Rather, the BRTs draw scientific conclusions about the current risk of extinction faced by ESUs, under the assumption that present conditions will continue into the future (recognizing, of course, that natural demographic and environmental variability are inherent features of "present conditions").

Factors for Decline

According to Section 4 of the ESA, the Secretary of Commerce or the Interior shall determine whether a species is threatened or endangered as a result of any or a combination of the following factors: destruction or modification of habitat, overutilization, disease or predation, inadequacy of existing regulatory mechanisms, or other natural or man-made factors. Collectively, these factors are often referred to as "factors for decline." In the *Federal Register* notices announcing the ESA listing decisions for West Coast salmon and steelhead (see Background and History subsection of each species for more detail), NMFS included sections identifying what have come to be known as the 4H factors for decline—habitat degradation and loss, hydropower development, overharvest, and hatchery propagation—as well as other factors. However, in the status reviews, the BRTs did not attempt a rigorous analysis of this subject, and the same is true for this report. There are several reasons for this approach.

- First, the BRTs chose to focus primarily on the question of whether an ESU is at risk, rather than how it came to be at risk. Although the latter question is important, a population or ESU that has been reduced to low abundance will continue to be at risk for demographic and genetic reasons until it reaches a larger size, regardless of the reasons for its initial decline. Furthermore, in some cases, a factor that was important in causing the original declines may no longer be an impediment to recovery.

- Second, unlike many other ESA-listed species that face a single primary threat, salmon face a bewildering array of potential threats throughout every stage of their complex life cycle. It is relatively easy to simply enumerate current and past threats to salmon populations, but it is much more difficult to evaluate the relative importance of a wide range of interacting factors.
- Third, evaluating the degree to which historical factors for decline will continue to pose a threat in the future generally requires consideration of issues that are more in the realm of social science than biological science—such as whether proposed changes will be funded, and, if funded, will be implemented effectively.

In its listing determination for the updated status reviews, NMFS considers factors for decline and the extent to which protective efforts have alleviated those factors. The BRTs expect that, for ESUs that remain listed, formal ESA recovery planning will address these issues in detail. The agency has outlined a two-step process for recovery planning: the first step is identifying biologically based delisting criteria, and the second step is developing a suite of actions (the Recovery Plan) that has a high probability of achieving the recovery goals. (For more information about ESA recovery planning for West Coast salmon and steelhead, visit http://www.nwfsc.noaa.gov/trt/about.htm.) Delisting occurs only after the ESU satisfies both the biological delisting criteria and associated administrative delisting criteria, which typically involve assurances that the threats to the continued existence of the ESU have been resolved.

Although this technical memorandum does not consider factors for decline in a comprehensive way, the BRTs considered major risk factors identified in previous status reviews. The sections focusing on specific ESUs summarize the previous BRT conclusions and identify any major changes in risk factors that have occurred since the time of listing.

Artificial Propagation

The 1993 NMFS ESA policy for artificial propagation of Pacific salmon and steelhead recognizes that artificial propagation can be one of the conservation tools used to help achieve recovery of ESA-listed species, but it does not consider hatcheries to be a substitute for conservation of the species in its natural habitat. Therefore, ESA risk analyses for salmon and steelhead ESUs were conducted for "natural-origin" fish (which are defined as the progeny of naturally spawning fish), based on whether or not the natural populations can be considered self-sustaining without regular infusion of hatchery fish. This is the same provision articulated in the joint USFWS-NMFS policy on artificial propagation of all species under the ESA (USFWS and NMFS 2002) and is consistent with the approach the USFWS has used to evaluate captive propagation programs for other species, such as the California condor (USFWS 1996) and the bonytail chub (USFWS 2002).

The draft revised salmon hatchery policy outlines a three-step approach for considering artificial propagation in listing determinations:

1. Identify which hatchery populations are part of the ESU (see previous section).
2. Review the status of the ESU.
3. Evaluate existing protective efforts and make a listing determination.

This document is concerned with step 2—reviewing the status for listed salmon and steelhead ESUs via risk analyses.

The draft revised hatchery policy interprets the purpose of the ESA as to conserve threatened and endangered species in their natural habitats. In its risk evaluations, the BRTs therefore used the approach they have in the past—focusing on whether populations and ESUs are self-sustaining in their natural habitat. In this report, therefore, when we refer to BRT evaluations or conclusions regarding the status of ESUs, we are referring to analyses conducted using the criterion of self-sustainability of natural populations.

Artificial propagation can be used as a conservation tool. Potential benefits of artificial propagation for natural populations include reducing the short-term risk of extinction, helping to maintain a population until the factors limiting recovery can be addressed, reseeding vacant habitat, and helping to speed recovery. Whether these potential benefits will be realized in any particular case is difficult to predict. To the extent that such benefits have already occurred, they are reflected in the population abundance and trend data the BRTs considered. The draft revised hatchery policy also indicates that the potential future conservation benefits of artificial propagation should be considered before making a listing determination. NMFS regional office and headquarters staff will consider the potential conservation benefits of artificial propagation, together with other protective efforts, in determining whether to propose any changes to the current ESA listing for West Coast salmon and steelhead.

Artificial propagation is important to consider in ESA evaluations of anadromous Pacific salmonids for several other reasons. First, although natural fish are the subject of risk assessments, possible positive or negative effects of artificial propagation on natural populations must also be evaluated. For example, artificial propagation can alter life history characteristics such as smolt age and migration, and spawn timing. Second, in addition to the potential to increase abundance of fish, artificial propagation poses a number of risks to natural populations that may affect their risk of extinction or endangerment. In contrast to most other types of risk for salmon populations, those arising from artificial propagation are often not reflected in traditional indices of population abundance. For example, to the extent that habitat degradation, overharvest, or hydropower development have contributed to a population's decline, these factors will already be reflected in population abundance data and accounted for in the risk analysis. The same is not necessarily true of artificial propagation. Hatchery production may mask declines in natural populations that will be missed if only raw population abundance data are considered. Therefore, a true assessment of the viability of natural populations cannot be attained without information about the genetic and demographic contribution of naturally spawning hatchery fish. Furthermore, even if such data are available, they will not in themselves provide direct information about possible deleterious effects of fish culture. Such an evaluation requires consideration of the genetic and demographic risks of artificial propagation for natural populations.

Resident Fish

As indicated, the BRTs concluded in previous status reviews that at least some resident *O. mykiss* populations belonged to steelhead ESUs, and these resident fish were considered in the overall risk analyses for those ESUs. However, in most cases, little or no information was available about the numbers and distribution of resident fish, or about the extent and nature of their interactions with anadromous populations. Given this situation, the previous risk analyses for steelhead ESUs focused primarily on the status of anadromous populations.

In these updated status reviews, increased efforts have been made to gather biological information for resident *O. mykiss* populations to assist in the risk analyses. For example, although the two listed sockeye salmon ESUs considered in this report (Redfish Lake and Ozette Lake) have associated kokanee populations, in neither case are they considered to be part of the sockeye salmon ESU, so kokanee were not formally considered in the risk analyses. Information on resident fish is summarized in the steelhead sections (14–25), where ESU-specific information is discussed in more detail. The steelhead background information section also contains a more general discussion of how the BRTs considered resident fish in the risk analyses for steelhead ESUs.

Factors Considered in Status Assessments

Salmonid ESUs are typically metapopulations; that is, they are usually composed of multiple populations with some degree of interconnection, at least over evolutionary time periods. These multiple populations make the assessment of extinction risk difficult. The approach to this problem that NMFS adopted for recovery planning is outlined in the VSP report (McElhany et al. 2000). In this approach, risk assessment is addressed at two levels: first at the population level, then at the overall ESU level. We have modified previous BRT approaches to ESU risk assessments to incorporate VSP considerations.

Individual populations are assessed according to the four VSP criteria: abundance, growth rate/productivity, spatial structure, and diversity. We then summarize the condition of individual populations on the ESU level and consider larger-scale issues in evaluating the status of the ESU as a whole. These larger-scale issues include total number of viable populations, geographic distribution of these populations (to ensure inclusion of major life history types and to buffer the effects of regional catastrophes), and connectivity among these populations (to ensure appropriate levels of gene flow and recolonization potential in case of local extirpations). McElhany et al. (2000) details these considerations.

In previous status reviews, the BRTs have used a simple “risk matrix” for quantifying ESU-scale risks according to major risk factors. The revised matrix (Table 1) integrates the four major VSP criteria (abundance, productivity, spatial structure, and diversity) directly into the risk assessment process. After reviewing all relevant biological information for a particular ESU, each BRT member assigns a risk score (see below) to each of the four VSP criteria. Use of the risk matrix makes it easier to compare risk factors within and across ESUs. The BRT tallies and reviews the scores before making its overall risk assessment (see Forest Ecosystem Management Assessment Team [FEMAT] method, below). Although this process helps to integrate and quantify a large amount of diverse information, there is no simple way to translate the risk-matrix scores directly into an assessment of overall risk. For example, simply averaging the values of the various risk factors would not be appropriate: an ESU at high risk for low abundance would be at high risk even if there were no other risk factors.

Scoring VSP Criteria

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

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

Recent Events

The recent events category considers events that have predictable consequences for ESU status in the future but have occurred too recently to be reflected in the population data. Examples include a flood that decimated most eggs or juveniles in a recent broodyear, or large jack returns that generally anticipate strong adult returns in subsequent years. This category is scored as follows:

++	Expect a strong improvement in status of the ESU
+	Expect some improvement in status
0	Neutral effect on status
–	Expect some decline in status
– –	Expect strong decline in status

Historical Distribution and Abundance

The ESA has no provision that requires a species to occupy its entire historical habitat or reach historical levels of abundance before it can be considered no longer threatened or endangered. Using the VSP criteria described above, it is only necessary that an ESU contain enough viable populations and satisfy concerns for spatial structure and diversity. However, developing strictly quantitative viability criteria is extremely challenging, even at the population level (see Section 2, Methods). Therefore, other approaches that provide insight into viability are also important to consider. If our definitions of ESUs (groups of populations on independent evolutionary trajectories) and populations (demographically independent units over at least a 100-year time frame) are correct, then by definition they were sustainable at historical levels. Therefore, we can be confident that a population or ESU that approximates its historical distribution and abundance will be viable into the future. This a priori presumption of viability diminishes the further the current status departs from the historical template. For a population or ESU that is greatly reduced from its historical distribution or abundance, there is little a priori reason to assume the current status is viable. The viability of such a population or ESU is in considerable doubt unless independent data can be developed to assess viability.

Table 1. Template for the risk matrix used in BRT deliberations. The matrix is divided into five sections that correspond to the four viable salmonid population parameters from McElhany et al. (2000) plus a recent events category.

[Evolutionarily significant unit (ESU) name]

Risk category	**Score**[*]
Abundance Comments:	
Growth Rate/Productivity Comments:	
Spatial Structure and Connectivity Comments:	
Diversity Comments:	
Recent Events	

[*] Rate overall risk of ESU on 5-point scale (1 = very low risk; 2 = low risk; 3 = moderate risk; 4 = increasing risk; 5 = high risk), except recent events double plus (++ = strong benefit) to double minus (– – = strong detriment).

Marine Productivity

In the last decade, evidence has accumulated to demonstrate 1) recurring, decadal-scale patterns of ocean-atmosphere climate variability in the North Pacific Ocean (Mantua et al. 1997, Zhang et al. 1997), and 2) correlations between these oceanic productivity "regimes" and salmon population abundance in the Pacific Northwest and Alaska (Hare et al. 1999, Mueter et al. 2002). There seems to be little doubt that survival rates in the marine environment can be strong determinants of population abundance for Pacific salmon and steelhead. It is also generally accepted that for at least two decades, beginning about 1977, marine productivity conditions were unfavorable for the majority of salmon and steelhead populations in the Pacific Northwest (in contrast, many populations in Alaska attained record abundances during this period). Finally, evidence shows an important shift in ocean-atmosphere conditions occurred around 1998. One indicator of the ocean-atmosphere variation for the North Pacific is the Pacific Decadal Oscillation (PDO) index; Figure 2 shows that since 1999 (time period C on the graph), PDO values have been mostly negative, whereas the values were positive in most of the previous two decades (time period B) and generally negative again for a long period before that (period A). Negative PDO values are associated with relatively cool ocean temperatures (and generally high salmon productivity) off the Pacific Northwest, and positive values are associated with warmer, less productive conditions. As discussed in this report, increases in many salmon populations in recent years may be largely a result of more favorable ocean conditions.

Although these climate-related facts are relatively well established, much less certainty can be attached to predictions about what this means for the viability of listed salmon and

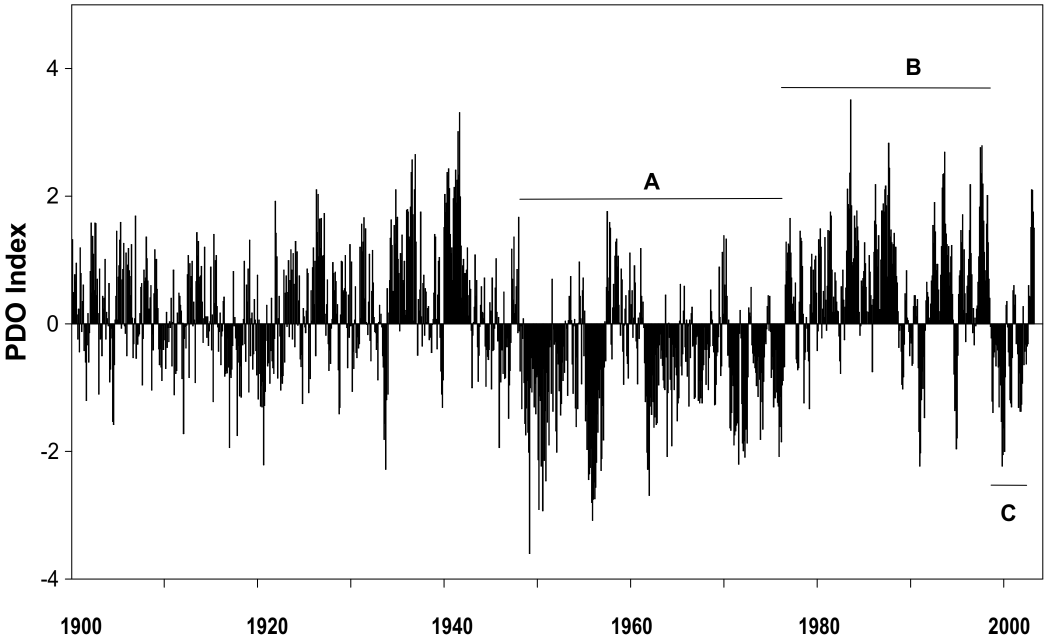

Figure 2. Monthly values for the Pacific Decadal Oscillation (PDO) index, which is based on sea surface temperatures in the North Pacific. Values shown are deviations from the long-term (1900–1993) mean. See text for discussion of time periods A, B, and C. Source: Online at http://tao.atmos.washington.edu/pdo/.

steelhead. For several reasons, considerable caution is needed to project into the future. First, empirical evidence for "cycles" in PDO, marine productivity, and salmon abundance extends back only about a century, or about three periods of two to four decades in duration. These periods form a very short data record for inferring future behavior of a complex system. Thus as with the stock market, the past record is no guarantee of future performance. Second, the past decade has seen particularly wide fluctuations not only in climatic indices (e.g., the 1997–1998 El Niño was in many ways the most extreme ever recorded, and the 2000 drought was one of the most severe on record) but also in abundance of salmon populations. In general, as the magnitude of climate fluctuations increases, the population extinction rate also increases. Third, if anthropogenically caused climate change occurs in the future, it could affect ocean productivity. The range of future climate change scenarios consistent with existing data is so great that future consequences cannot be predicted with any certainty; however, many models suggest that northern latitudes are likely to experience significant temperature increases (IPCC 2001). Finally, changes in the pattern of ocean-atmosphere interactions do not affect all species (or even all populations of a given species) in the same way (Peterman et al. 1998).

Based on these considerations, the BRTs identified a number of possible future scenarios for impacts of ocean productivity on listed salmon and steelhead populations:

1. The PDO index could remain primarily negative for another decade or two (a typical duration for regimes observed in the past), leading to marine productivity conditions that are generally more favorable to Pacific Northwest salmon and steelhead than those that occurred from the mid-1970s to the late 1990s.
2. The last several years might be an anomaly, and the PDO index might revert back to the positive regime it has largely been in since the mid-1970s. It is worth noting in this regard that the PDO index has been positive in every month from August 2002 through March 2003 (Figure 2).
3. Marine and freshwater systems may continue to see wide fluctuations in environmental conditions.
4. Anthropogenically caused climate change might be a significant factor in the future, with difficult-to-predict consequences.

Given all these uncertainties, the BRTs were reluctant to make any specific assumptions about the future behavior of the ocean-atmospheric systems or their effects on the distribution and abundance of salmon and steelhead. The BRTs were concerned that even under the most optimistic scenario (1), increases in abundance might be only temporary and could mask a failure to address underlying factors for decline. The real conservation concern for West Coast salmon and steelhead is not how they perform during periods of high marine survival, but how prolonged periods of poor marine survival affect the VSP parameters of abundance, growth rate, spatial structure, and diversity. It is reasonable to assume that salmon populations have persisted over time, under pristine conditions, through many such cycles in the past. Less certain is how the populations will fare in periods of poor ocean survival when their freshwater, estuary, and nearshore marine habitats are degraded.

Overall Risk Assessment

The BRT analysis of overall risk to the ESU uses categories that correspond to definitions in the ESA: in danger of extinction, likely to become endangered in the foreseeable future, or neither. (As discussed, these evaluations do not consider protective efforts, and therefore are not recommendations regarding listing status.) The overall risk assessment reflects each BRT member's professional judgment. The results of the risk matrix analysis as well as expectations about likely interactions among factors guide this assessment. For example, a single factor with a "high risk" score might be sufficient to result in an overall score of "in danger of extinction," but a combination of several factors with more moderate risk scores could also lead to the same conclusion.

To allow for uncertainty in judging the actual risk facing an ESU, the BRTs have adopted a "likelihood point" method, often referred to as the FEMAT method because it is a variation of a method scientific teams used in evaluating options under President Clinton's Forest Plan (FEMAT 1993). In this approach, each BRT member distributes 10 likelihood points among the three ESU risk categories, reflecting the member's opinion of how likely that category correctly reflects the true ESU status. Thus, if a reviewer were certain that the ESU was in the "not at risk" category, he or she could assign all 10 points to that category. A reviewer with less certainty about ESU status could split the points among two or even three categories. This method has been used in all status review updates for anadromous Pacific salmonids since 1999.

2. Methods

The BRTs requested data on abundance, the fraction of hatchery-origin spawners, harvest, age structure, and hatchery releases from state, federal, and tribal sources (NMFS 2002a) and compiled the data with previous data to conduct updated risk analyses for each ESU. The BRTs obtained data on adult returns from a variety of sources, including time series of freshwater spawner surveys, redd counts, and counts of adults migrating past dams or weirs. Time series were assembled and analyzed at the scale of VSP populations where TRTs have identified these populations, or putative populations where TRTs are in the process of identifying them.

State, federal, and tribal comanagers reviewed preliminary data and analyses for accuracy and completeness. Where possible, the BRTs obtained population or ESU-level estimates of the fraction of hatchery-origin spawners or calculated estimates from information using scale analyses, fin clips, and so on. Harvest estimates were obtained for some stocks directly; for others, harvest rates on nearby indicator stocks were used to estimate the number of fish in the target population that would have returned to spawn in the absence of harvest. See appendices for each species section for detailed information and references for data sources.

Recent Abundance

Recent abundance of natural spawners is reported as the geometric mean (and range) of the most recent data to be consistent with previous coastwide status reviews of these species (Weitkamp et al. 1995, Busby et al. 1996, Gustafson et al. 1997, Johnson et al. 1997, Myers et al. 1998). Geometric means were calculated to represent the recent abundance of natural spawners for each population or quasi-population within an ESU. Geometric means were calculated for the most recent 5 years (Chinook, steelhead), 4 years (chum, sockeye), or 3 years (coho); these time frames were selected to correspond with modal age at maturity for each species. 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. The geometric mean is the *n*th root of the product of the *n* data:

$$\overline{X}_G = \sqrt[n]{N_1 N_2 N_3 \ldots N_n} \tag{1}$$

where N_t is the abundance of natural spawners in year t. Arithmetic means (and ranges) were also calculated for the most recent abundance data:

$$\overline{X}_A = \frac{\sum N_i}{n} \tag{2}$$

where N_t is the abundance of natural spawners in year t.

Trends in Abundance

Short- and long-term trends were calculated from time series of the total number of adult spawners. Short-term trends were calculated using data from 1990 to the most recent year, with a minimum of 10 data points in the 13-year span. Long-term trends were calculated using all data in a time series.

Trend was calculated as the slope of the regression of the number of natural spawners (log-transformed) over the time series; to mediate for zero values, 1 was added to natural spawners before transforming the data. Trend was reported in the original units as exponentiated slope, such that a value great than 1 indicates a population trending upward, and a value greater than 1 indicates a population trending downward. The regression was calculated as:

$$\ln(N+1)=\beta_0+\beta_1 X+\varepsilon \tag{3}$$

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

$$\exp(\ln(b_1)-t_{0.05(2),df}s_{b_1})\leq\beta_1\leq\exp(\ln(b_1)+t_{0.05(2),df}s_{b_1}) \tag{4}$$

where b_1 is the estimate of the true slope, β_1, $t_{0.05(2),\,df}$ is the two-sided t-value for a confidence level of 0.95, df is equal to $n-2$, n is the number of data points in the time series, and s_{b1} is the standard error of the estimate of the slope, b_1. The probability that the trend value was declining [P(trend < 1)] was also calculated.

Population Growth Rate

In addition to analyses of trends in natural spawners, we calculated the median short-term population growth rate (λ) of natural-origin spawners as a measure for comparative risk analysis. Lambda more accurately reflects the biology of salmon and steelhead, as it incorporates overlapping generations and calculates running sums of cohorts. It is an essential parameter in viability assessment, as most population extinctions are the result of steady declines ($\lambda < 1$). It has been developed for data sets with high sampling error and age-structure cycles (Holmes 2001). These methods have been extensively tested using simulations for both threatened and endangered populations as well as for stocks widely believed to be at low risk (Holmes 2004), and cross-validated with time-series data (Holmes and Fagan 2002).

The λ of natural-origin spawners was calculated in two ways for each population over the short-term time frame (1990–most recent year). The first (λ) assumed that hatchery-origin spawners had zero reproductive success, while the second (λ_h) assumed that hatchery-origin spawners had reproductive success equivalent to that of natural-origin spawners. These extreme assumptions bracket the range likely to occur in nature. Empirical studies indicate that hatchery-origin spawning fish generally have lower (and perhaps much lower) reproductive success than natural-origin spawners (reviewed by Reisenbichler and Rubin 1999). However, this difference can vary considerably across species and populations, and it is very rare that data are available for a particular population of interest. Therefore, to be conservative, we bracketed the scenarios that are likely to be occurring in nature.

A multistep process based on methods developed by Holmes (2001), Holmes and Fagan (2002) and described in McClure et al. (2003) was used to calculate estimates for λ, its 95% confidence intervals, and its probability of decline [P(λ < 1)]. The first step was calculating 4-year running sums for natural-origin spawners as

$$R_t = \sum_{i=1}^{4} N_{t-i+1} \tag{5}$$

where N_{t} is the number of natural-origin spawners in year *t.* A 4-year running sum window was used for all species, as analysis by McClure et al. (2003) indicates that this is an appropriate window for a diverse range of species life histories.

Next, an estimate of μ, the rate at which the median of *R* increases through time (Holmes 2001), was calculated as

$$\hat{\mu} = mean\left(\ln\left(\frac{R_{t+1}}{R_t}\right)\right) \tag{6}$$

the mean of the natural log-transformed running sums of natural-origin spawners. The point estimate for λ was then calculated as the median annual population growth rate,

$$\hat{\lambda} = e^{\hat{\mu}} \tag{7}$$

Confidence intervals (95%) were calculated for λ to provide a measure of the uncertainty associated with the growth rate point estimate. First, an estimate of variability for each population was determined by calculating an estimate for σ^2_{pop} using the slope method (Holmes 2001). The slope method formula is

$$\hat{\sigma}^2_{pop} = \text{slope of var}\left(\ln\left(\frac{R_{\mathrm{t}+\tau}}{R_t}\right)\right) \text{vs.}\ \tau. \tag{8}$$

where τ is a temporal lag in the time series of running sums.

Individual population variance estimates were highly uncertain, so a more robust variance estimate, σ^2_{avg}, was obtained by averaging the σ^2_{pop} estimates from all the populations in an ESU. This average variance estimate was then applied as the variance for every population in an ESU. The degrees of freedom associated with the average variance estimate are obtained by summing the degrees of freedom for each of the individual population variance estimates. The degrees of freedom for the individual population estimates were determined using the method of Holmes and Fagan (2002), which identifies the adjusted degrees of freedom associated with slope method variance estimates. The calculation for the adjusted degrees of freedom is

$$df = 0.212n - 1.215 \tag{9}$$

where *n* is the length of the time series. Using the average variance estimate and the summed degrees of freedom, the 95% confidence intervals for λ were calculated as

$$\exp\left(\hat{\mu} \pm t_{.05(2),df}\sqrt{\hat{\sigma}_{slp}{}^{2}/(n-4)}\right) \tag{10}$$

In addition, the probability that the population growth rate was declining [P($\lambda < 1$)] was calculated using the fact that ln(λ) follows a *t*-distribution. This probability is calculated by finding the probability that the natural log of the calculated lambda divided by its standard error is less than zero.

The preceding treatment ignores contributions of hatchery-origin spawners to the next generation, in effect assuming that they had zero reproductive success. This assumption produces the most optimistic view of viability of the natural population. The other extreme assumption (that hatchery-origin spawners have reproductive success equivalent to that of natural-origin spawners), produces the most pessimistic view of viability of the natural population, given any particular time series of data. To calculate the median growth rate under this assumption (λ_h), a modified approach to the method Holmes (2001) developed was used to calculate estimates for λ_h, 95% confidence intervals for λ_h, and to determine $P(\lambda_h < 1)$. The first step was calculating 4-year running sums (*RN*) for natural-origin spawners as

$$(RN)_t = \sum_{i=1}^{4} N_{t-i+1} \tag{11}$$

Next, the 4-year running sum of hatchery-origin spawners was calculated as

$$(RH)_t = \sum_{i=1}^{4} H_{t-i+1} \tag{12}$$

where H_t is the number of hatchery spawners in year *t*.

The ratio of total spawners to natural-origin spawners was calculated as

$$\psi_t = \frac{(RN)_t + (RH)_t}{(RN)_t}. \tag{13}$$

The average age at reproduction, *T*, was calculated in three steps:

1. Determine the total number of spawners for each age (*A*) by calculating

$$A_j = \sum_{j=1}^{\max\text{ age}} \sum_{all\ t} a_j (N+H)_t. \tag{14}$$

2. Calculate the total number of spawners (*G*):

$$G = \sum_{j=1}^{\max age} A_j \tag{15}$$

3. Determine the average age at reproduction (*T*) by calculating

$$T = \sum_{j=1}^{\max age} \frac{j \times A_j}{G} \tag{16}$$

Next, an estimate of μ, the rate at which the median increases through time (Holmes 2001), was calculated as

$$\hat{\mu} = mean\left(\ln\left(\frac{(RN)_{t+1}}{(RN)_t}\right) - \frac{1}{T}\ln(\psi_t)\right). \tag{17}$$

The point estimate for λ_h was then calculated as the median annual population growth rate (Equation 7).

Confidence intervals (95%) for λ_h and its probability of decline [$P(\lambda_h < 1)$] were calculated as for λ, with modification to the slope method for calculating the variance

$$\hat{\sigma}^2 = \text{slope of var}\left(\ln\left(\frac{(RN)_{t+\tau}}{(RN)_t}\right) - \frac{1}{T}\ln\left(\prod_{i=0}^{\tau-1}\psi_{t+i}\right)\right) \text{vs. } \tau. \tag{18}$$

Calculating Recruits

Recruits, or spawners in the next generation, from a given broodyear were calculated as

$$C_t = \sum_{i=1}^{MaxAge} N_{t+i} A(i)_{t+i} \tag{19}$$

where C_t is the number of recruits from broodyear *t*, N_t is the number of natural-origin spawners in year *t*, and $A(i)_t$ is the fraction of age *i* spawners in year *t*. The estimate of preharvest recruits is similarly

$$C(preHarvest)_t = \sum_{i=1}^{MaxAge} P_{t+i} A(i)_{t+i} \tag{20}$$

where $C(preHarvest)_t$ is the number of preharvest recruits in year *t*, P_t is the number of natural-origin spawners that would have returned in year *t* if there had not been a harvest, and $A(i)_t$ is the fraction of age *i* spawners in year *t* had there not been a harvest. (Because P_t is in terms of the number of fish that would have appeared on the spawning grounds had there not been a harvest, it can be quite difficult to estimate; thus simplifying assumptions are often made.)

Population Viability Analysis

Scientists have used a variety of quantitative approaches to population viability analysis (PVA) with Pacific salmonids. Because no consensus has emerged on how best to model population viability in salmon, we did not employ a standardized PVA model in this report. However, we considered results of population viability analyses that had been conducted for specific populations.

CHINOOK SALMON

3. Background and History of Chinook Salmon Listings

Chinook salmon (*Oncorhynchus tshawytscha*), also commonly referred to as king, spring, quinnat, Sacramento, California, or tyee salmon, is the largest of the Pacific salmon (Myers et al. 1998). The species historically ranged from the Ventura River in California to Point Hope, Alaska, in North America; and in northeastern Asia from Hokkaido, Japan, to the Anadyr River in Russia (Healey 1991). Additionally, Chinook salmon have been reported in the Mackenzie River area of northern Canada (McPhail and Lindsey 1970). Chinook salmon exhibit diverse and complex life history strategies. Healey (1986) described 16 age categories for Chinook salmon, 7 total ages with 3 possible freshwater ages. This level of complexity is roughly comparable to sockeye salmon, although sockeye salmon have a more extended freshwater residence period and use different freshwater habitats (Miller and Brannon 1982, Burgner 1991). Gilbert (1912) initially described two generalized freshwater life history types: "stream-type" Chinook salmon reside in freshwater for a year or more following emergence, whereas "ocean-type" Chinook salmon migrate to the ocean predominantly within their first year. Healey (1983, 1991) promoted the use of broader definitions for ocean type and stream type to describe two distinct races of Chinook salmon. This racial approach incorporates life history traits, geographic distribution, and genetic differentiation, and provides a valuable frame of reference for comparisons of Chinook salmon populations. For this reason, the BRTs have adopted the broader "racial" definitions of ocean and stream type for this review.

Of the two life history types, ocean-type Chinook salmon exhibit the most varied and plastic life history trajectories. Ocean-type Chinook salmon juveniles emigrate to the ocean as fry, subyearling juveniles (during their first spring or fall), or as yearling juveniles (during their second spring), depending on environmental conditions. Ocean-type Chinook salmon also undertake distinct, coastally oriented, ocean migrations. The timing of the return to freshwater and spawning is closely related to the ecological characteristics of a population's spawning habitat. Five different run times are expressed by different ocean-type Chinook salmon populations: spring, summer, fall, late-fall, and winter. In general, early run times (spring and summer) are exhibited by populations that use high spring flows to access headwater or interior regions. Ocean-type populations within a basin that express different run times appear to have evolved from a common source population. Stream-type populations appear to be nearly obligate yearling outmigrants (some 2-year-old smolts have been identified); they undertake extensive offshore ocean migrations and generally return to freshwater as spring- or summer-run fish. Stream-type populations are found in northern British Columbia, Alaska, and the headwater regions of the Fraser River and Columbia River interior tributaries.

Prior to development of the ESU policy (Waples 1991), NMFS recognized Sacramento River winter-run Chinook salmon as a DPS under the ESA (NMFS 1987). Subsequently, in reviewing the biological and ecological information concerning West Coast Chinook salmon, BRTs have identified additional ESUs for Chinook salmon from Washington, Oregon, and California:

Snake River fall-run Chinook salmon ESU (Waples et al. 1991a)

Snake River spring- and summer-run Chinook salmon ESU (Matthews and Waples 1991)

Upper Columbia River summer- and fall-run Chinook salmon ESU (originally the Mid-Columbia River summer- and fall-run Chinook salmon ESU, Waknitz et al. 1995)

Puget Sound Chinook salmon ESU

Washington Coast Chinook salmon ESU

Lower Columbia River Chinook salmon ESU

Upper Willamette River Chinook salmon ESU

Middle Columbia River spring-run Chinook salmon ESU

Upper Columbia River spring-run Chinook salmon ESU

Oregon Coast Chinook salmon ESU

Upper Klamath and Trinity rivers Chinook salmon ESU

Central Valley fall- and late-fall-run Chinook salmon ESU

Central Valley spring-run Chinook salmon ESU (Myers et al. 1998)

Southern Oregon/Northern California Coasts Chinook salmon ESU

California Coastal Chinook salmon ESU

Deschutes River Chinook salmon ESU (NMFS 1999a)

Of the 17 Chinook salmon ESUs NMFS identified, 8 are not listed under the ESA; 7 are listed as threatened (Snake River spring- and summer-run Chinook salmon, and Snake River fall-run Chinook salmon [NMFS 1992], Puget Sound Chinook salmon, Lower Columbia River Chinook salmon, and Upper Willamette River Chinook salmon [NMFS 1999a], Central Valley fall-run, and California Coastal Chinook salmon [NMFS 1999a]), and 2 are listed as endangered (Sacramento River winter-run Chinook salmon [NMFS 1994a] and Upper Columbia River spring-run Chinook salmon [NMFS 1999a]).

NMFS convened a BRT to update the status of listed Chinook salmon ESUs in Washington, Oregon, California, and Idaho. The Chinook salmon BRT[2] met in March and April 2003 in Seattle, Washington, to review updated information on each ESU under consideration.

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[2] The BRT for the updated Chinook salmon status review included the following: from the NMFS Northwest Fisheries Science Center, Thomas Cooney, Dr. Robert Iwamoto, Dr. Robert Kope, Gene Matthews, Dr. Paul McElhany, Dr. James Myers, Dr. Mary Ruckelshaus, Dr. Thomas Wainwright, Dr. Robin Waples, and Dr. John Williams; from the NMFS Southwest Fisheries Science Center, Dr. Peter Adams, Dr. Eric Bjorkstedt, and Dr. Steve Lindley; from the NMFS Alaska Fisheries Science Center (Auke Bay Laboratory), Alex Wertheimer; and from the USGS Biological Resource Division, Dr. Reginald Reisenbichler.

4. Snake River Fall-Run Chinook Salmon ESU

Snake River fall-run Chinook salmon enter the Columbia River in July and August. The Snake River component of the Chinook salmon fall run migrates past the lower Snake River mainstem dams from August through November. Spawning occurs from October through early December. Juveniles emerge from the gravels in March and April of the following year. Snake River fall-run Chinook salmon exhibit an ocean-type life history pattern, with juveniles migrating downstream from their natal spawning and rearing areas from June through early fall.

Fall-run Chinook salmon returns to the Snake River generally declined through the first half of the 20th century (Irving and Bjornn 1981). In spite of the declines, the Snake River basin remained the largest single natural production area for fall-run Chinook salmon in the Columbia River drainage into the early 1960s (Fulton 1968). The construction of a series of Snake River mainstem dams significantly reduced spawning and rearing habitat for Snake River fall-run Chinook salmon. Historically, the primary fall-run Chinook salmon spawning areas were located on the upper mainstem Snake River. Currently, natural spawning is limited to the area from the upper end of Lower Granite Reservoir to Hells Canyon Dam, the lower reaches of the Imnaha, Grande Ronde, Clearwater, and Tucannon rivers, and small mainstem sections in the tailraces of the lower Snake River hydroelectric dams.

Adult salmon counts at Snake River dams are an index of the annual return of Snake River fall-run Chinook salmon to spawning grounds. Lower Granite Dam is the uppermost of the mainstem Snake River dams that allow for passage of anadromous salmonids. Adult traps at Lower Granite Dam have allowed for sampling of the adult run as well as for removal of a portion of nonlocal hatchery fish prior to passage above the dam. The dam count at Lower Granite covers a majority of fall-run Chinook salmon returning to the Snake River basin. However, Snake River fall-run Chinook salmon do return to locations downstream of Lower Granite Dam and are therefore not included in the ladder count. Lyons Ferry Hatchery is located on the mainstem Snake River below both Little Goose and Lower Monumental dams. Although a fairly large proportion of adult returns from the Lyons Ferry Hatchery program do stray to Lower Granite Dam, a substantial proportion of the run returns directly to the facility. In addition, mainstem surveying efforts have identified relatively small numbers of fall-run Chinook salmon spawning in the tailraces of lower Snake River mainstem hydroelectric dams (Dauble et al. 1999).

Lyons Ferry Hatchery was established as one of the hatchery programs under the Lower Snake Compensation Plan, administered through USFWS. Snake River fall-run Chinook salmon production is a major program for Lyons Ferry Hatchery, which is operated by the Washington Department of Fish and Wildlife (WDFW) and is located along the Snake River main stem between Little Goose Dam and Lower Monumental Dam. WDFW began developing a Snake

River fall-run Chinook salmon broodstock in the early 1970s through a trapping program at Ice Harbor and Lower Granite dams. The Lyons Ferry facility became operational in the mid-1980s and took over incubation and rearing for the Snake River fall-run Chinook mitigation and compensation program.

Summary of Previous BRT Conclusions

Previous Chinook salmon status reviews (Waples et al. 1991b, Myers et al. 1998) identified several concerns regarding Snake River fall-run Chinook salmon: steady and severe decline in abundance since the early 1970s, loss of primary spawning and rearing areas upstream of the Hells Canyon Dam complex, increase in nonlocal hatchery contribution to adult escapement over Lower Granite Dam, and relatively high aggregate harvest impacts by ocean and in-river fisheries.

Listing status: Threatened.

New Data and Updated Analyses

The Lyons Ferry Hatchery Snake River fall-run Chinook salmon broodstock has been used to supply a major natural spawning supplementation effort in recent years (Bugert and Hopley 1989, Bugert et al. 1995). Facilities adjacent to major natural spawning areas have been used to acclimate release groups of yearling smolts. Additional releases of subyearlings have been made in the vicinity of the acclimation sites. The level of subyearling releases depends on the availability of sufficient broodstock to maintain the on-station program and the off-station yearling releases (Table 2). Returns in 2000 and 2001 reflect increases in the level of off-station plants and relatively high marine survival rates.

Abundance

The 1999 NMFS status review update noted increases in the Lower Granite Dam counts in the mid-1990s (Figure 3), and the upward trend in returns has continued. The 2001 count over Lower Granite Dam exceeded 8,700 adult fall-run Chinook salmon. The 1997 through 2001 escapements were the highest on record since the count of 1,000 in 1975. Returns of naturally produced Chinook salmon and increased hatchery returns from the Lyons Ferry Hatchery (on-station releases and supplementation program) account for the increase in escapements over Lower Granite Dam (Table 3).

Returns classified as natural origin exceeded 2,600 in 2001. The 1997–2001 geometric mean natural-origin count over Lower Granite Dam was 871 fish, approximately 35% of the delisting abundance criteria proposed for this run (2,500 natural-origin spawners averaged over an 8-year period). The largest increase in fall-run Chinook salmon returns to the Snake River spawning area was from the Lyons Ferry Hatchery–Snake River stock component. Returns increased from under 200 per year prior to 1998 to over 1,200 and 5,300 adults in 2000 and 2001, respectively. The increase includes returns from the on-station release program as well as returns from large supplementation releases above Lower Granite Dam. Smolt releases from the

Table 2. Escapement and stock composition of fall-run Chinook salmon at Lower Granite Dam, 1975–2001. Source: Stock composition is based on marked recoveries from Lower Granite Dam adult trapping (Yuen 2002).

				Stock composition of Lower Granite Dam escapement*		
Run year	**Lower Granite Dam count**	**Marked fish to Lyons Ferry Hatchery**	**Lower Granite Dam escapement**	**Natural origin**	**Hatchery origin (Snake River)**	**Hatchery origin (non–Snake River)**
1975	1,000	–	1,000	1,000	–	–
1976	470	–	470	470	–	–
1977	600	–	600	600	–	–
1978	640	–	640	640	–	–
1979	500	–	500	500	–	–
1980	450	–	450	450	–	–
1981	340	–	340	340	–	–
1982	720	–	720	720	–	–
1983	540	–	540	428	112	–
1984	640	–	640	324	310	6
1985	691	–	691	438	241	12
1986	784	–	784	449	325	10
1987	951	–	951	253	644	54
1988	627	–	627	368	201	58
1989	706	–	706	295	206	205
1990	385	50	335	78	174	83
1991	630	40	590	318	202	70
1992	855	187	668	549	100	19
1993	1,170	218	952	742	43	167
1994	791	185	606	406	20	180
1995	1,067	430	637	350	1	286
1996	1,308	389	919	639	74	206
1997	1,451	444	1007	797	20	190
1998	1,909	947	962	306	479	177
1999	3,381	1,519	1,862	905	879	78
2000	3,830	1,372	2,458	857	1,278	323
2001	10,782	2,064	8,718	2,652	5,330	736

* Returning adults produced from naturally spawning parents (regardless of the origin of the parents) are classified as natural origin.

Table 3. Fall-run Chinook salmon hatchery releases[a] into the Snake River basin, 1985–2001. Source: The 1994–2001 data are from Milks et al. (2003); 1985–1993 release data are from the Fish Passage Center Hatchery database (NWPPC 2003).

			Acclimation sites							
	Lyons Ferry (direct)		**Pittsburg Landing**		**Capt. John**		**Big Canyon (Clearwater River)**		**Hells Canyon Dam[a]**	
Release year	**Yearling[b]**	**Sub-yearling**	**Yearling[b]**	**Sub-yearling[c]**	**Yearling[b]**	**Sub-yearling[c]**	**Yearling[b]**	**Sub-yearling[c]**	**Yearling[b]**	**Sub-yearling[c]**
1985	650,300	539,392	–	–	–	–	–	–	–	–
1986	481,950	1,789,566	–	–	–	–	–	–	–	–
1987	386,600	1,012,500	–	–	–	–	–	–	–	–
1988	407,500	4,563,500	–	–	–	–	–	–	–	–
1989	413,017	1,710,865	–	–	–	–	–	–	–	–
1990	436,354	3,043,756	–	–	–	–	–	–	–	–
1991	224,439	–	–	–	–	–	–	–	–	–
1992	689,601	–	–	–	–	–	–	–	–	–
1993	206,775	–	–	–	–	–	–	–	–	–
1994	603,661	–	–	–	–	–	–	–	–	–
1995	349,124	–	–	–	–	–	–	–	–	–
1996	407,503	–	114,299	–	–	–	–	–	–	–
1997	456,872	–	147,316	–	–	–	199,399	252,705	–	–
1998	419,002	–	141,814	–	133,205	–	61,172	–	–	–
1999	432,166	204,194	142,885	–	157,010	–	229,608	347,105	–	-
2000	456,401	196,643	134,709	400,156	131,186	892,847	131,306	890,474	–	-
2001	338,757	199,976	103,741	374,070	101,976	501,129	113,215	856,968	–	115,251

[a] All releases are from Lyons Ferry Hatchery–origin broodstock. Hells Canyon Dam releases increased to 500,000 in 2002.

[b] On-station releases and acclimation site yearling releases are marked or tagged.

[c] Acclimation site subyearling releases are generally unmarked.

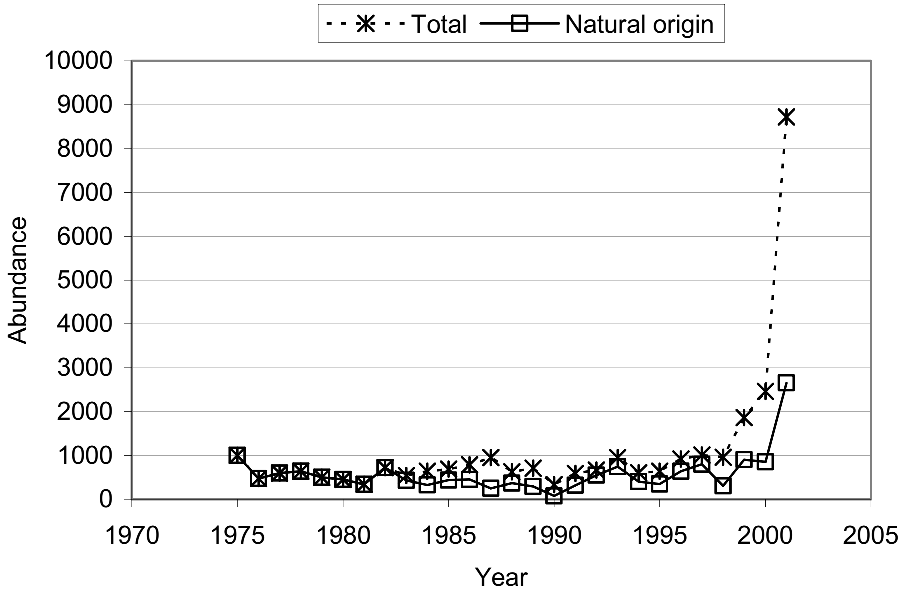

Figure 3. Estimated spawning escapement of fall-run Chinook salmon at Lower Granite Dam, 1975–2001.

acclimation sites above Lower Granite Dam were marked. In recent years, large numbers of unmarked subyearling Lyons Ferry Hatchery fall-run Chinook have been released from the acclimation sites. These fish will contribute to adult returns over Lower Granite Dam, complicating the estimation of natural production rates (WDFW 2003). Escapement over Lower Granite Dam represents the majority of Snake River fall-run Chinook salmon returns. In addition, Snake River fall-run Chinook salmon returns to the Tucannon River system (≤100 spawners per year based on redd counts) and to Lyons Ferry Hatchery (recent average returns to the facility have been approximately 1,100 fish per year). Small numbers of fall-run Chinook salmon redds have also been reported in tailrace areas below the mainstem Snake River dams (Dauble et al. 1999).

Productivity

Both the long- and short-term trends in total returns are positive (1.05, 1.22). The short-term (1990–2001) estimates of the median population growth rate (λ) are 0.98, assuming a hatchery-spawning effectiveness of 1.0 (equivalent to that of wild spawners), and 1.137 with an assumed hatchery-spawning effectiveness of 0. The estimated long-term growth rate for the Snake River fall-run Chinook salmon population is strongly influenced by the hatchery-effectiveness assumption. If hatchery spawners have been equally effective as natural-origin spawners in contributing to broodyear returns, the long-term λ estimate is 0.899, and the associated probability that λ is less than 1.0 is estimated as 99%. If hatchery returns over Lower Granite Dam are not contributing at all to natural production (hatchery effectiveness of 0.0), the long-term estimate of λ is 1.024. The associated probability that λ is less than 1.0 is 0.26.

Broodyear returns-per-spawner estimates were low for 3 or more consecutive years in the mid-1980s and the early 1990s (Figure 4). The large increase in natural abundance in 2000

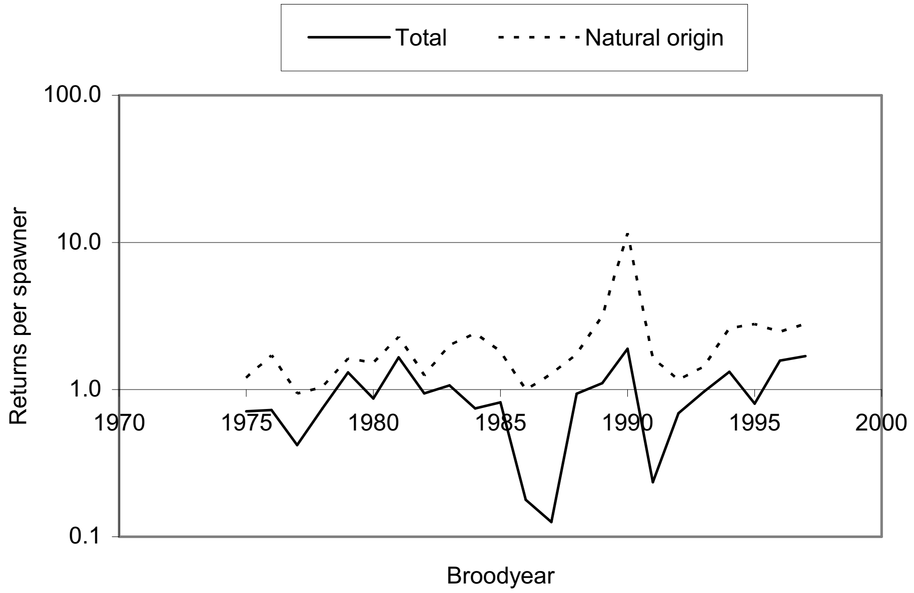

Figure 4. Returns per spawner plotted against broodyear escapements for Snake River fall-run Chinook salmon, 1975–1997 (escapement estimates are from Lower Granite Dam counts, assuming a 10% prespawning mortality). Broodyear returns are estimated by applying sample age-at-return estimates to annual dam counts.

and 2001 is reflected in the 1996 and 1997 return-per-spawner estimates (1997 returns per spawner is based on 4-year-old component only).

Harvest Impacts

Due to their patters of ocean distribution and the timing of their spawning run up the Columbia River, Snake River fall-run Chinook salmon are subject to harvest in a wide range of fisheries. Coded-wire tag studies using Lyons Ferry Hatchery fish of Snake River origin indicate that Snake River fall-run Chinook salmon have a broad distribution. Coastal fisheries in California, Oregon, Washington, British Columbia, and southeast Alaska have reported recoveries of tagged fish from the Snake River. The timing of the return and upriver spawning migration of Snake River fall-run Chinook salmon overlaps the Hanford Reach upriver bright Chinook salmon returns, as well as several large hatchery runs returning to lower river release areas or to the major hatcheries adjacent to the lower mainstem Columbia River.

Harvest impacts on Snake River fall-run Chinook salmon declined after listing and have remained relatively constant at approximately 35–40% in recent years (Figure 5). The decline and subsequent listing of Snake River fall-run Chinook salmon prompted major restrictions on U.S. fisheries impacting this stock. In-river gillnet and sport fisheries are “shaped” in time and space to maximize the catch of harvestable hatchery and natural (Hanford Reach) stocks while minimizing impacts on the intermingled Snake River fall-run Chinook salmon. Reductions in ocean fishery impacts on Snake River fall-run Chinook salmon resulted from management measures designed to protect weakened or declining stocks specific to each set of fisheries.

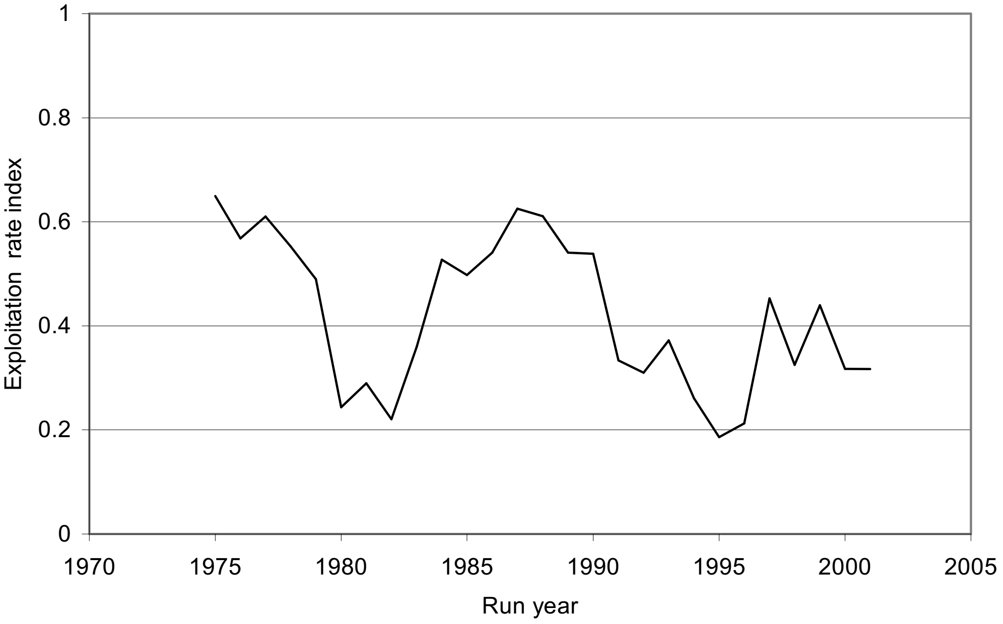

Figure 5. Aggregate (ocean and in-river fisheries) exploitation rate index for Snake River fall-run Chinook salmon, 1975–2001. Source: Data from Marmorek et al. (1998); 1998–2001 data from Columbia River Technical Advisory Committee database.[3]

Mainstem Hydropower Impacts

Migration conditions for subyearling Chinook salmon from the Snake River have generally improved since the early 1990s (FCRPS 2000). The lack of baseline data prior to the mid-1990s precludes quantifying the changes.

Habitat

There have been no major changes in available habitat for Snake River fall-run Chinook salmon since the previous status review.

New Hatchery Information

Sampling marked returns determines the composition of the fall Chinook salmon run at Lower Granite Dam. Since the early 1980s, the run has consisted of three major components: unmarked returns of natural origin, marked returns from the Lyons Ferry Hatchery program, and strays from hatchery programs outside of the mainstem Snake River (Table 3). Although all three components of the fall run have increased in recent years, returns of Snake River–origin Chinook salmon have increased disproportionately to outside hatchery strays. Prior to the 1998–1999 status reviews, the 5-year average contribution of outside stocks to the escapement over Lower Granite Dam exceeded 26.2%. The most recent 5-year average (1997–2001) was 12.4%, with the contribution in 2001 being just over 8%. The drop in relative contribution by outside stocks reflects the disproportionate increase in returns of the Lyons Ferry Hatchery

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[3] H. Yuen, U.S. Fish and Wildlife Service, Vancouver, WA. Pers. commun., December 2002.

component, the systematic removal of marked hatchery fish at the Lower Granite Dam trap, and modifications to the Umatilla program to increase homing of fall-run Chinook salmon release groups intended to return to the Umatilla River.

The primary contributor of non-ESU strays to Lower Granite Dam continues to be releases from the Umatilla fall-run Chinook salmon program (Priest Rapids stock). In addition, low numbers of returns from releases into the Klickitat River have been consistently detected at the Lower Granite Dam adult trap. In 2000–2002, two or three adult Chinook salmon with Klickitat Hatchery coded-wire tags were detected in each sampling year (Milks et al. 2003). Recoveries of Umatilla-origin adult tags at the Lower Granite Dam trap ranged from 43 to 166 for the same 3-year period (Milks et al. 2003).

One of the concerns leading to the listing of Snake River fall-run Chinook salmon under the ESA was the possibility of significant introgression due to increased straying by outside stocks into the natural spawning areas above Lower Granite Dam. Removal of all outside-origin stock at Lower Granite Dam is not feasible—the trapping operation does not handle 100% of the run at the dam, and outside stocks are generally not 100% marked. A genetic analysis of outmigrant smolts produced from spawning above Lower Granite Dam was conducted to evaluate the potential for introgression of outside stocks. Marshall et al. (2000) concluded that distinctive patterns of allelic diversity persisted in the stock, indicating that the natural Snake River Chinook salmon fall run remains a distinct resource.

Categorizations of Snake River fall-run Chinook salmon hatchery stocks (SSHAG 2003) can be found in Appendix A, Table A-1.

5. Snake River Spring/Summer-Run Chinook Salmon ESU

NMFS classified spring- and summer-run Chinook salmon returning to the major tributaries of the Snake River as an ESU (Matthews and Waples 1991). This ESU includes production areas characterized by spring- and summer-timed returns, and combinations from the two adult timing patterns. Runs classified as spring-run Chinook salmon are counted at Bonneville Dam beginning in early March and ending the first week of June; runs classified as summer-run Chinook salmon return to the Columbia River from June through August. Returning fish hold in deep mainstem and tributary pools until late summer, when they emigrate up into tributary areas and spawn. In general, spring-run type Chinook salmon tend to spawn in higher-elevation reaches of major Snake River tributaries in mid- through late August, and summer-run Snake River Chinook salmon spawn approximately one month later than spring-run fish. Summer-run Chinook salmon tend to spawn lower in the Snake River drainages, although their spawning areas often overlap with spring-run spawners.

Many of the Snake River tributaries spring/summer-run Chinook salmon use exhibit two major features: extensive meanders through high-elevation meadowlands and relatively steep lower sections joining the drainages to the mainstem Salmon River (Matthews and Waples 1991). The combination of relatively high summer temperatures and the upland meadow habitat creates the potential for juvenile salmonid high productivity. Historically, the Salmon River system may have supported more than 40% of the total return of spring/summer-run Chinook salmon to the Columbia River system (e.g., Fulton 1968).

The Snake River spring/summer-run Chinook salmon ESU includes current runs to the Tucannon River, the Grande Ronde River system, the Imnaha River, and the Salmon River (Matthews and Waples 1991). The Salmon River system contains a range of habitats used by spring- and summer-run Chinook salmon. The South Fork and Middle Fork Salmon River currently support the bulk of natural production in the drainage. Two large tributaries entering above the confluence of the Middle Fork Salmon River, the Lemhi and Pahsimeroi rivers, drain broad alluvial valleys and are believed to have historically supported substantial, relatively productive anadromous fish runs. Returns into the upper Salmon River tributaries were reestablished following the opening of passage around Sunbeam Dam on the mainstem Salmon River downstream of Stanley, Idaho. Sunbeam Dam in the upper Salmon River was a serious impediment to migration of anadromous fish and may have been a complete block in at least some years before its partial removal in 1934 (Waples et al. 1991b).

Current runs returning to the Clearwater River drainages were not included in the Snake River spring/summer-run Chinook salmon ESU. Lewiston Dam in the lower main stem of the Clearwater River was constructed in 1927 and functioned as an anadromous block until the early 1940s (Matthews and Waples 1991). Spring and summer Chinook salmon runs were reintroduced into the Clearwater system via hatchery outplants beginning in the late 1940s. As a result, Matthews and Waples (1991) concluded that even if a few native salmon survived the hydropower dams, "the massive outplantings of nonindigenous stocks presumably substantially altered, if not eliminated, the original gene pool."

Spring/summer-run Chinook salmon from the Snake River basin exhibit stream-type life history characteristics (Healey 1983). Eggs are deposited in late summer and early fall, incubate over the following winter, and hatch in late winter and early spring of the following year. Juveniles rear through the summer, overwinter, and migrate to sea in the spring of their second year of life. Depending on the tributary and the specific habitat conditions, juveniles may migrate extensively from natal reaches into alternative summer-rearing or overwintering areas. Snake River spring/summer-run Chinook salmon return from the ocean to spawn primarily as 4- and 5-year-old fish, after 2 to 3 years in the ocean. A small fraction of the fish return as 3-year-old "jacks," heavily predominated by males.

Summary of Previous BRT Conclusions

The 1991 ESA status review (Matthews and Waples 1991) of the Snake River spring/summer-run Chinook salmon ESU concluded that the ESU was at risk. Aggregate abundance of naturally produced Snake River spring and summer Chinook salmon runs had dropped to a small fraction of historical levels. Short-term projections (including jack counts and habitat/flow conditions in the broodyears producing the next generation of returns) were for a continued downward trend in abundance. Risk modeling indicated that if the historical trend in abundance continued, the ESU as a whole was at risk of extinction within 100 years. The review identified related concerns at the population level within the ESU. Given the large number of potential production areas in the Snake River basin and the low levels of annual abundance, risks to individual subpopulations may be greater than the extinction risk for the ESU as a whole. The 1998 Chinook salmon status review (Myers et al. 1998) summarized and updated these concerns. Both short- and long-term abundance trends had continued downward. The report identified continuing disruption due to the impact of mainstem hydroelectric development, including altered flow regimes and impacts on estuarine habitats. The 1998 review also identified regional habitat degradation and risks associated with the use of outside hatchery stocks in particular areas—specifically including major sections of the Grande Ronde River basin.

Direct estimates of annual runs of historical spring/summer-run Chinook salmon to the Snake River are not available. Chapman (1986) estimated that the Columbia River produced 2.5 million to 3.0 million spring/summer-run Chinook salmon per year in the late 1800s. Total spring/summer-run Chinook salmon production from the Snake River basin contributed a substantial proportion of those returns; the total annual production of Snake River spring/summer-run Chinook salmon may have been in excess of 1.5 million adult returns per year (Matthews and Waples 1991). Returns to Snake River tributaries had dropped to roughly 100,000 adults per year by the late 1960s (Fulton 1968). Increasing hatchery production contributed to subsequent years' returns, masking a continued decline in natural production.

Listing status: Threatened.

New Data and Updated Analyses

Abundance

Aggregate returns of spring-run Chinook salmon (as measured at Lower Granite Dam) showed a large increase over recent year abundances (Figure 6). The 1997–2001 geometric mean return of natural-origin Chinook salmon exceeded 3,700. The increase was largely driven by the 2001 return—estimated to have exceeded 17,000 naturally produced spring-run Chinook salmon—however, a large proportion of the run in 2001 was estimated to be of hatchery origin (88%). The summer run over Lower Granite Dam has increased as well (Figure 7). The 1997–2001 geometric mean total return was slightly more than 6,000. The geometric mean return for the broodyears for recent returns (1987–1996) was 3,076. (Note: This figure does not address hatchery versus wild breakdowns of the aggregate run.)

Returns in other production areas are shown in Figures 8–21 and summarized in Table 4. The lowest 5-year geometric mean returns for almost all individual Snake River spring/summer-run Chinook salmon production areas were in the 1990s. Sulphur Creek and Poverty Flat production areas had low 5-year geometric mean returns in the early 1980s. Many, but not all, production areas had large increases in return year 2001. Recent return levels are also compared against interim delisting criteria (abundance) for those production areas with designated levels (Table 4). The Snake River Salmon Recovery Team (Bevan et al. 1994) suggested the interim abundance criteria, and in some cases it was developed for use in analyses supporting the Federal Columbia River Power System biological opinions.

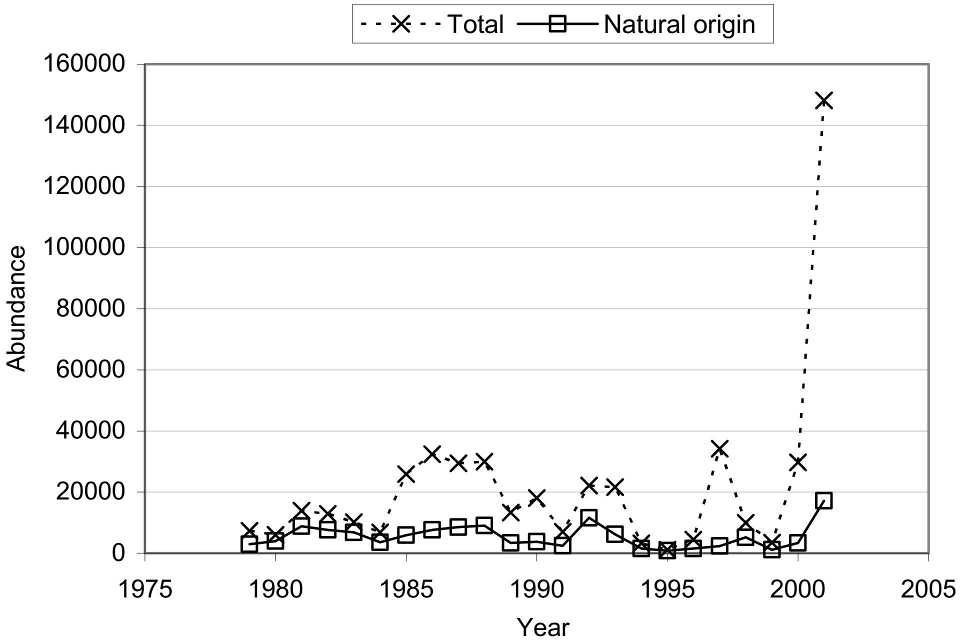

Figure 6. Snake River spring-run Chinook salmon escapement over Lower Granite Dam, 1979–2001.

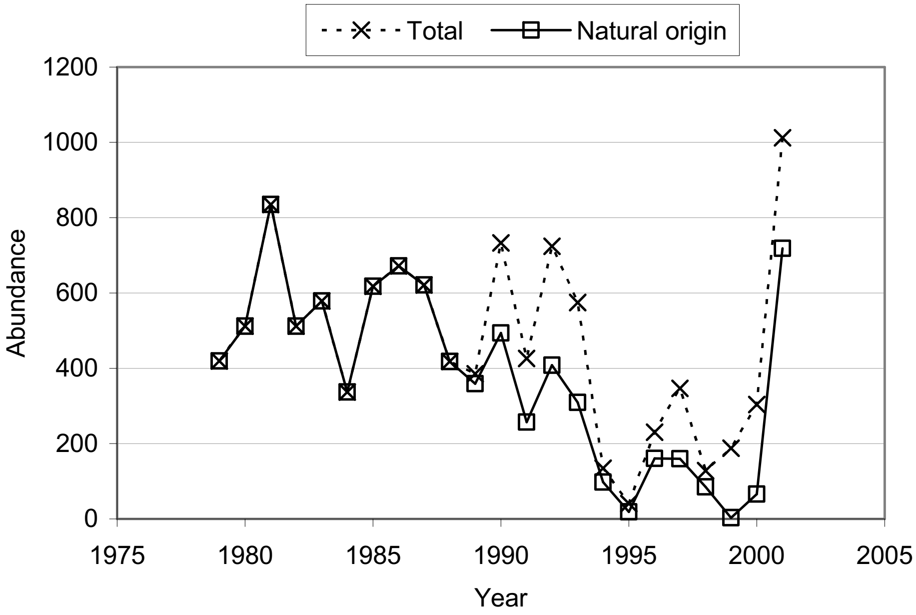

Figure 7. Snake River summer-run Chinook salmon escapement, 1979–2002.

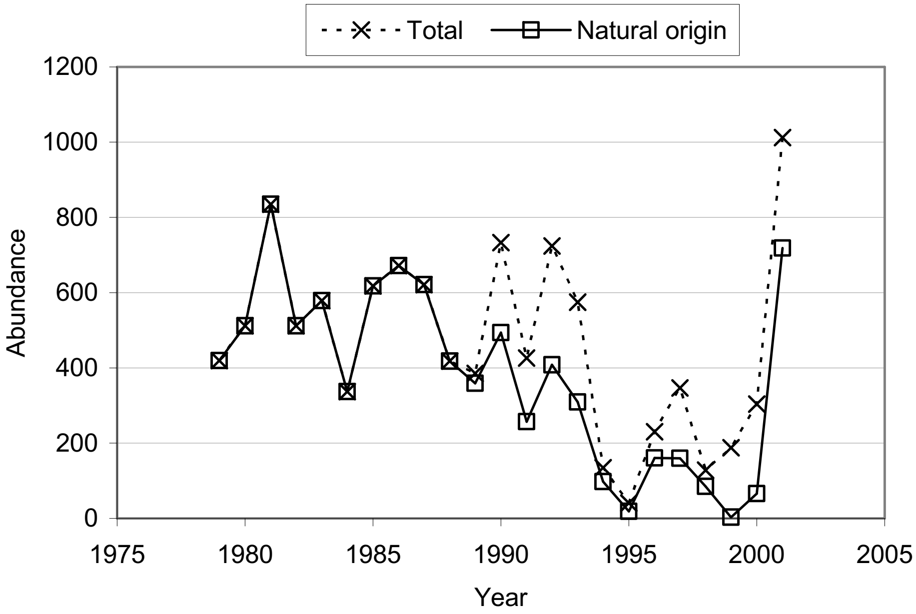

Figure 8. Tucannon River spring-run Chinook salmon spawning escapement, 1979–2001. Estimates are based on trap counts and expanded redd estimates. See Appendix A, Table A-2 for abundance source information.

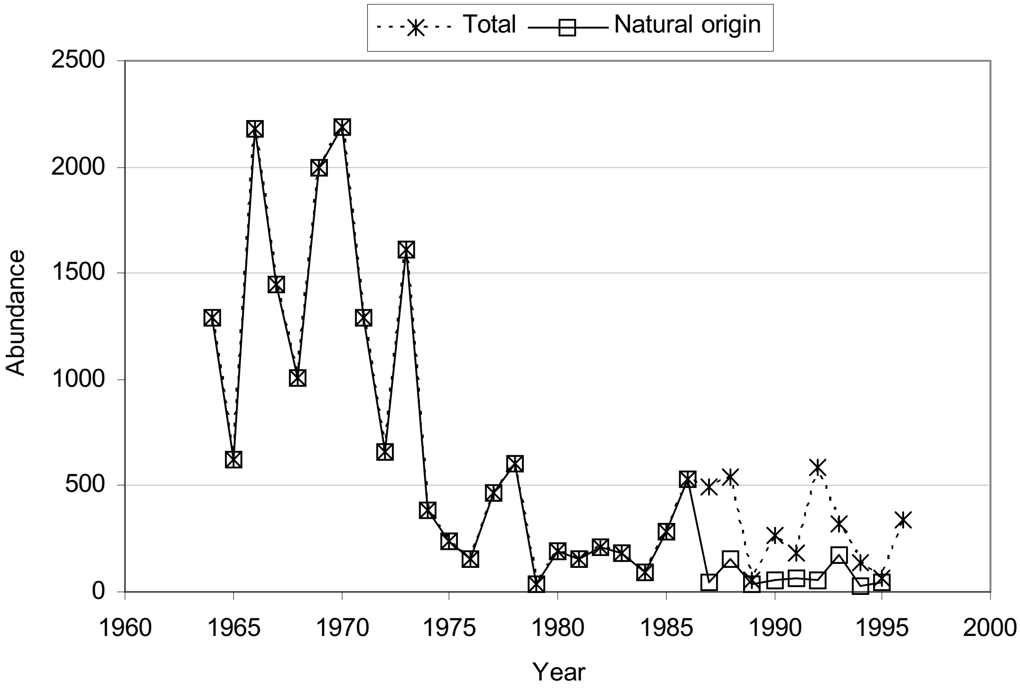

Figure 9. Wenaha River spring-run Chinook spawning escapement, 1964–1996. Estimates are expanded from redd counts.

Productivity

Long-term trend and λ estimates were less than 1 for all natural production data sets, reflecting the large declines since the 1960s. Short-term trends and λ estimates were generally positive, with relatively large confidence intervals (Table 4 and Figure 22). Grande Ronde and Imnaha data sets had the highest short-term growth rate estimates. Tucannon River, Poverty Flat (2000 and 2001 not included), and Sulphur Creek index areas had the lowest short-term λ estimates in the series. Patterns in returns per spawner for stocks with complete age information (e.g., Minam River) show a series of extremely low return rates in the 1990s, followed by increases in the 1995–1997 broodyears (Figure 23).

Hydropower Impacts

Snake River spring/summer-run Chinook salmon must migrate past a series of mainstem Snake and Columbia river hydroelectric dams to and from the ocean. The Tucannon River population must migrate through six dams; all other major Snake River drainages supporting spring/summer-run Chinook salmon production are above eight dams. Earlier status reviews concluded that mainstem Columbia and Snake river hydroelectric projects have resulted in major disruption of migration corridors and have affected flow regimes and estuarine habitat.

Table 4. Summary of abundance and trend information for Snake River spring/summer-run Chinook salmon ESU relative to previous BRT status review analyses.

Populations	Recent 5-year geometric mean[a]				Short-term trend (percent/year)		Interim target (nos.)[b]	Current vs. interim target[c]
	Percent natural origin (previous)	Total	Natural					
		Mean (range)	Current	Previous	Current	Previous		
Tucannon River	24	303 (128–1,012)	80	190	–4.1	–11.0	1,000	30%
Wenaha River[d]	36	225 (67–586)	82	–	–9.4	–23.6	–	–
Wallowa River	95	0.57 redds (0.0–29.0)	–	–	+11.5	–	–	–
Lostine River	95	34 redds (9–131)	–	–	+12.7	–	–	–
Minam River	95	180 (96–573)	172	69	+3.3	–14.5	439[d]	41%
Catherine Creek[d]	44	50 (13–262)	22	45	–25.1	–22.5	–	–
Upper Grande Ronde River[d]	42	46 (3–336)	20	–	–9.4	–	–	–
South Fork Salmon River	91	496 redds (277–679)	–	–	+1.1	-13.6	–	–
Secesh River	96	144 redds (38–444)	–	–	+9.8	–	–	–
Johnson Creek	100	131 redds (49–444)[e]	–	–	–1.5	–	286[d]	46%
Big Creek spring run	100	53 (21–296)	53	–	+5.4	–34.2	–	–
Big Creek summer run	?	5 redds (2–58)	–	–	+1.7	–27.9	–	–
Loon Creek	100	27 redds (6–255)	–	–	+12.2	–	–	–
Marsh Creek	100	53 (0–164)	53	–	–4.0	–	911[d]	6%
Bear Valley/Elk Creek	100	266 (72–712)	266	–	+6.2	–	426[d]	62%
North Fork Salmon River[e]	?	5.6 redds (2.0–19.0)	–	–	–	–	–	–
Lemhi River	100	72 redds (35–216)	–	–	+12.8	–27.4	2,200	–
Pahsimeroi River	?	161 (72–1,097)	–	–	+12.8	–	1,300	–
East Fork Salmon spring run[f]	?	0.27 rpm[g] (0.2–1.41)	–	–	–5.7	–	700	–
East Fork Salmon summer run	100	1.22 rpm[g] (0.35–5.32)	–	–	+0.9	–32.9	–	–
Yankee Fork spring run[f]	?	0.0 rpm[g] (0.0–0.0)	–	–	–6.3	–	–	–
Yankee Fork summer run	100	2.9 redds (1.0–18.0)	–	–	+4.1	–	–	–
Valley Creek spring run	100	7.4 redds (2.0–28.0)	–	–	+14.9	–25.9	–	–
Valley Creek summer run[h]	?	2.14 rpm[g] (0.71–9.29)	–	–	+5.8	–29.3	–	–
Upper Salmon spring run	?	69 redds (25–357)	–	–	+5.3	–	–	–

Table 4 continued. Summary of abundance and trend information for Snake River spring/summer-run Chinook salmon ESU relative to previous BRT status review analyses.

	Recent 5-year geometric mean[a]				Short-term trend (percent/year)			
	Percent natural origin (previous)	Total	Natural					
Populations		Mean (range)	Current	Previous	Current	Previous	Interim target (nos.)[b]	Current vs. interim target[c]
Upper Salmon summer run[f]	?	0.24 rpm[g] (0.07–0.58)	–	–	–3.3	–	2,000	–
Alturas Lake Creek	?	2.7 redds (0–18)	–	–	+10.2	–	–	–
Imnaha River	38	564 redds (194–3,041)[i]	–	216	+12.8	–24.1	2,500	9%
Big Sheep Creek	3	0.25 redds (0.0–1.0)	–	–	+0.8	–	–	–
Lick Creek	41	1.4 redds (0.0–29.0)	–	–	+11.7	–	–	–

[a] Five-year geometric means calculated using years 1997–2001 unless otherwise noted. Previous natural geomean for 1987–1996 period.

[b] Interim targets from Ford et al. (2001), Lohn (2002).

[c] Comparison of current (recent 5-year geometric mean) to interim target only for those production areas with estimated spawners and corresponding interim target.

[d] Five-year geometric mean calculated using years 1992–1996.

[e] Five-year geometric mean calculated using years 1996–2000.

[f] Five-year geometric mean calculated using years 1993–1997.

[g] rpm = redds per mile.

[h] Five-year geometric mean calculated using years 1997, 2000, and 2001 only.

[i] Expanded redds.

Harvest

Harvest impacts on Snake River spring-run Chinook salmon are generally low. Ocean harvest rates are also low. Historical harvest estimates reflect the impact of mainstem and tributary in-river fisheries. In response to initial declines in returns, in-river harvests of both spring- and summer-run Chinook salmon were restricted beginning in the early 1970s (Matthews and Waples 1991).

Fishery impacts were further reduced following ESA listing in 1991, with lower harvest rates from 1991 to 1999. In response to the large increase in returns of spring-run Chinook salmon, additional impacts were allowed beginning in 2000. The management agreement providing for increased impacts as a function of abundance also calls for additional reductions if and when runs drop below prescribed thresholds.[4]

Habitat

Tributary habitat conditions vary widely among the various drainages of the Snake River basin. Habitat is degraded in many areas of the basin, reflecting the impacts of forest, grazing, and mining practices. Impacts relative to anadromous fish include lack of pools, higher water temperatures, low water flows, poor overwintering conditions, and high sediment loads. Substantial portions of the Salmon River drainage, particularly in the middle fork, are protected in wilderness areas.

New Hatchery Information

Spring/summer-run Chinook salmon are produced from a number of artificial production facilities in the Snake River basin (Table 5). Much of the production was initiated under the Lower Snake River Compensation Plan. Lyons Ferry Hatchery serves as a rearing station for Tucannon River spring-run Chinook salmon broodstock. Rapid River Hatchery and McCall Hatchery provide rearing support for a regionally derived summer-run Chinook salmon broodstock released into lower Salmon River areas. Two major hatchery programs have operated in the upper Salmon Basin—the Pahsimeroi and Sawtooth facilities. Since the mid-1990s, small-scale natural stock supplementation studies and captive breeding efforts have been initiated in the Snake River basin.

Historically, releases from broodstock originating outside the basin constituted a relatively small fraction of the total release into the basin. The 1998 Chinook salmon status review (Myers et al. 1998) identified concerns regarding the use of the Rapid River Hatchery stock reared at Lookingglass Hatchery in the Grande Ronde River basin. The Rapid River Hatchery stock was originally developed from broodstock collected from the spring-run Chinook salmon returns to historical production areas above the Hells Canyon Dam complex.

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[4] Order approving interim management agreement for upriver spring Chinook, summer Chinook, and sockeye. Approved 5 April 2001. *United States v. Oregon Technical Advisory Committee*, Civil 68-513.

Use of the Rapid River Hatchery stock in Grande Ronde drainage hatchery programs has been actively phased out since the late 1990s. In addition, a substantial proportion of marked returns of Rapid River Hatchery stock released in the Grande Ronde River have been intercepted and removed at the Lower Granite Dam ladder and at some tributary-level weirs. Carcass survey data indicate significant declines in hatchery contributions to natural spawning in areas previously subject to Rapid River Hatchery stock strays.

Concerns for the high incidence of bacterial kidney disease (BKD) in Snake River basin hatchery facilities were also identified (Myers et al. 1998). Categorization of Snake River spring/summer-run Chinook salmon hatchery stocks (SSHAG 2003) can be found in Appendix A, Table A-1.

Table 5. Total hatchery releases of spring/summer-run Chinook salmon into the Snake River basin, by stock and release site. Source: Information from Fish Passage Center (NWPPC 2003) smolt release database.

		Average releases per year		
Basin	**Stock**	**1985–1989**	**1990–1994**	**1995–2001**
Mainstem Snake River	Rapid River	405,192	445,411	146,728
	Leavenworth	32,857	–	–
	Lookingglass	–	–	20,622
	Mixed	–	–	29,369
	Mainstem Total	438,049	445,411	196,719
Mainstem Grande Ronde River	Carson	784,785	100,934	–
	Imnaha River	24,700	–	–
	Lookingglass	396,934	–	–
	Rapid River	452,786	642,605	239,756
	Grande Ronde River	–	–	581
Catherine Creek	Carson	60,893	–	–
	Rapid River	–	14,000	–
	Catherine Creek	7,552	–	24,973
	Lookingglass	153,420	–	–
Wallowa River	Carson	70,529	–	–
	Lookingglass	55,120	–	–
	Lostine River	–	–	25,847
	Rapid River	–	28,863	–
	Grande Ronde Total	2,006,718	786,401	291,158
Little Salmon River	Rapid River	2,374,325	2,631,741	1,552,835
South Fork Salmon River	South Fork Salmon River	929,351	1,020,393	888,469
Pahsimeroi River	Pahsimeroi River	418,160	479,382	74,934
	Salmon River	55,809	–	40,444
East Fork Salmon River	Salmon River	182,598	147,614	6,222
Upper Salmon River	Pahsimeroi River	145,100	–	–
	Rapid River	10,020	20,000	–
	Salmon River	1,220,188	1,091,576	96,877
	Salmon River Total	5,335,551	5,390,706	2,656,782
Imnaha River	Imnaha River	98,425	339,928	269,886
ESU Total	All stocks	7,942,476	7,071,402	3,511,286

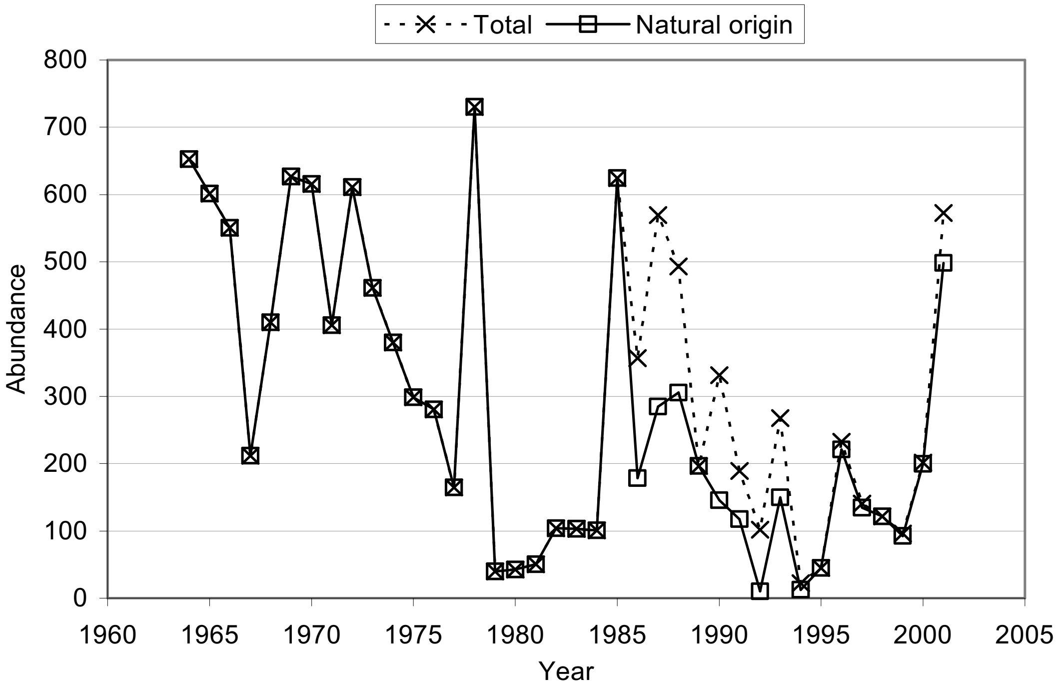

Figure 10. Minam River Chinook salmon spawning escapements, 1964–2001. Estimates are based on expanded redd counts and carcass sampling. See Appendix A, Table A-2 for abundance source information.

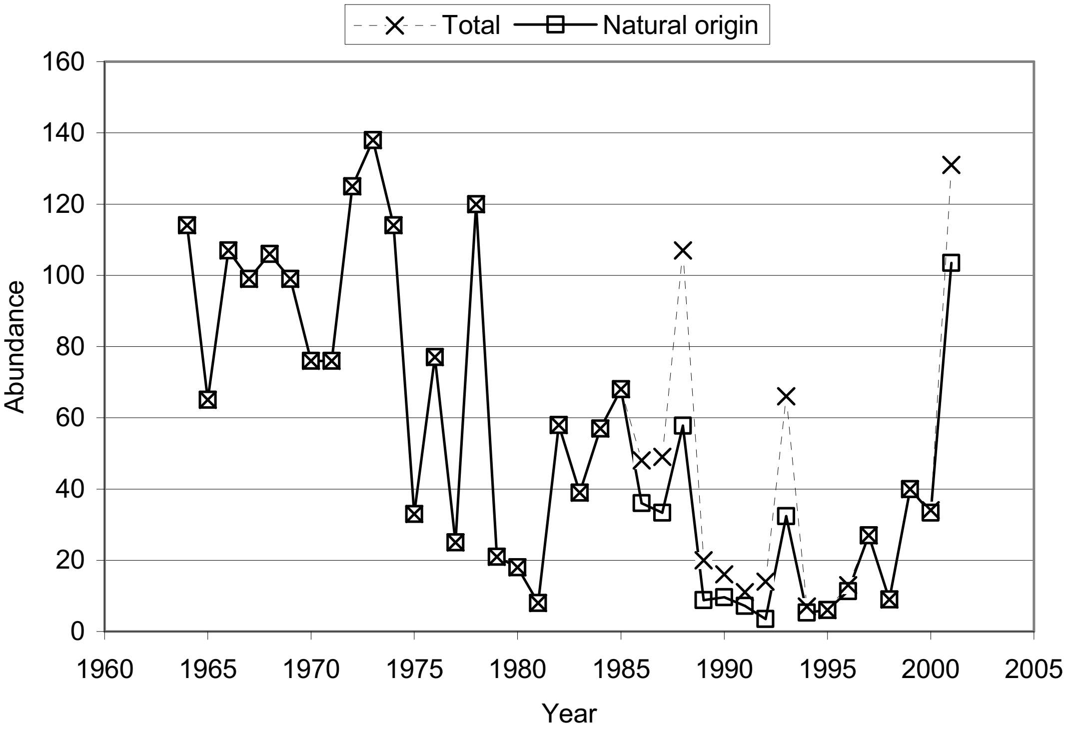

Figure 11. Lostine River spring-run Chinook salmon total counts, 1964–2001. Estimates are based on redd count expansions and carcass sampling. See Appendix A, Table A-2 for abundance source information.

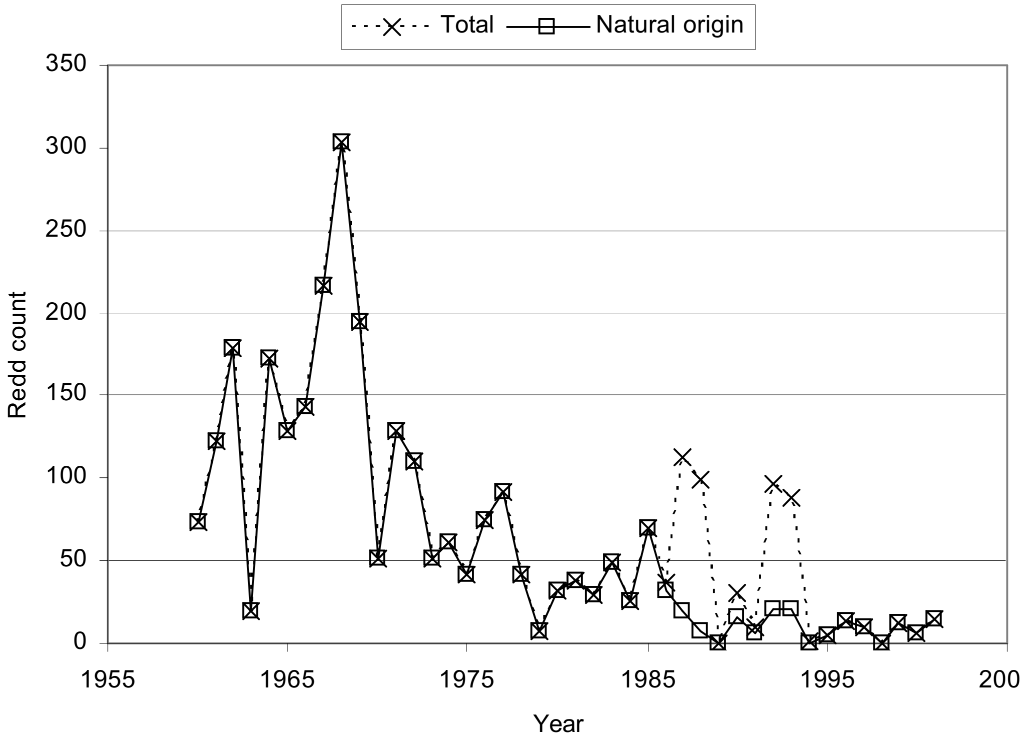

Figure 12. Upper Grande Ronde River spring-run Chinook salmon redd counts, 1960–2001. Hatchery contributions are based on carcass sampling. See Appendix A, Table A-2 for abundance source information.

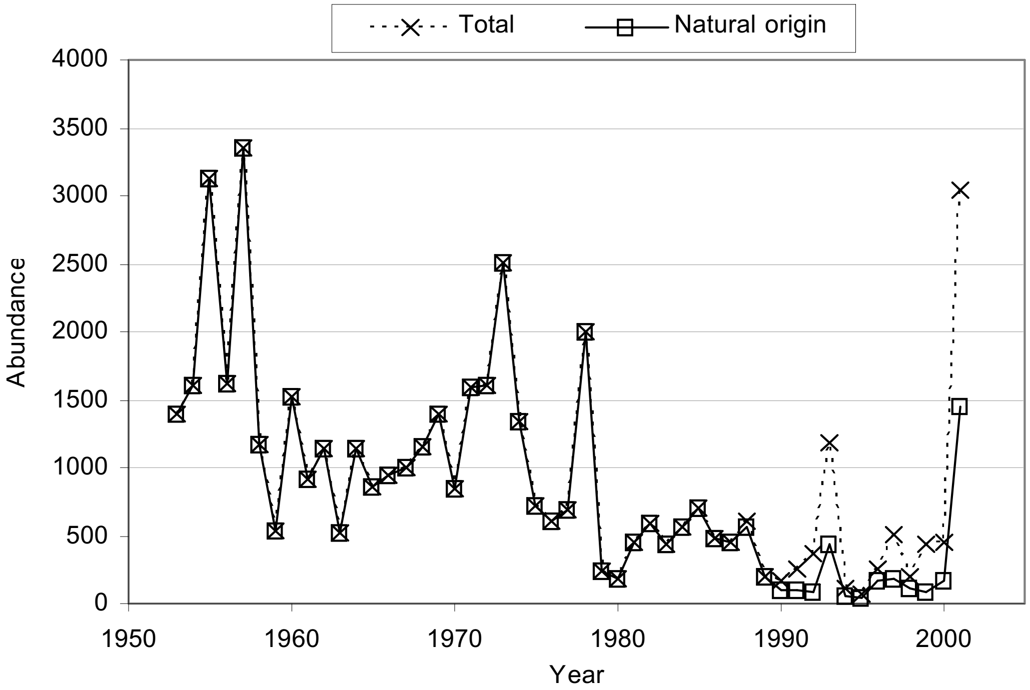

Figure 13. Imnaha River spring-run Chinook salmon spawning escapement, 1953–2001. Estimates are based on expanded redd counts and carcass sampling. See Appendix A, Table A-2 for abundance source information.

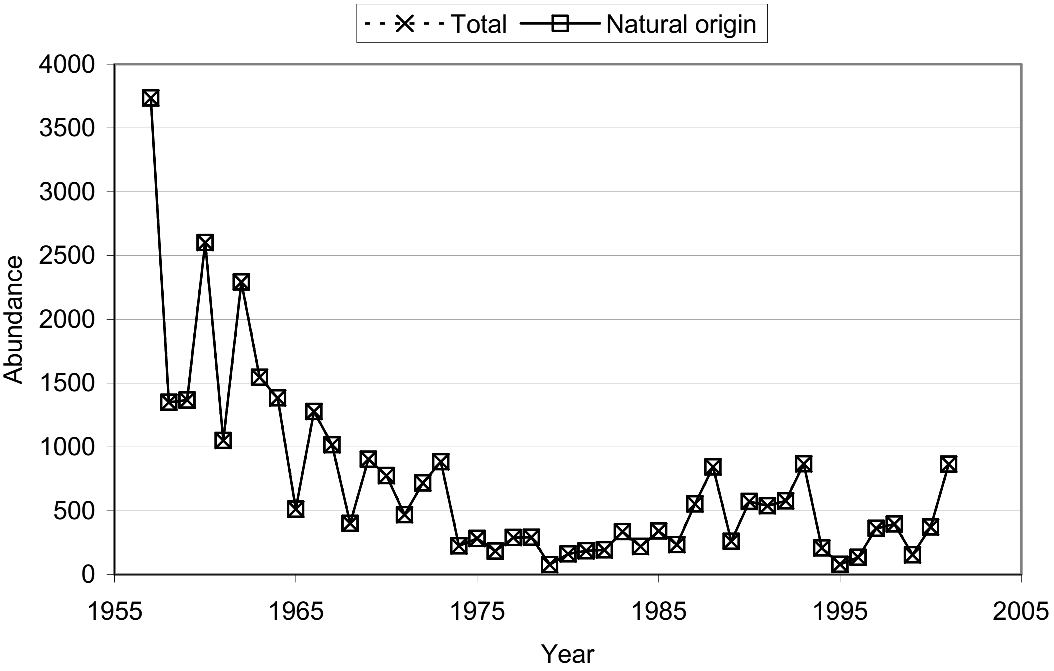

Figure 14. Poverty Flat summer-run Chinook salmon spawning escapement, 1957–2001. Estimates are based on redd count expansions. See Appendix A, Table A-2 for abundance source information.

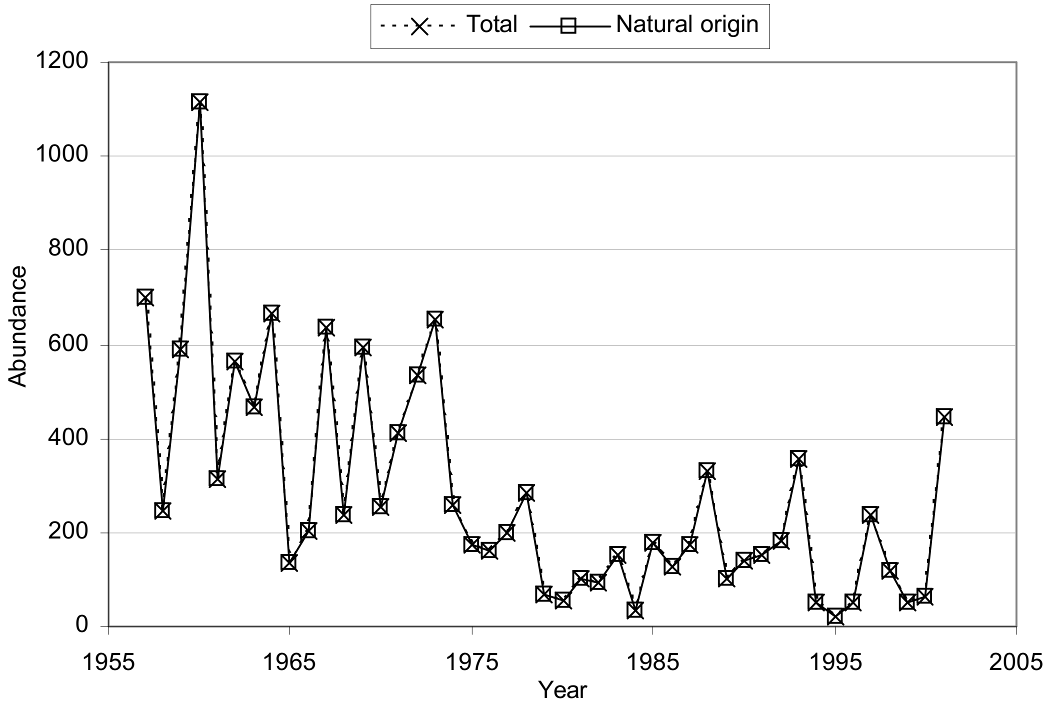

Figure 15. Johnson Creek summer-run Chinook salmon spawning escapement, 1957–2001. Estimates are based on expanded redd counts. See Appendix A, Table A-2 for abundance source information.

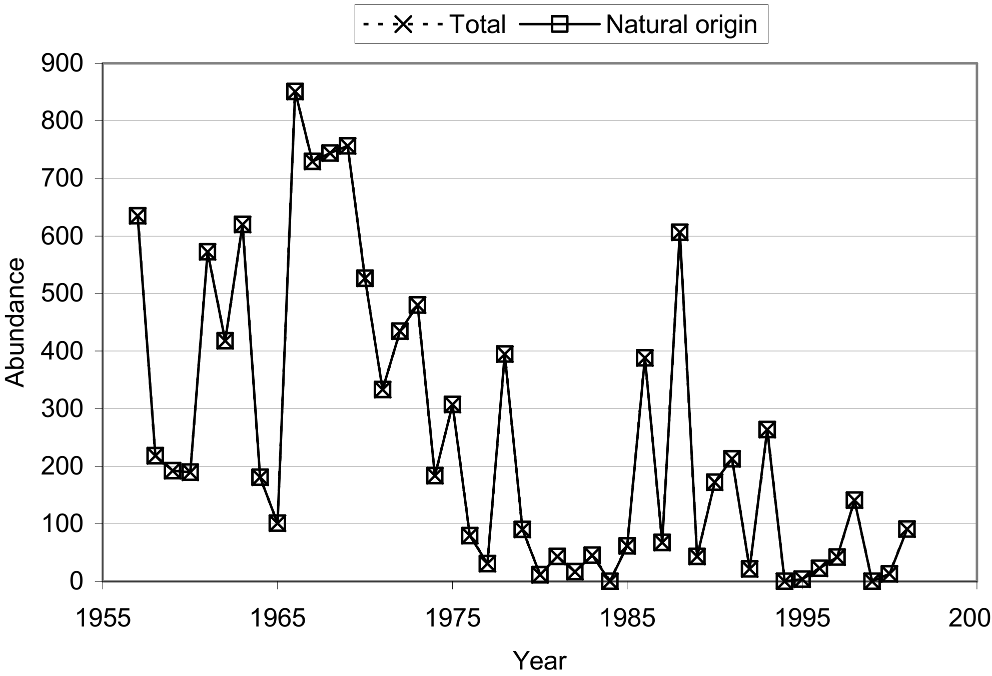

Figure 16. Sulphur Creek spring-run Chinook salmon spawning escapement, 1957–2001. Estimates are based on expanded redd counts and carcass surveys. See Appendix A, Table A-2 for abundance source information.

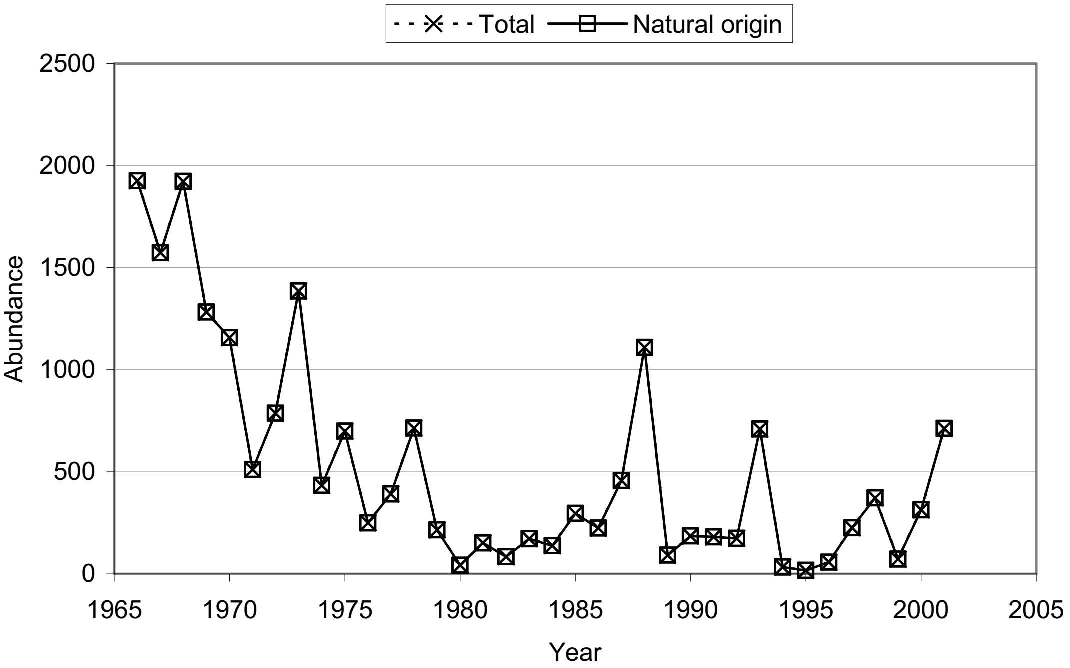

Figure 17. Bear Valley/Elk Creek spring-run Chinook spawning escapement, 1966–2001. Estimates are based on expanded redd counts and carcass surveys. See Appendix A, Table A-2 for abundance source information.

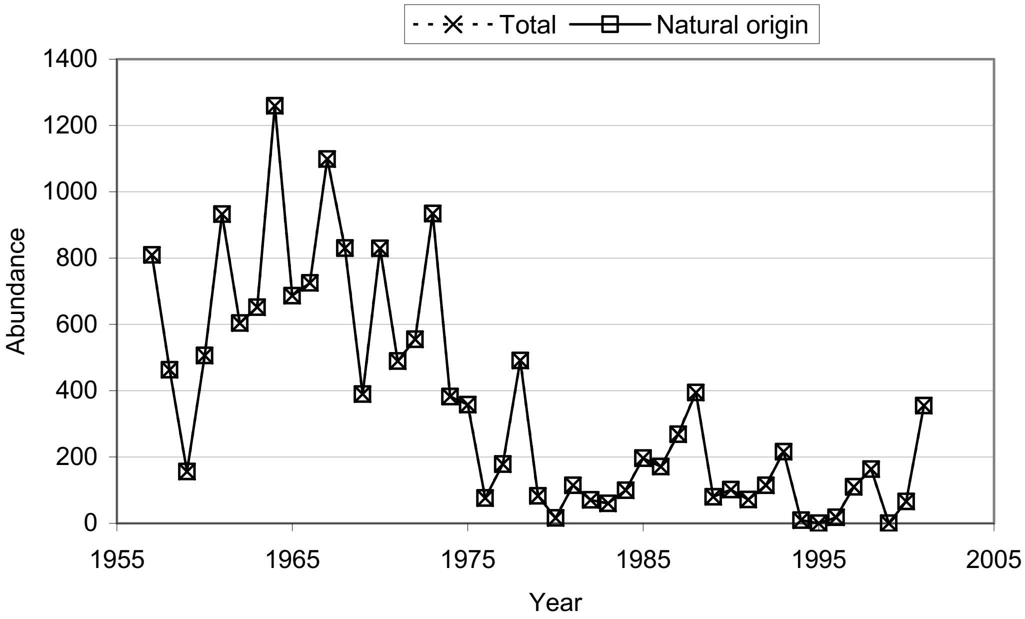

Figure 18. Marsh Creek spring-run Chinook salmon spawning escapement, 1957–2001. Estimates are based on expanded redd counts and carcass sampling. See Appendix A, Table A-2 for abundance source information.

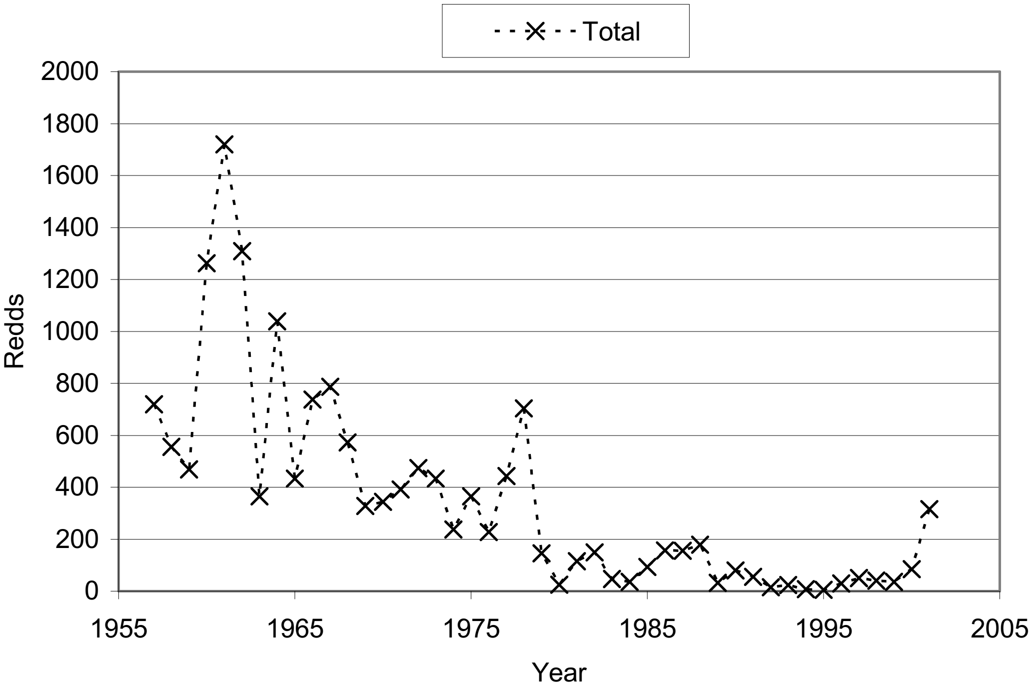

Figure 19. Total redd count in the Lemhi River (includes hatchery and natural returns), 1957–2001.

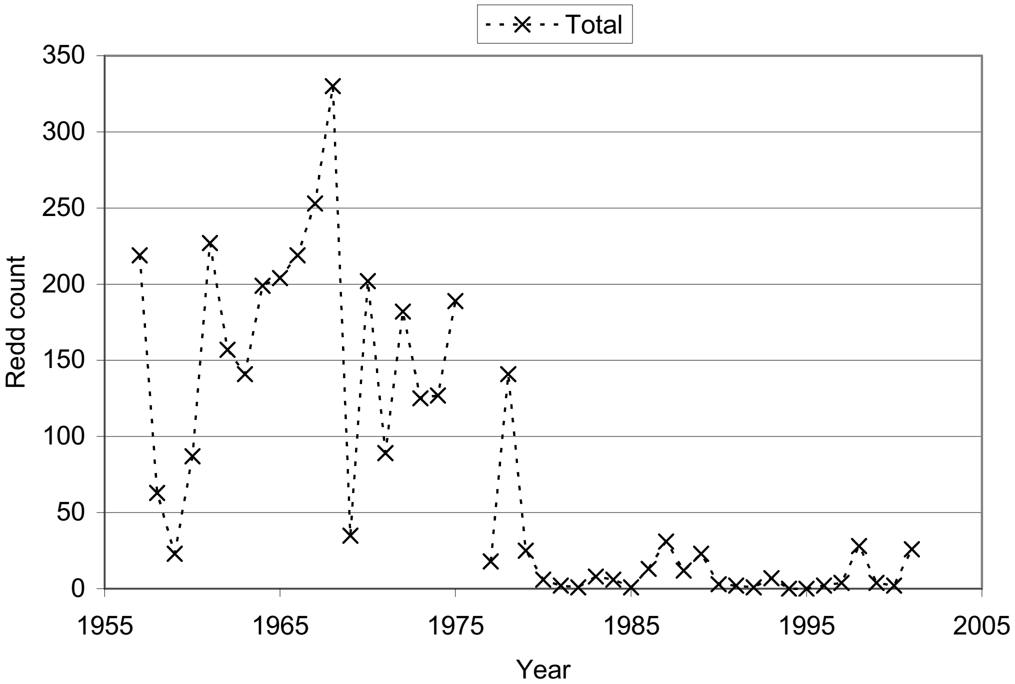

Figure 20. Upper Valley Creek spring-run Chinook salmon redd counts, 1957–2001.

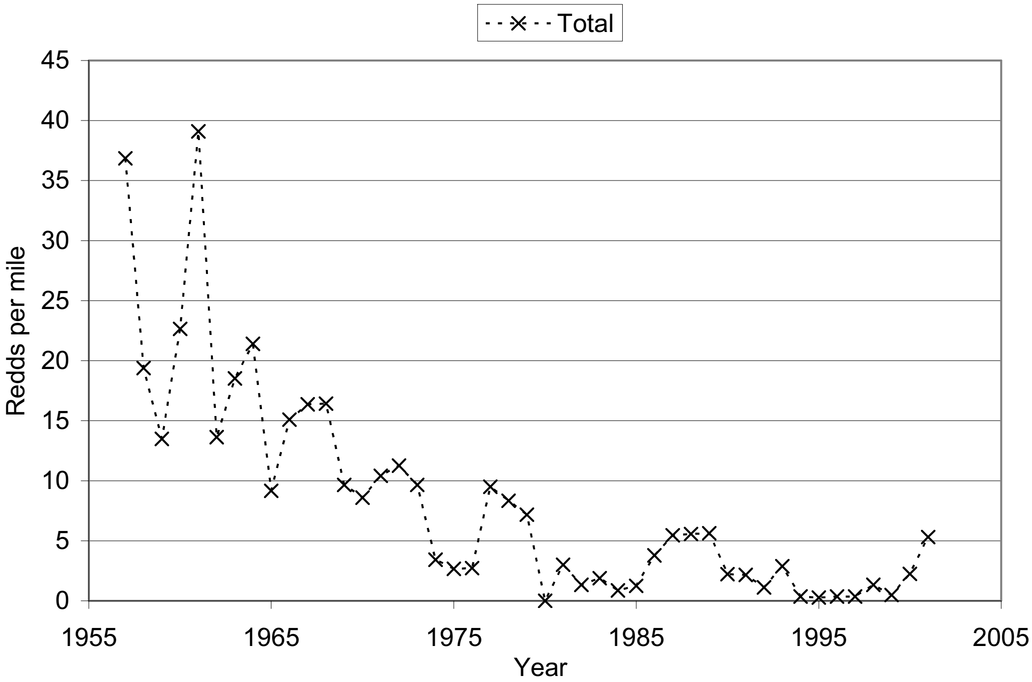

Figure 21. East Fork Salmon River summer-run Chinook salmon redds per mile, 1957–2001.

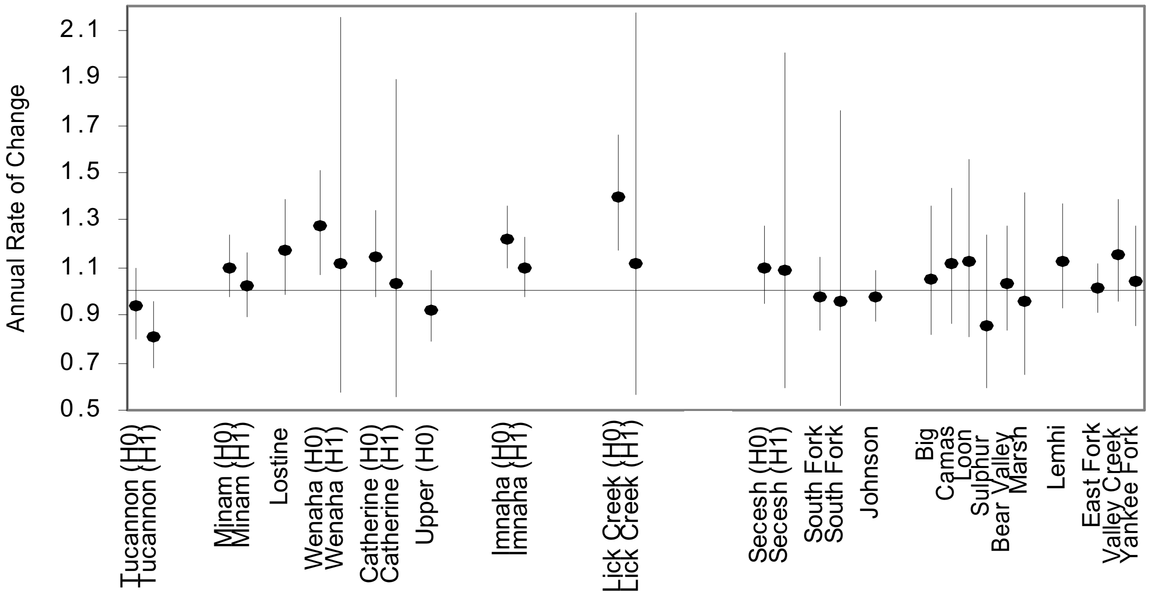

Figure 22. Short-term median growth rate (1990–2001) for total spawners for Snake River spring/summer-run production areas. Error bars represent 95% confidence limits of the trend. H0 = hatchery-origin spawners are assumed to have zero reproductive success. H1 = hatchery-origin spawners are assumed to have the same reproductive success as natural-origin fish.

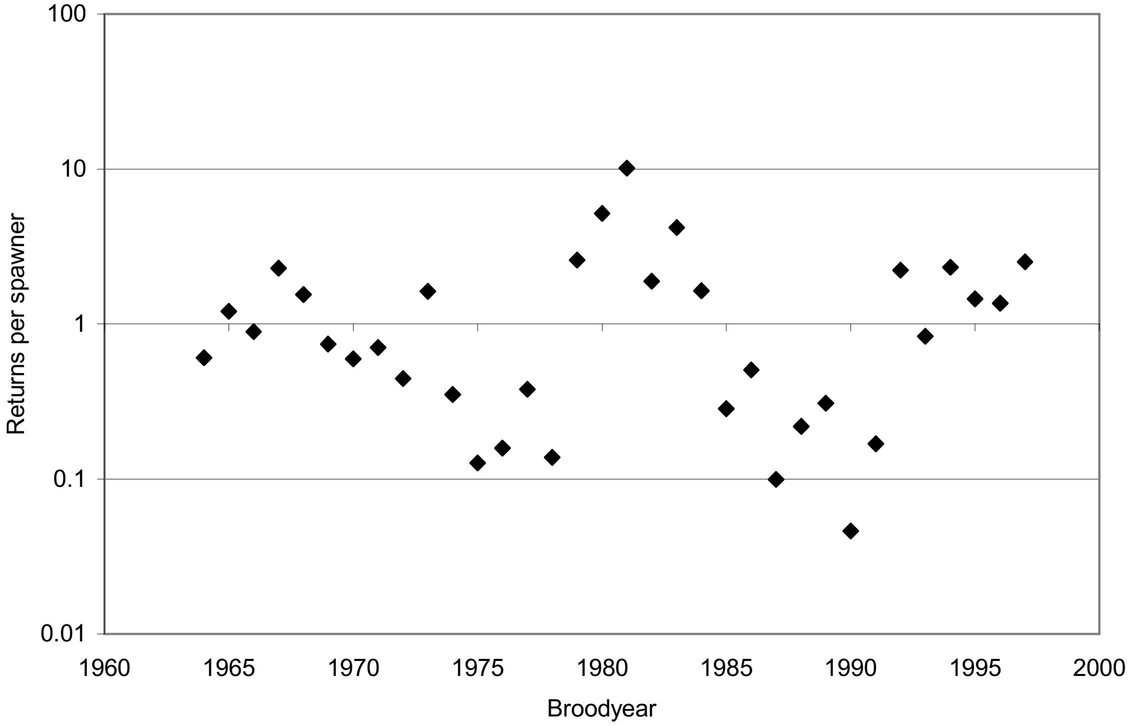

Figure 23. Spring/summer-run Chinook salmon returns per spawner for the Minam River, 1964–1997, calculated as estimated natural returns to the spawning grounds divided by broodyear total spawners.

6. Upper Columbia River Spring-Run Chinook Salmon ESU

There are no estimates of historical abundance specific to the Upper Columbia River spring-run Chinook salmon ESU prior to the 1930s. The drainages supporting this ESU are all above Rock Island Dam on the upper Columbia River. Rock Island Dam is the oldest major hydroelectric project on the Columbia River; it began operations in 1933. Counts of returning Chinook salmon have been made since the 1930s. Annual estimates of the aggregate return of spring-run Chinook salmon to the upper Columbia River are derived from the dam counts, based on the nadir between spring and summer return peaks. Spring-run Chinook salmon currently spawn in three major drainages above Rock Island Dam—the Wenatchee, Methow, and Entiat rivers. Annual counts of spawning redds are used to estimate returns to specific production areas within each of these tributary drainages. Historically, spring-run Chinook salmon may have also used portions of the Okanogan River.

Grand Coulee Dam, completed in 1938, formed an impassable block to the upstream migration of anadromous fish. Chief Joseph Dam was constructed on the mainstem Columbia River downstream from Grand Coulee Dam and is also an anadromous block. There are no specific estimates of historical production of spring-run Chinook salmon from mainstem tributaries above Grand Coulee Dam. Habitat typical of that spring-run Chinook salmon use in accessible portions of the Columbia River basin is found in the middle and upper reaches of mainstem tributaries above Grand Coulee Dam. It is possible that the historical range of this ESU included these areas; alternatively, fish from the upper reaches of the Columbia River may have been in a separate ESU.

Artificial production efforts in the area the Upper Columbia River spring-run Chinook salmon ESU occupy extend back to the 1890s. Hatchery efforts were initiated in the Wenatchee and Methow river systems to augment catches in response to declining natural production (e.g., Craig and Soumela 1941). Although there are no direct estimates of adult production from early efforts, contributions were likely small.

In the late 1930s, the Grand Coulee Fish Maintenance Program (GCFMP) was initiated to address the fact that the completion of the Grand Coulee Dam cut off anadromous access above the dam site. Returning salmonids, including spring-run Chinook salmon, were trapped at Rock Island Dam and either transplanted as adults or released as juveniles into selected production areas within the accessible drainages below Grand Coulee Dam. Nason Creek in the Wenatchee system was a primary adult transplantation area in this effort. The program was conducted annually from 1938 until the mid-1940s.

Summary of Previous BRT Conclusions

In late 1998, the previous BRT reviewed the Upper Columbia River spring-run Chinook salmon ESU (NMFS 1998a). That team expressed concern regarding the relatively low abundance and the strong downward trend in annual returns for the ESU, noting that although the aggregate return (mainstem dam count minus returns to hatchery facilities) was just under 5,000 fish from 1990 to 1994, returns to natural spawning areas declined dramatically. As a result "escapements in 1994–1996 were the lowest in at least 60 years." The team was concerned that at these population sizes, negative effects of demographic and genetic stochastic processes are likely to occur.

The BRT recognized that the implementation of emergency natural broodstocking and captive broodstocking efforts for the ESU "indicate[s] the severity of the population declines to critically small sizes." The BRT also noted that "habitat degradation, blockages and hydrosystem passage mortality all have contributed to the significant declines in this ESU."

Listing status: Endangered.

New Data and Updated Analyses

WDFW, the Yakama Tribe, and USFWS conduct annual redd count surveys in nine selected production areas within the geographical area encompassed by this ESU (Carie 2000, Hubble and Crampton 2000, Mosey and Murphy 2002). Prior to 1987, redd count estimates were single-survey peak counts. From 1987 on, annual redd counts have been generated from a series of on-the-ground counts and represent the total number of redds constructed in any particular year. The agencies use annual dam counts from the mainstem mid-Columbia River dams as the basis for expanding redd counts to estimates of total spring-run Chinook salmon returns. In the Wenatchee River basin, video counts at Tumwater Dam are available for recent years. Returns to hatchery facilities are subtracted from the dam counts prior to the expansion. Updated returns are summarized in Tables 6 and 7 and in Figures 24–29.

An initial set of population definitions for the Upper Columbia River spring-run Chinook salmon ESU, along with basic criteria for evaluating the status of each population, were developed using the VSP guidelines described in McElhany et al. (2000). The definitions and criteria are described in Ford et al. (2001) and were used in the development and review of Mid-Columbia River Public Utility District plans and the Federal Columbia River Power System Biological Opinion (FCRPS 2000). The interim definitions and criteria are being reviewed as the Interior Columbia TRT recommendations. Briefly, the joint technical team recommended that the Wenatchee, Entiat, and Methow rivers be considered separate populations within the Upper Columbia River steelhead ESU. The historical status of spring-run Chinook salmon production in the Okanogan River is uncertain. The committee deferred a decision on the Okanogan to the Interior Columbia TRT. Abundance, productivity, and spatial structure criteria for each population in the ESU were developed and are described in Ford et al. (2001).

Table 6. Summary of abundance and trend information for the Upper Columbia River spring-run Chinook salmon ESU relative to previous BRT status review.

	Recent 5-year geometric mean[a]				Short-term trend (percent/yr/)			
	Percent Natural origin	Total	Natural					
Populations	**(previous[b])**	**Mean (range)**	**Current**	**Previous[b]**	**Current**	**Previous[b]**	**Interim target[c]**	**Current vs. interim target[c]**
Methow River total[d]	41	680 (79–9,904)	282	144	+2.0	–15.3	2,000	34%
Methow River main stem[d]	41	161 redds (17–2,864)	–	–	+6.5	–	–	–
Twisp River[d]	46	58 redds (10–369)	–	87	–9.8	–27.4	–	–
Chewuch River	59	58 redds (6–1,105)	–	62	–2.9	–28.1	–	–
Lost/Early Winters creeks[d]	46	12 (3–164)	6	62[b]	–14.1	–23.2[e]	–	–
Entiat River	58	111 (53–444)	65	89	–1.2	–19.4	500	22%
Wenatchee River total	58	470 (119–4,446)	274	27	–1.5	–37.4	3,750	13%
Chiwawa River	53	109 redds (34–1,046)	–	134	–0.7	–29.3	–	–
Nason Creek	61	54 redds (8–374)	–	85	–1.5	–26.0	–	–
Upper Wenatchee River	34	8 redds (0–215)	–	–	–8.9	–	–	–
White River	92	9 redds (1–104)	–	25	–6.6	–35.9	–	–
Little Wenatchee River	79	11 redds (3–74)	–	57	–25.8	–25.8	–	–

[a] Five-year geometric means calculated using years 1997 to 2001 unless otherwise noted.

[b] Previous years 1987–1996.

[c] Interim targets from Ford et al. (2001).

[d] Five-year geometric mean calculated without year 1998; no data available.

[e] Lost River only.

Table 7. Upper Columbia River spring-run Chinook salmon ESU hatchery returns, 1994–2001.

Watershed	Years	Hatchery	Stock	Release site	Total
Methow River	1994	Methow	Chewuch	Chewuch River	40,882
	1995–2000	Methow	Chewuch	Chewuch River	737,621
	1994	Methow	Twisp	Twisp River	35,881
	1992–2001	Methow	Twisp	Twisp River	322,863
	1995–2001	Methow	Methow	Methow River	1,164,289
	1992, 1993	Methow	Leavenworth NFH*	Methow River	–
	1991–1994	Winthrop NFH	Carson NFH	Methow River	3,013,272
	1991–1996	Winthrop NFH	Methow	Methow River	1,639,498
	1998–2001	Winthrop NFH	Methow	Methow River	1,564,392
Entiat River	1994	Entiat NFH	Entiat NFH	Entiat River	873 adults
	1992–1996	Entiat NFH	Entiat NFH	Entiat River	2,485,310
	1997–2001	Entiat NFH	Entiat NFH	Entiat River	1,828,029
	1991, 1992	Entiat NFH	Carson NFH	Entiat River	1,539,803
	1995, 1996	Entiat NFH	Leavenworth NFH	Entiat River	276,699
Wenatchee River	1991–1994	Chiwawa Pond	Chiwawa	Chiwawa River	243,421
	1995–2000	Chiwawa Pond	Chiwawa	Chiwawa River	608,066
	1992	Eastbank	Leavenworth NFH	Icicle Creek	530,700
	1991–1993	Leavenworth NFH	Carson NFH	Icicle Creek	7,292,301
	1994–1996	Leavenworth NFH	Leavenworth NFH	Icicle Creek	4,942,554
	1997–2001	Leavenworth NFH	Leavenworth NFH	Icicle Creek	7,568,173

* NFH = National Fish Hatchery.

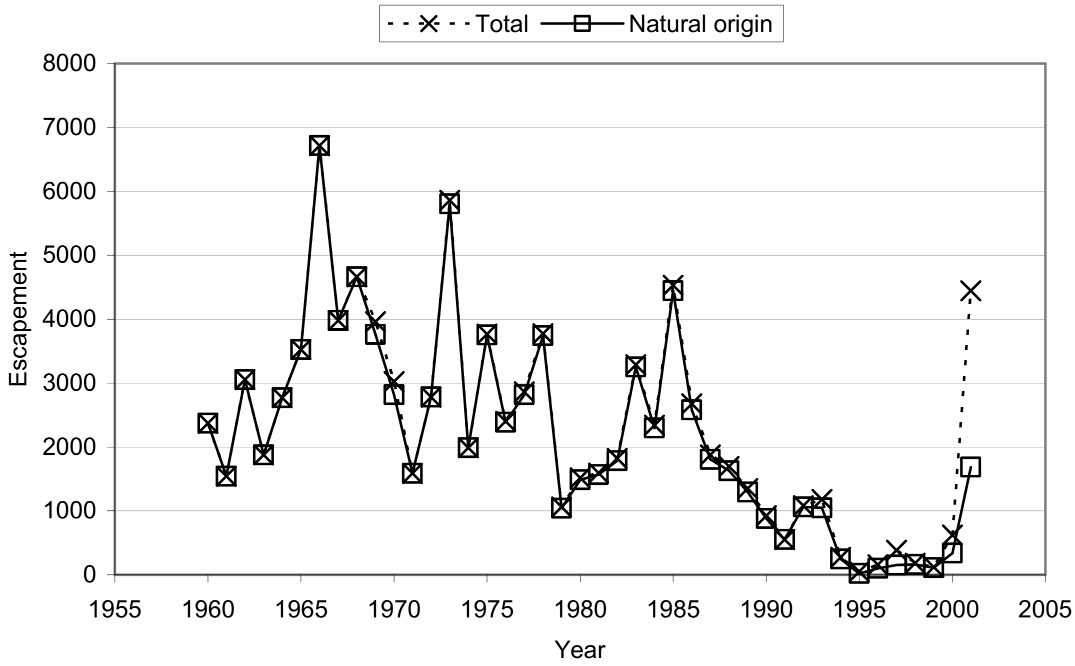

Figure 24. Wenatchee River spring-run Chinook salmon spawning escapement, 1960–2001. Sources: Estimates expanded from redd counts (Beamesderfer et al. 1998, Cooney 2001); 2001 data from Mosey and Murphy (2002).

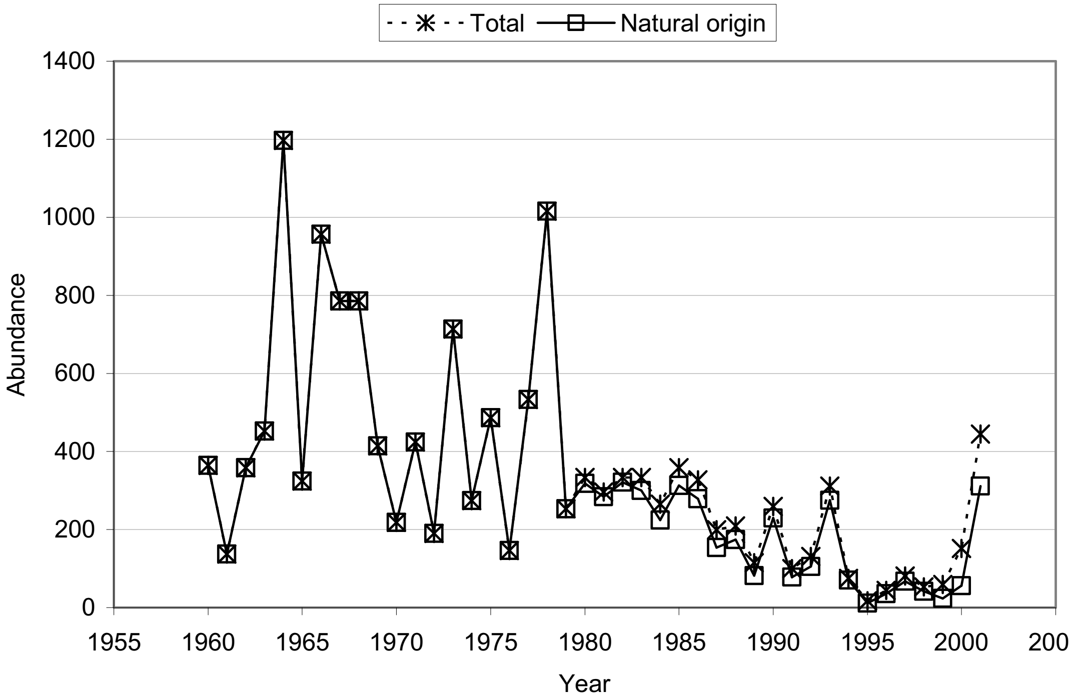

Figure 25. Entiat River spring-run Chinook salmon spawning escapement, 1960–2001. Sources: Estimates from expanded redd counts (Beamesderfer et al. 1998, Cooney 2001); recent year data from Carie (2002).

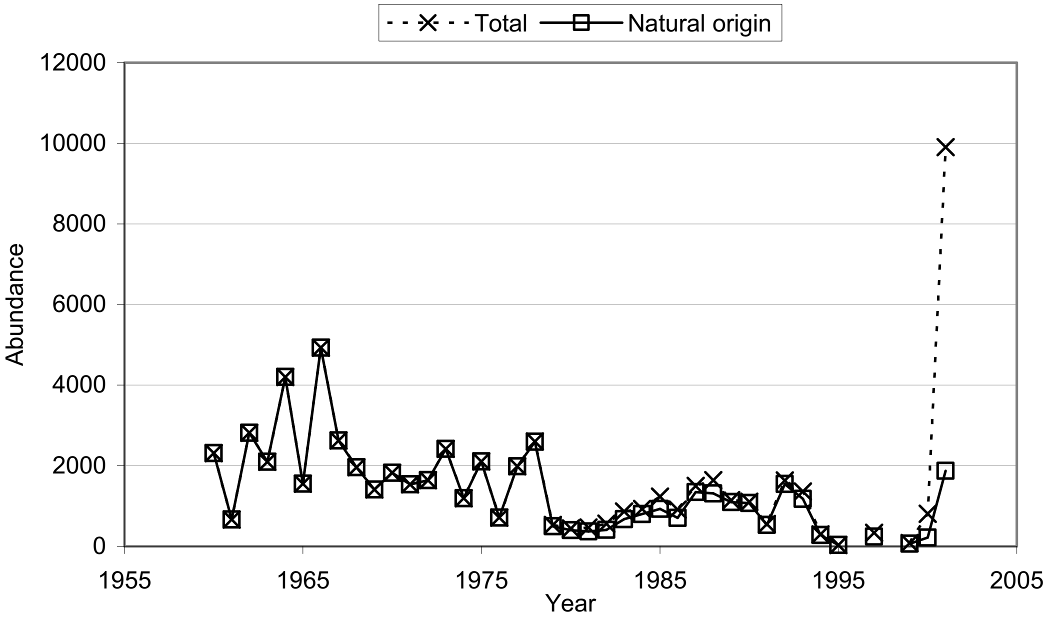

Figure 26. Methow River spring-run Chinook salmon spawning escapement, 1960–2001. Sources: Estimates expanded from redd counts (Beamesderfer et al. 1998, Cooney 2001); recent year data from Yakama Indian Nation Fisheries.[5]

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[5] J. Hubbell, Confederated Tribes and Bands of the Yakama Nation, Fisheries Resource Management, Toppenish, WA. Pers. commun., November 2002.

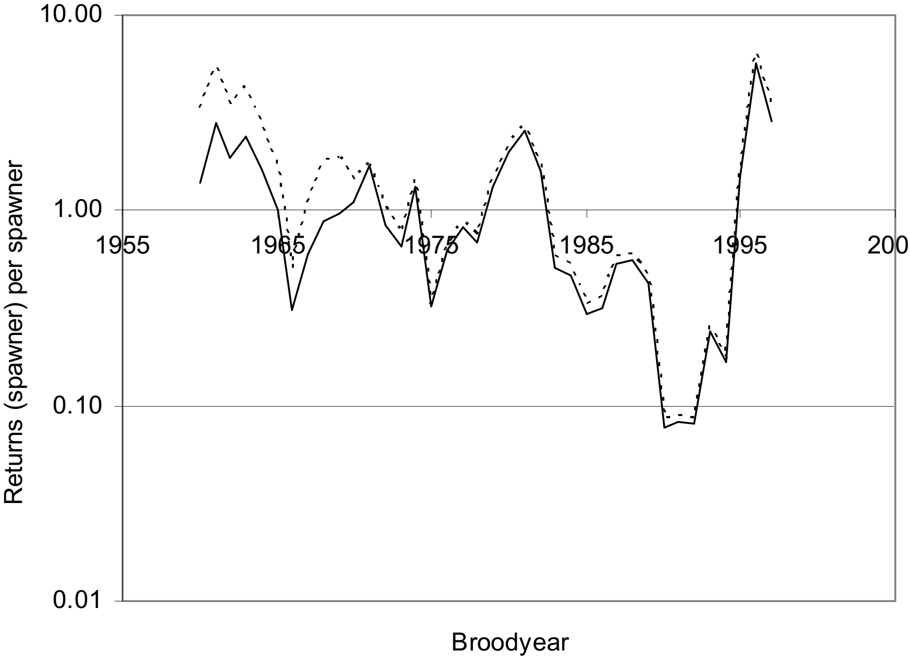

Figure 27. Wenatchee River spring-run Chinook salmon returns per spawner by broodyear, 1960–2001 (returns to spawning grounds). Calculated as estimated natural returns to the spawning grounds divided by broodyear total spawners (solid line) and returns adjusted to recent average harvest rate (1985–2001; dashed line).

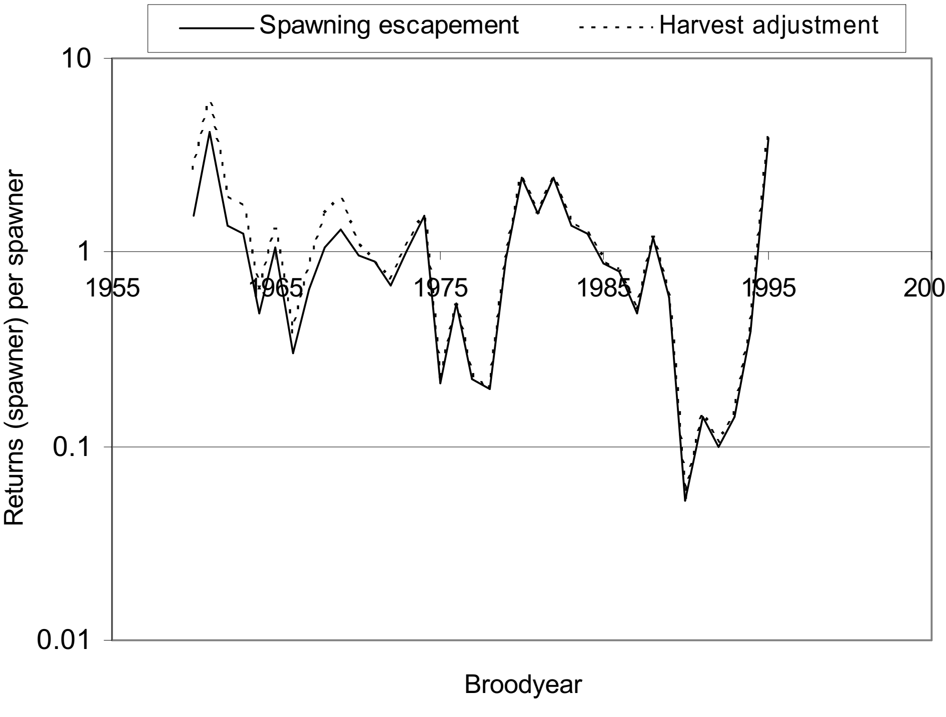

Figure 28. Methow River spring-run Chinook salmon returns per spawner by broodyear, 1960–1995 (returns to spawning grounds).

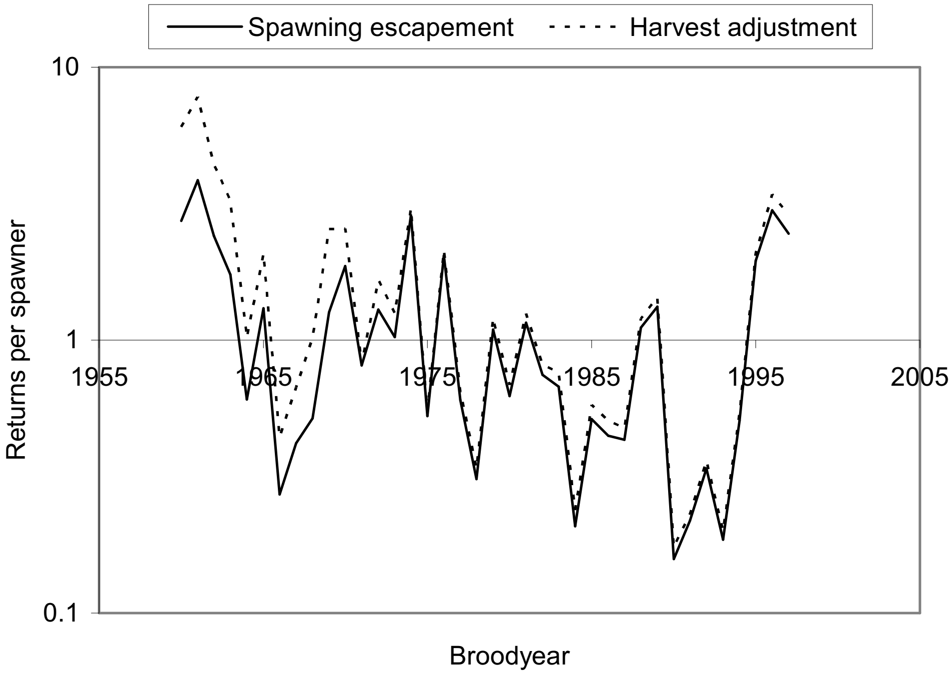

Figure 29. Entiat River spring-run Chinook salmon returns per spawner by broodyear, 1960–1997 (returns to spawning grounds).

New Hatchery Information

Three national fish hatcheries operated by the USFWS are located within the geographic area associated with this ESU. These hatchery programs were established as mitigation programs for the construction of Grand Coulee Dam. Leavenworth National Fish Hatchery (NFH), located on Icicle Creek, a tributary to the Wenatchee River system (RKm 42), has released Chinook salmon since 1940. Entiat NFH is located on the Entiat River, approximately 10 km upstream of the confluence with the Columbia River main stem. Spring-run Chinook salmon have been released from this facility since 1974. Winthrop NFH is on the Methow River main stem, approximately 72 km upstream of the confluence with the Columbia River. Spring-run Chinook salmon were released from 1941 to 1961, and from 1974 to the present. Initial spring-run Chinook salmon releases from these facilities were for the GCFMP project. Leavenworth NFH hatchery returns served as the principal stock source for all three facilities until the early 1990s. Production was augmented with eggs transferred into the programs from facilities outside the ESU, primarily Carson NFH. Broodstocking for each hatchery program has been switched to emphasize locally returning broodstocks. Management objectives for the Winthrop NFH have been modified to this conservation strategy. The Entiat and Leavenworth hatchery programs retain the original harvest augmentation objectives but are managed to restrict interactions with natural populations. Carcass surveys and broodstocking efforts in the upstream natural spawning areas of the Wenatchee and Entiat rivers support the assumption that the stray rate from the downstream hatchery facilities is low—on the order of 1–5%. Significantly higher contribution rates have been observed in mainstem Methow River natural spawning areas, possibly due to the close proximity of the hatchery and to the recent shift to locally adapted stocks.

Additional spring-run Chinook salmon hatchery production efforts were initiated in the 1980s as mitigation for smolt losses at mainstem mid-Columbia River projects operated by PUDs. These programs are aimed at directly supplementing targeted natural production areas in the Wenatchee and Methow river systems. In the Wenatchee River drainage, this program targeted the Chiwawa River, a major spring-run Chinook production tributary entering at river kilometer (RKm) 78.2. Broodstock are collected at a weir located approximately 2 km upstream of the mouth of the Chiwawa River. In some years, broodstocking has been augmented by using marked adults collected at Tumwater Dam. Release groups are returned to an acclimation pond adjacent to the lower Chiwawa River for final acclimation and release.

In the Methow River, the supplementation program began in 1992 with broodstock collected from the natural runs to the Chewuch and Twisp rivers. The Methow Fish Hatchery, operated by WDFW, has actively managed broodstock collection and mating to maintain separate groups for use in the Chewuch, Twisp, and Methow rivers. In 1996, and again in 1998, extremely low adult returns led to a decision to collect all adults at Wells Dam. Scale reading, elemental scale analysis, and extraction or reading of coded-wire tags have been used at the Methow NFH to help maintain broodstock separation.

Beginning in 1998, a composite stock was initiated, and the management objectives for Winthrop NFH were established. Since that time, Methow and Winthrop hatcheries have worked together on broodstock collection and spawning activities. Juveniles are reared at the Winthrop facility and released into the mainstem Methow River in coordination with releases from acclimation sites on the Twisp and Chewuch rivers. The Methow Fish Hatchery program was initiated with Winthrop NFH hatchery stock and is being converted to local broodstock. These supplementation programs have had two major impacts on natural production areas. Returns to natural spawning areas have included increasing numbers of supplementation fish in recent years, especially in the Methow River mainstem spawning areas adjacent to the Winthrop NFH.

The WDFW Salmon and Steelhead Stock Inventory (SASSI) report identified nine stocks of spring-run Chinook salmon within the Upper Columbia River spring-run Chinook salmon ESU. Ford et al. (2001) describes the results of applying the population definition and criteria provided in McElhany et al. (2000) to current Upper Columbia River spring-run Chinook salmon production. The conclusions of the effort were that “there are (or historically were) three or four independent viable populations of spring-run Chinook salmon in the upper Columbia River basin, inhabiting the Wenatchee, Entiat, Methow and (possibly) the Okanogan River basins. There appears to be considerable population substructure within the Wenatchee and Methow River basins, which should be considered when evaluating recovery goals and management actions.”[6]

Hatchery impacts vary among production areas. Large on-station production programs in the Wenatchee and Entiat river drainages are located in the lower reaches, some distance downstream of natural spawning areas. In the Methow Basin, Winthrop NFH is upstream, adjacent to part of the mainstem spawning reach for spring-run Chinook salmon and steelhead. Straying of returning hatchery-origin adults into the natural production areas is thought to be low

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[6] Spring Chinook salmon spawning in Icicle Creek, Peshastin Creek, Ingalls Creek, and Leavenworth National Fish Hatchery are considered an independent, hatchery-derived population that is not part of the ESU (NMFS 1999a).

for the Wenatchee and Entiat rivers. The supplementation programs in the upper Wenatchee and the Methow river basins are designed to specifically boost natural production. In years when the return of natural-origin adults is extremely low, the proportion of hatchery-origin adults on the spawning grounds can be high, even if the dispersal rate of the returning hatchery fish is low. It is likely that returning hatchery fish contribute to spawning in natural production areas in the Methow River at a higher rate. Carcass sampling data are available for a limited number of year and area combinations for the upper Columbia River drainages (e.g., Mosey and Murphy 2002).

Spring-run Chinook salmon returns to the Wenatchee and the Methow river systems have included relatively large numbers of supplementation program fish in recent years. The total return to natural spawning areas in the Wenatchee River system for 2001 is estimated to be approximately 4,000—with 1,200 returning from natural spawning and 2,800 from the hatchery-based supplementation program. The return to spawning areas for the Methow in 2001 was estimated at well over 9,000. Carcass surveys indicate that returning supplementation adults accounted for approximately 80% of the 2001 run to the Methow spawning areas. Supplementation programs have contributed substantially to getting fish on the spawning grounds in recent years. Little information is available to assess the long-term impact of high levels of supplementation on productivity. Categorization for upper Columbia River spring-run Chinook salmon hatchery stocks (SSHAG 2003) can be found in Appendix A, Table A-1.

Comparison with Previous Data

All three existing Upper Columbia River spring-run Chinook salmon populations have exhibited similar trends and patterns in abundance over the past 40 years. The 1998 Chinook salmon status review (Myers et al. 1998) reported that long-term trends in abundance for upper Columbia River spring-run Chinook salmon populations were generally negative, ranging from –5% to +1%. Analyses of the data series, updated to include 1996–2001 returns, indicate that those trends have continued. The long-term trend in spawning escapement is downward for all three systems. Since 1958, Wenatchee River spawning escapements have declined at an average rate of 5.6% per year, the Entiat River population at an average of 4.8% per year, and the Methow River population at an average of 6.3% per year. These rates of decline were calculated from the redd count data series.[7]

Mainstem spring-run Chinook salmon fisheries harvested Chinook salmon at rates between 30% and 40% per year through the early 1970s. Restricting mainstem commercial fisheries and sport harvest in the mid-1970s substantially reduced the harvest. The calculated downward trend in abundance for the upper Columbia River stocks would be higher if the early redd counts had been revised to reflect the potential “transfer” from harvest to escapement for the early years in the series.

In the 1960s and 1970s, spawning escapement estimates were relatively high, with substantial year-to-year variability. Escapements declined in the early 1980s, then peaked at

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[7] Prior to 1987, annual redd counts were obtained from single surveys and reported as peak counts. Since 1987, redd counts have been derived from multiple surveys and are reported as annual total counts. An adjustment factor of 1.7 was used to expand the pre-1987 redd counts for comparison with the more recent total counts (Beamesderfer et al. 1998).

relatively high levels in the mid-1980s. Returns declined sharply in the late 1980s and early 1990s. Returns from 1990 to 1994 were at the lowest levels observed in the 40-plus years of the data sets. The Upper Columbia Biological Requirements Workgroup (Ford et al. 2001) recommended interim delisting levels of 3,750, 500, and 2,200 spawners for the populations returning to the Wenatchee, Entiat, and Methow river drainages, respectively. The most recent 5-year geometric mean spawning escapements (1997–2001) were at 8–15% of these levels. Target levels have not been exceeded since 1985 for the Methow River run, and since the early 1970s for the Wenatchee and Entiat river populations.

Short-term trends for the aggregate population areas reported in the 1998 BRT status review (Myers et al. 1998) ranged from –15.3% (Methow River) to –37.4% (Wenatchee River). Escapements from 1996 to 1999 reflected that downward trend. Escapements increased substantially in 2000 and 2001 in all three systems. Returns to the Methow and Wenatchee rivers reflected the higher return rate on natural production as well as a large increase in contributions from supplementation programs. Short-term trends (1990–2001) in natural returns remain negative for all three Upper Columbia River spring-run Chinook salmon ESU populations. Natural returns to the spawning grounds for the Entiat, Methow, and Wenatchee river populations continued downward at average rates of 3%, 10%, and 16% respectively.

Short- and long-term trends in returns to the individual subpopulations within the Wenatchee and Methow systems were consistent with the aggregate population-level trends. Long- and short-term trends for upper Columbia River spring-run Chinook salmon populations are shown in Figures 30 and 31.

McClure et al. (2003) reported standardized quantitative risk assessment results for 152 listed salmon stocks in the Columbia River basin, including representative data sets (1980–2000 return years) for upper Columbia River spring-run Chinook salmon. Average annual growth rate (λ) for the upper Columbia River spring-run Chinook salmon population was estimated at 0.85, the lowest average reported for any of the Columbia River ESUs analyzed in the study. Assuming that population growth rates were to continue at the 1980–2000 levels, upper Columbia River spring-run Chinook salmon populations are projected to have a very high probability of a 90% decline within 50 years (0.87 for the Methow River population, 1.0 for the Wenatchee and Entiat runs).

The major harvest impacts on upper Columbia River spring-run Chinook salmon have been in mainstem fisheries below McNary Dam and in sport fisheries in each tributary. There are no specific estimates of historical harvest impacts on upper Columbia River spring-run Chinook salmon runs. Assuming that upper Columbia River spring-run Chinook salmon runs were equally available to mainstem commercial fisheries, as were the runs to other areas of the Snake and Columbia rivers, harvest rates in the lower Columbia River commercial fisheries were likely to be on the order of 20–40% of the in-river run. Lower Columbia River harvest rates on up-river spring-run Chinook salmon stocks were sharply curtailed beginning in 1980 and were again reduced after the listing of Snake River spring/summer-run Chinook salmon in the early 1990s. Sport fishery impacts were also curtailed. Harvest impacts are currently being managed under a harvest management schedule—harvest rates are curtailed even further if the average return drops below a predefined level, or increased at high run sizes.

Upper Columbia River spring-run Chinook salmon are subject to passage mortalities associated with mainstem hydroelectric projects. Production from all upper Columbia River tributary drainages passes through the four lower Columbia River federal dam projects and a varying number of mid-Columbia River Public Utility District dam projects. The Wenatchee River enters the Columbia River above seven mainstem dams, the Entiat above eight dams, and the Methow and Okanogan rivers above nine dams. In the early 1990s, the draft Mid-Columbia Habitat Conservation Plan established salmonid survival objectives for Wells, Rocky Reach, and Rock Island dams. Interim operating guidelines apply to Wanapum and Priest Rapids dams. Operational improvements were made to increase outmigrant survival through the mainstem mid-Columbia River Public Utility District hydroelectric dams (Cooney 2001, FCRPS 2000).

Each upper Columbia River spring-run Chinook salmon area has a particular set of habitat problems. In general, tributary habitat problems affecting this ESU include increasing urbanization on the lower reaches, irrigation and flow diversions in upriver sections of the major drainage, and impacts of grazing on middle reaches.

Previous assessments of stocks within this ESU identified several populations as being at risk or of concern. WDF et al. (1993) considered nine such stocks within this ESU, eight of

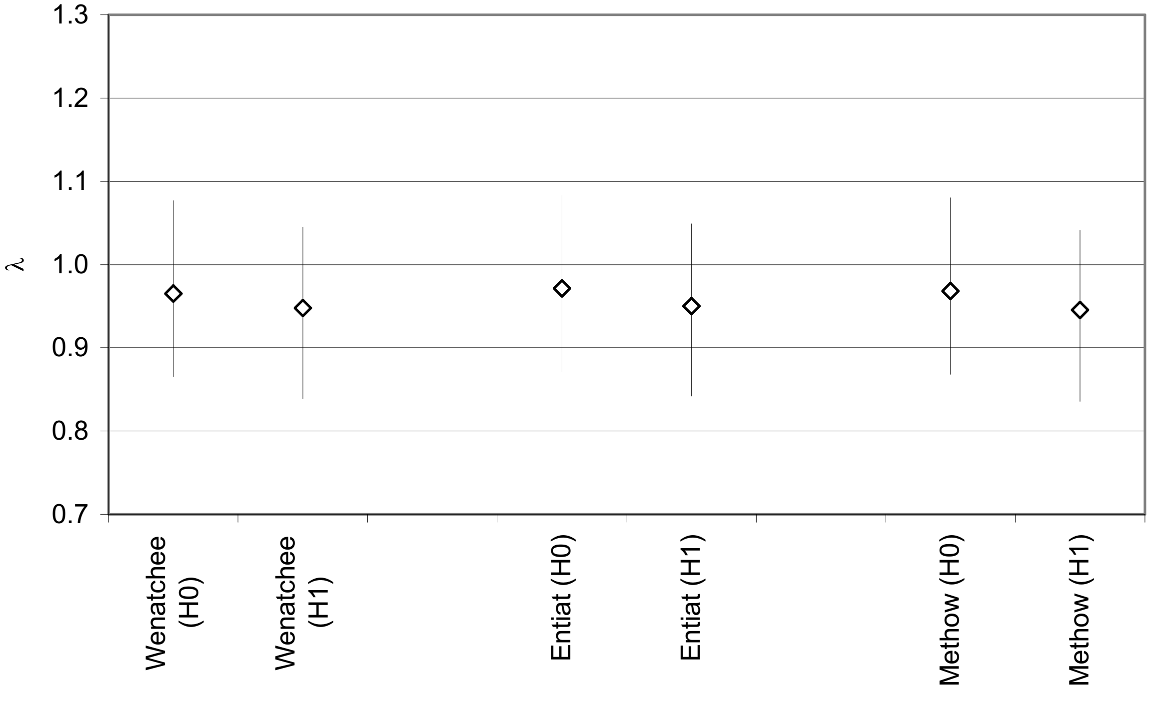

Figure 30. Long-term (1960–2001) annual growth rates (λ) for Upper Columbia River spring-run Chinook salmon ESU populations. Error bars represent 95% confidence limits. H0 = hatchery fish are assumed to have zero reproductive success; H1 = hatchery-origin spawners are assumed to have the same reproductive success as natural-origin fish.

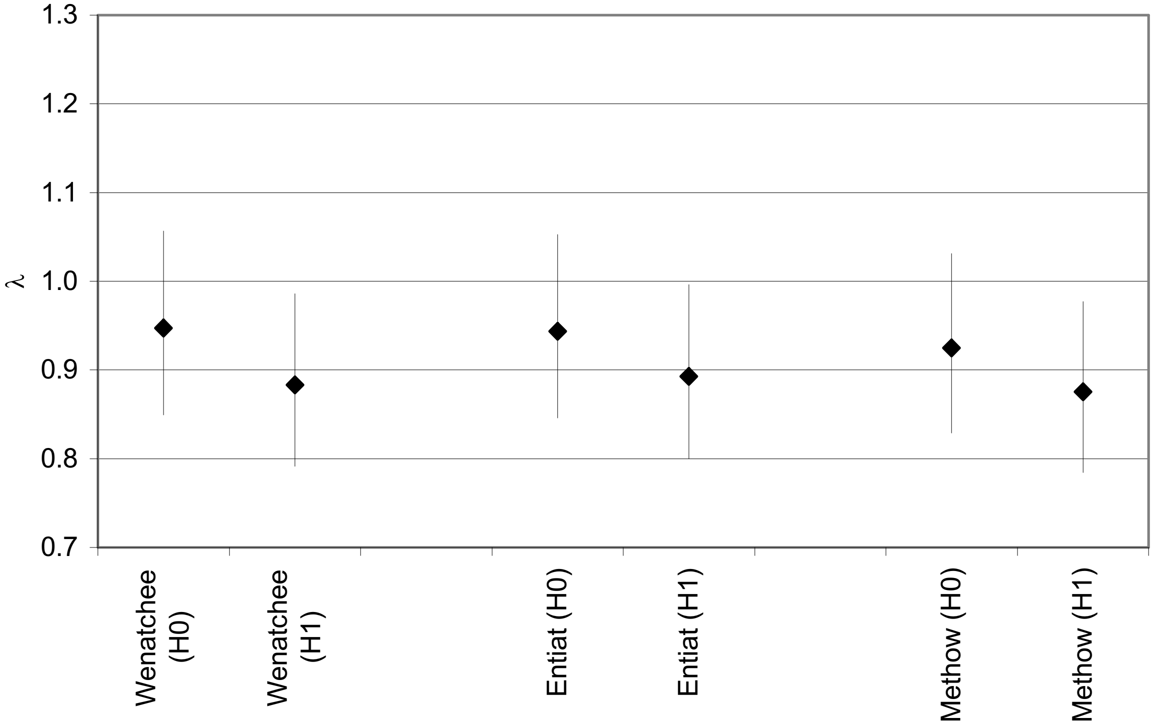

Figure 31. Short-term (1990–2001) annual growth rates (λ) for Upper Columbia River spring-run Chinook salmon ESU populations. Error bars represent 95% confidence limits of the trend. H0 = hatchery fish are assumed to have zero reproductive success; H1 = hatchery-origin spawners are assumed to have the same reproductive success as natural-origin fish.

which were considered of native origin and predominantly natural production. The status of all nine stocks was considered to be depressed. Nehlsen et al. (1991) listed six additional stocks from the upper Columbia River as extinct, all of them associated with drainages entering the Columbia River main stem above Chief Joseph and Grand Coulee dams. Those dams blocked access by adult anadromous fish to the upper Columbia River basin.

7. Puget Sound Chinook Salmon ESU

The status of Puget Sound Chinook salmon was formally assessed during a coastwide status review (Myers et al. 1998). In November 1998, a BRT was convened to update the status of this ESU by summarizing information received since that review and comments on the 1997 status review (NMFS 1998a). The subsection below, Summary of Previous BRT Conclusions, summarizes findings and conclusions made at the time of the 1998 status review update; New Data and Updated Analyses reports on new information received through March 2003 and the 2003 BRT's conclusions, based on the new information.

Summary of Previous BRT Conclusions

Status and Trends

The BRT concluded in 1998 that the Puget Sound Chinook salmon ESU was likely to become endangered in the foreseeable future. The estimated total run size of Chinook salmon to Puget Sound in the early 1990s was 240,000 Chinook, down from an estimated 690,000 historical run size. The 5-year geometric mean of spawning escapement of natural Chinook salmon runs in north Puget Sound during the period from 1992 to 1996 was approximately 13,000. Both long- and short-term trends for these runs were negative, with few exceptions. In south Puget Sound, spawning escapement of the natural runs averaged 11,000 spawners at the time of the last status review update. In this area, both long- and short-term trends were predominantly positive. In Hood Canal, spawning populations in six streams were considered a single stock by the comanagers because of extensive transfers of hatchery fish (WDF et al. 1993). Fisheries in the area were managed primarily for hatchery production and secondarily for natural escapement; high harvest rates directed at hatchery stocks resulted in failure to meet natural escapement goals in most years (USFWS 1997).

The 5-year geometric mean natural spawning escapement at the time of the last update was 1,100, with negative short- and long-term trends (except in the Dosewallips River). The ESU also includes the Dungeness and Elwha rivers, which have natural Chinook salmon runs as well as hatchery runs. The Dungeness River had a run of spring- and summer-run Chinook salmon, with a 5-year geometric mean natural escapement of 105 fish at the time of the last status review update. The Elwha River had a 5-year geometric mean escapement of 1,800 fish during the mid-1990s, which includes a large, but unknown fraction of naturally spawning hatchery fish. Both the Elwha and Dungeness river populations exhibited downward trends in abundance in the 1990s.

Threats

Habitat throughout the ESU has been blocked or degraded. In general, forest practices impacted upper tributaries, and agriculture or urbanization impacted lower tributaries and mainstem rivers. WDF et al. (1993) cited diking for flood control, draining and filling of freshwater and estuarine wetlands, and sedimentation due to forest practices and urban development as problems throughout the ESU. Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in several basins. Bishop and Morgan (1996) identified a variety of critical habitat issues for streams in the range of this ESU, including changes in flow regime (all basins), sedimentation (all basins), high temperatures (Dungeness, Elwha, Green/Duwamish, Skagit, Snohomish, and Stillaguamish rivers), streambed instability (most basins), estuarine loss (most basins), loss of large woody debris (Elwha, Snohomish, and White rivers), loss of pool habitat (Nooksack, Snohomish, and Stillaguamish rivers), and blockage or passage problems associated with dams or other structures (Cedar, Elwha, Green/Duwamish, Snohomish, and White rivers).

The Puget Sound Salmon Stock Review Group of the Pacific Fishery Management Council (PFMC 1997a) provided an extensive review of habitat conditions for several stocks in this ESU. It concluded that reductions in habitat capacity and quality have contributed to escapement problems for Puget Sound Chinook salmon, citing evidence of direct losses of tributary and mainstem habitat due to dams, and of slough and side-channel habitat due to diking, dredging, and hydromodification. It also cited reductions in habitat quality due to land management activities.

WDF et al. (1993) classified 11 out of 29 stocks in this ESU as being sustained, in part, through artificial propagation. Nearly 2 billion fish have been released into Puget Sound tributaries since the 1950s (Myers et al. 1998). The vast majority of these fish were derived from local returning fall-run adults. Returns to hatcheries have accounted for 57% of total spawning escapement, although the hatchery contribution to spawner escapement is probably much higher than that, due to hatchery-derived strays on the spawning grounds. Almost all releases into this ESU have come from stocks within this ESU, with the majority of within-ESU transfers coming from the Green River Hatchery or hatchery broodstocks derived from Green River stock (Marshall et al. 1995). The electrophoretic similarity between Green River fall-run Chinook salmon and several other fall-run stocks in Puget Sound (Marshall et al. 1995) suggests that there may have been a significant effect from some hatchery transplants. Overall, the pervasive use of Green River stock throughout much of the extensive hatchery network that exists in this ESU may reduce the genetic diversity and fitness of naturally spawning populations.

Harvest impacts on Puget Sound Chinook salmon stocks were quite high. Ocean exploitation rates on natural stocks averaged 56–59%; total exploitation rates averaged 68–83% (1982–1989 broodyears) (PSC 1994). Total exploitation rates on some stocks have exceeded 90% (PSC 1994).

Previous assessments of stocks within this ESU identified several stocks as being at risk or of concern (reviewed in Myers et al. 1998).

Listing status: Threatened.

New Data and Updated Analyses

ESU Status at a Glance

Historical peak run size	≈690,000
Historical populations	31
Extant populations	22
5-year geometric mean natural spawners per population	222–9,489 (median = 766)
Long-term trend per population	0.92–1.2 (median = 1.0)
Recent λ (H1) per population	0.67–1.2 (median = 1.0)

ESU Structure

The Puget Sound Chinook salmon ESU is composed of 31 historically quasi-independent populations, 22 of which are believed to be extant currently (Puget Sound TRT 2001, 2002). The populations presumed to be extinct are mostly early returning fish; most of these are in mid- to southern Puget Sound or Hood Canal and the Strait of Juan de Fuca (Table 8). The ESU populations with the greatest estimated fractions of hatchery fish tend to be in mid- to southern Puget Sound, Hood Canal, and the Strait of Juan de Fuca (Table 9).

New information obtained for the 22 Chinook salmon populations in the Puget Sound ESU is summarized in Appendix A, Table A-2. Data sources and detailed information on data years are provided for each population separately in the appendix.

Abundance of Natural Spawners

The most recent 5-year (1998–2002) geometric mean of natural spawners in populations of Puget Sound Chinook salmon ranges from 222 (in the Dungeness River) to almost 9,500 fish (in the upper Skagit River population). Most populations contain natural spawners numbering in the high hundreds (median recent natural escapement = 766); and of the 10 populations with greater than 1,000 natural spawners, only 2 are thought to have a low fraction of hatchery fish (Table 9, Figures 32–53). Estimates of the fraction of natural spawners that are of hatchery origin are sparse—data are available for only 12 of the 22 populations in the ESU, and such information is available for only the most recent 5–10 years (Table 9). Estimates of the hatchery fraction of natural spawners come from counts of otolith-marked local hatchery fish sampled from carcasses (Nooksack River basin, Snohomish River basin), adipose fin-clip counts from redd count surveys (Skagit River basin), and coded-wire tag sampling (North Fork Stillaguamish and Green rivers). In general, populations in the Skagit River basin are the only ones with presumed low estimates of naturally spawning hatchery fish. The Stillaguamish and Snohomish populations have moderate estimates of naturally spawning hatchery fish. Estimates of historical equilibrium abundance from predicted pre-European settlement habitat conditions range from 1,700 to 51,000 potential Chinook salmon spawners per population (Mobrand 2000). The historical estimates of equilibrium abundance are several orders of magnitude higher than realized spawner abundances currently observed throughout the ESU.

Table 8. Historical populations of Chinook salmon in the Puget Sound ESU, run-timing types for each population, and each population's biogeographic region.

Population[a]	Status	Run-timing[b]	Bio-geographic region[b]	Reference
North Fork Nooksack	Extant	Early	Strait of Georgia	–
South Fork Nooksack	Extant	Early	Strait of Georgia	–
Nooksack late	Extinct	Late	Strait of Georgia	Puget Sound TRT (2001)
Lower Skagit	Extant	Late	Whidbey Basin	–
Upper Skagit	Extant	Late	Whidbey Basin	–
Lower Sauk	Extant	Late	Whidbey Basin	–
Upper Sauk	Extant	Early	Whidbey Basin	–
Suiattle	Extant	Early	Whidbey Basin	–
Upper Cascade	Extant	Early	Whidbey Basin	–
North Fork Stillaguamish	Extant	Late	Whidbey Basin	–
South Fork Stillaguamish	Extant	Late	Whidbey Basin	–
Stillaguamish early	Extinct	Early	Whidbey Basin	Nehlsen et al. (1991), WDF et al. (1993)
Skykomish	Extant	Late	Whidbey Basin	–
Snoqualmie	Extant	Late	Whidbey Basin	–
Snohomish early	Extinct	Early	Whidbey Basin	Nehlsen et al. (1991), WDF et al. (1993)
Cedar	Extant	Late	Main/South Basins	–
North Lake Washington	Extant	Late	Main/South Basins	–
Green/Duwamish	Extant	Late	Main/South Basins	–
Green/Duwamish early	Extinct	Early	Main/South Basins	Nehlsen et al. (1991), WDF et al. (1993)
Puyallup	Extant	Late	Main/South Basins	–
White	Extant	Early	Main/South Basins	–
Puyallup early	Extinct	Early	Main/South Basins	Nehlsen et al. (1991)
Nisqually	Extant	Late	Main/South Basins	–
Nisqually early	Extinct	Early	Main/South Basins	Nehlsen et al. (1991), ONRC and Kawa (1995)
Skokomish	Extant	Late	Hood Canal	–
Skokomish early	Extinct	Early	Hood Canal	Nehlsen et al. (1991), WDF et al. (1993)
Dosewallips	Extant	Late	Hood Canal	–
Dosewallips early	Extinct	Early	Hood Canal	Nehlsen et al. (1991), ONRC and Kawa (1995)
Dungeness	Extant	Late	Strait of Juan de Fuca	–
Elwha	Extant	Late	Strait of Juan de Fuca	–
Elwha early	Extinct	Early	Strait of Juan de Fuca	Nehlsen et al. (1991)

[a] Puget Sound Technical Recovery Team (2001).

[b] Puget Sound Technical Recovery Team (2001, 2002).

Table 9. Abundance of natural spawners, estimates of the fraction of hatchery fish in natural escapements, and estimates of historical capacity of Puget Sound streams. Sources: For data sources, see Appendix A, Table-2.

Population	Geometric mean natural spawners (1998–2002)	Arithmetic mean natural spawners (1998–2002) (minimum, maximum)	Geometric mean natural–origin spawners (1998–2002)	Average % hatchery fish in escapement[a] 1997–2001 (min.–max. since 1992)	Chinook salmon hatcheries in basin	Hatchery fraction data? (years)	EDT estimate of historical abundance[b]
North Fork Nooksack[c]	1,538	2,275 (366–4,671)	125	91 (88–95)	Kendall (NFH; RM 45)	Yes (1995–2002)	26,000
South Fork Nooksack[c]	338	372 (157–620)	197	40 (24–55)	Kendall (NFH; RM45)	Yes (1999–2002)	13,000
Lower Skagit	2,527	2,833 (1,043–4,866)	2,519	0.2 (0–0.7)	Marblemount (mouth of Cascade)[d]	Yes (1998–2001)	22,000
Upper Skagit	9,489	10,468 (3,586–13,815)	9,281	2 (2–3)	Marblemount (mouth of Cascade)[d]	Yes (1995–2000)	35,000
Upper Cascade	274	329 (83–625)	274	0.3	Marblemount (mouth of Cascade)[d]	No (assume low)	1,700
Lower Sauk	601	669 (295–1,103)	601	0	Marblemount (mouth of Cascade)[d]	Yes (2001)	7,800
Upper Sauk	324	349 (180–543)	324	0	Marblemount (mouth of Cascade)[d]	No (assumed)	4,200
Suiattle	365	399 (208–688)	365	0	Marblemount (mouth of Cascade)[d]	No (assumed)	830
North Fork Stillaguamish	1,154	1,172 (845–1,403)	671	40 (13–52)	Tribal (NF)	Yes (1988–1999)	24,000
South Fork Stillaguamish	270	272 (243–335)	NA	NA	Tribal (NF)	None	20,000
Skykomish	4,262	4,286 (3,455–4,665)	2,392	40 (11–66)	Wallace River	Yes (1979–2001)	51,000
Snoqualmie	2,067	2,229 (1,344–3,589)	1,700	16 (5–72)	Wallace River	Yes (1979–2001)	33,000
North Lake Washington	331	351 (227–537)	NA	NA	Lake Washington, Issaquah, University of Washington	None	NA
Cedar	327	394 (120–810)	NA	NA	Lake Washington, Issaquah, University of Washington	None	NA
Green	8,884	9,286 (6,170–13,950)	1,099	83 (35–100)	Soos, Icy, Keta creeks	Yes (1989–1997)	NA
White[e]	844	1,039 (316–2,002)	NA	NA	White River (RM 23); Voights Creek (Carbon River), Diru (RM 5)	None	NA

Table 9 continued. Abundance of natural spawners, estimates of the fraction of hatchery fish in natural escapements, and estimates of historical capacity of Puget Sound streams. Sources: For data sources, see Appendix A, Table-2.

Population	Geometric mean natural spawners (1998–2002)	Arithmetic mean natural spawners (1998–2002) (minimum, maximum)	Geometric mean natural–origin spawners (1998–2002)	Average % hatchery fish in escapement[a] 1997–2001 (min.–max. since 1992)	Chinook salmon hatcheries in basin	Hatchery fraction data? (years)	EDT estimate of historical abundance[b]
Puyallup	1,653	1,679 (1,193–1,988)	NA	NA	Voights Creek (Carbon River), Diru (RM 5)	None	33,000
Nisqually	1,195	1,221 (834–1,542)	NA	NA	Kalama, Clear Creek	None	18,000
Skokomish	1,392	1,437 (926–1,913)	NA	NA	George Adams (Purdy Creek, lower Skok)	None	NA
Dosewallips[f]	48	50 (29–65)	NA	NA	None	None	4,700
Duckabush[f]	43	57 (20–151)	NA	NA	None	None	NA
Hamma Hamma[f]	196	278 (32–557)	NA	NA	None	None	NA
Mid Hood Canal	311	381 (95–762)	NA	NA	None	None	NA
Dungeness[e]	222	304 (75–663)	NA	NA	Dungeness (and Hurd Creek)	None	8,100
Elwha[g, h]	688	691 (633–813)	NA	NA	Tribal (RM 1) and state (RM 3.2)	None	NA

NFH = National Fish Hatchery.

[a] Estimates of the fraction of hatchery fish in natural spawning escapements are from the Puget Sound TRT database; Green River estimates are from Alexandersdottir (2001).

[b] Estimates of historical equilibrium abundance based on an EDT analysis conducted by the comanagers in Puget Sound (Puget Sound TRT 2002).

[c] North Fork Nooksack natural escapement counts include estimated numbers of spawners from the Middle Fork Nooksack River since the late 1990s and Chinook salmon returning to the North Fork hatchery that were released back into the North Fork to spawn; South Fork Nooksack natural escapement estimates contain naturally spawning hatchery fish from the early run and late-run hatchery programs in the Nooksack River basin.

[d] Previous summer-run Chinook salmon hatchery program discontinued—last returns in 1996; current summer-run program (initiated in 1994) collects hatchery broodstock from spawners in upper Skagit River.

[e] Captive broodstock program for early run Chinook salmon ended in 2000; estimates of natural spawning escapement include an unknown fraction of naturally spawning hatchery-origin fish from late- and early run hatchery programs in the White and Puyallup River basins.

[f] The Puget Sound TRT considers Chinook salmon spawning in the Dosewallips, Duckabush, and Hamma Hamma rivers to be subpopulations of the same historically independent population; annual counts in those three streams are variable due to inconsistent visibility during spawning ground surveys.

[g] Year 2002 natural escapement data are not available.

[h] Estimates of natural escapement do not include volitional returns to the hatchery or those fish gaffed or seined from spawning grounds for broodstock collection.

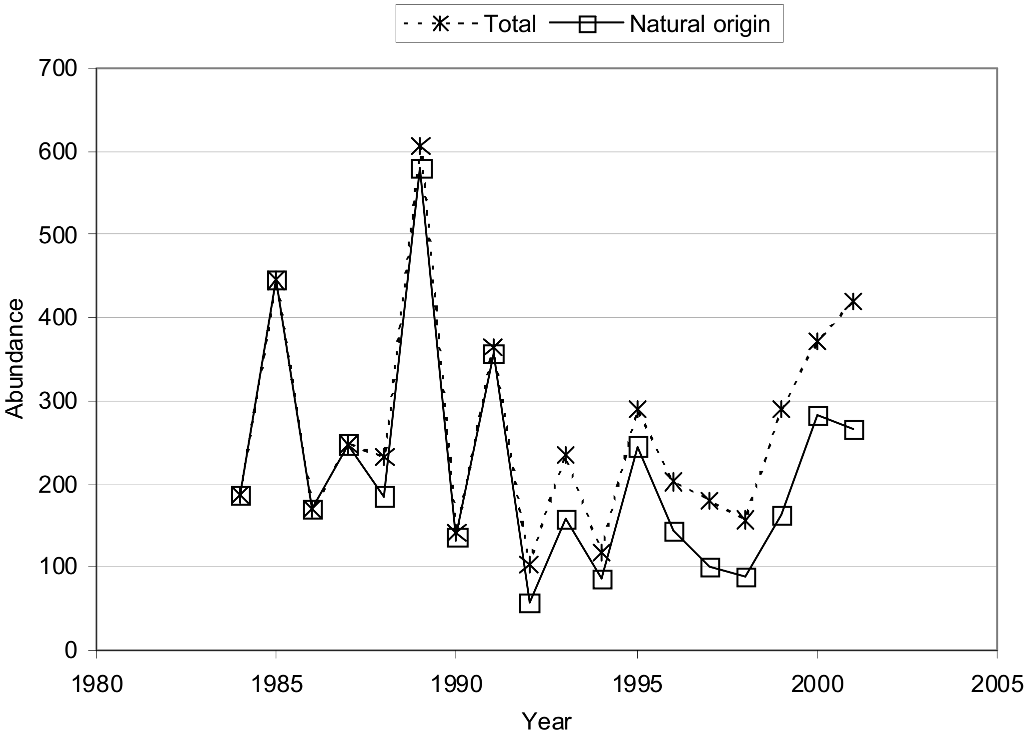

Figure 32. Total and natural-origin spawner abundance estimates versus year for the North Fork Nooksack River population of Chinook salmon, 1984–2001.

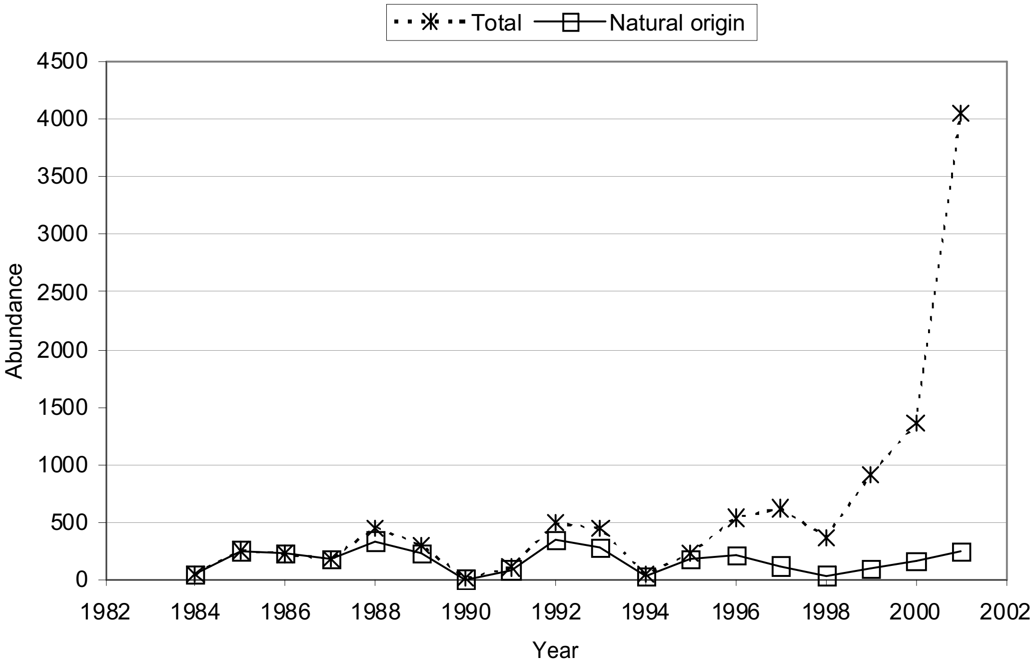

Figure 33. Total and natural-origin spawner abundance estimates versus year for the South Fork Nooksack River population of Chinook salmon, 1984–2001.

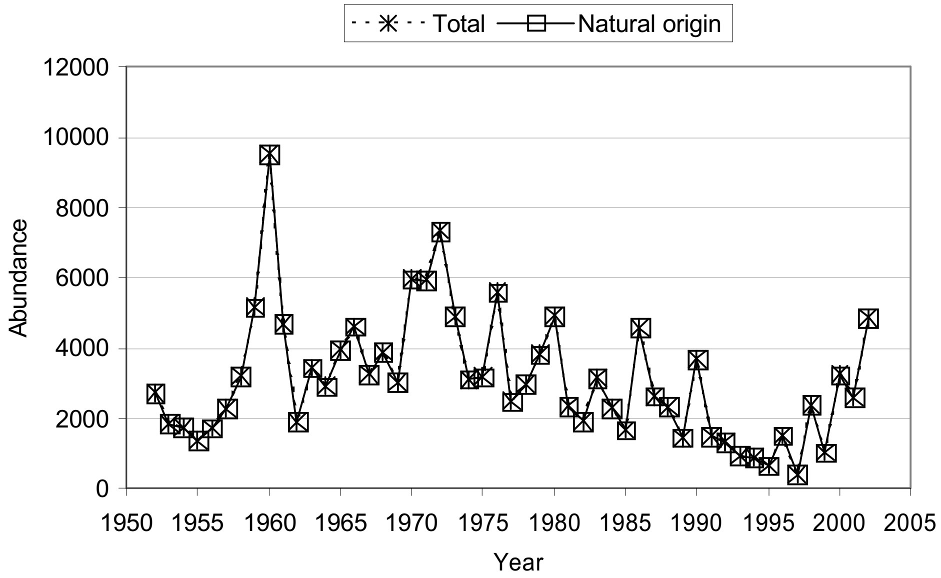

Figure 34. Total and natural-origin spawner abundance estimates versus year for the lower Skagit River population of Chinook salmon, 1951–2002.

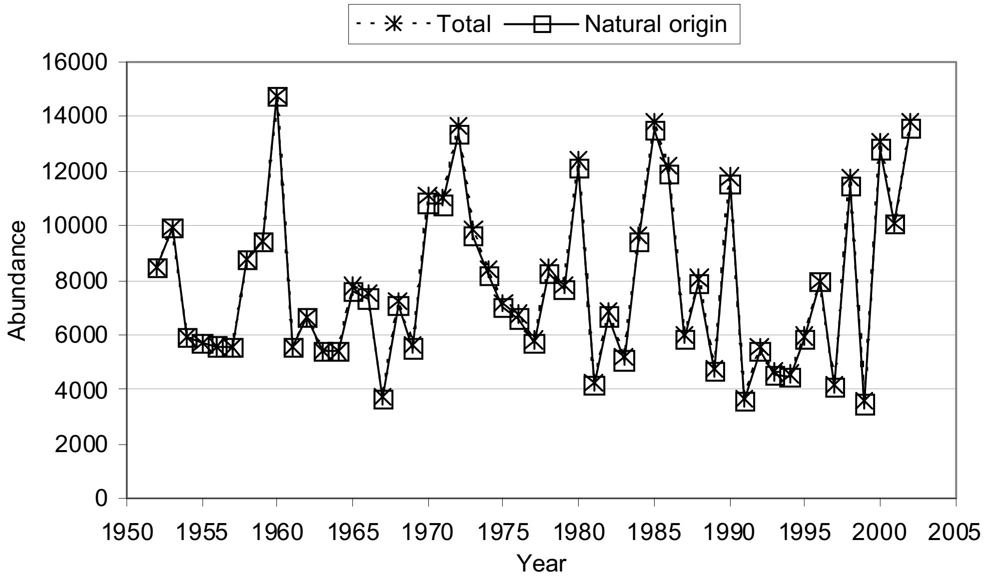

Figure 35. Total and natural-origin spawner abundance estimates versus year for the upper Skagit River population of Chinook salmon, 1951–2002.

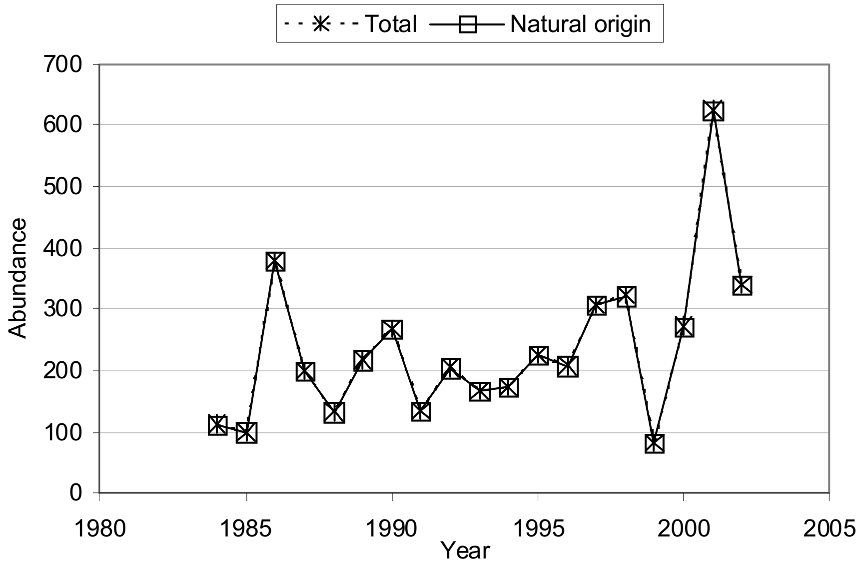

Figure 36. Total and natural-origin spawner abundance estimates versus year for the upper Cascade River population of Chinook salmon, 1984–2002.

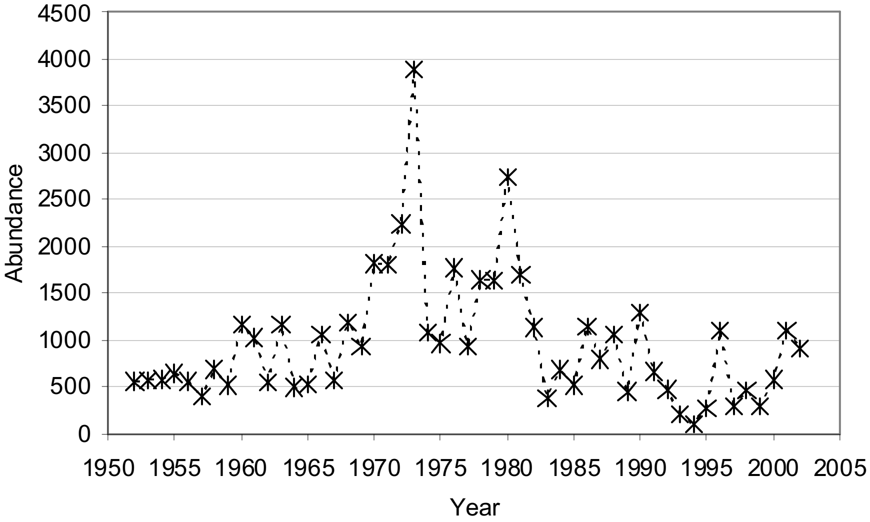

Figure 37. Total spawner abundance estimates versus year for the lower Sauk River population of Chinook salmon, 1952–2002.

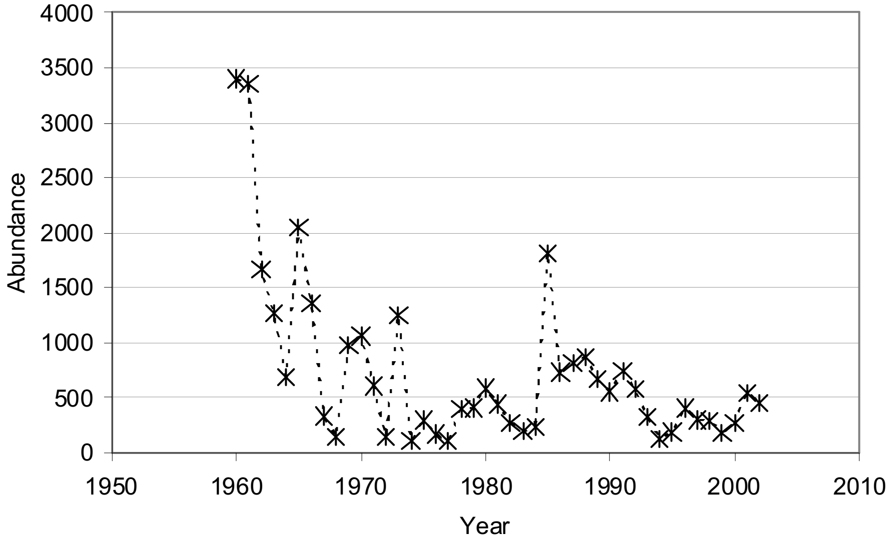

Figure 38. Total spawner abundance estimates versus year for the upper Sauk River population of Chinook salmon, 1960–2002.

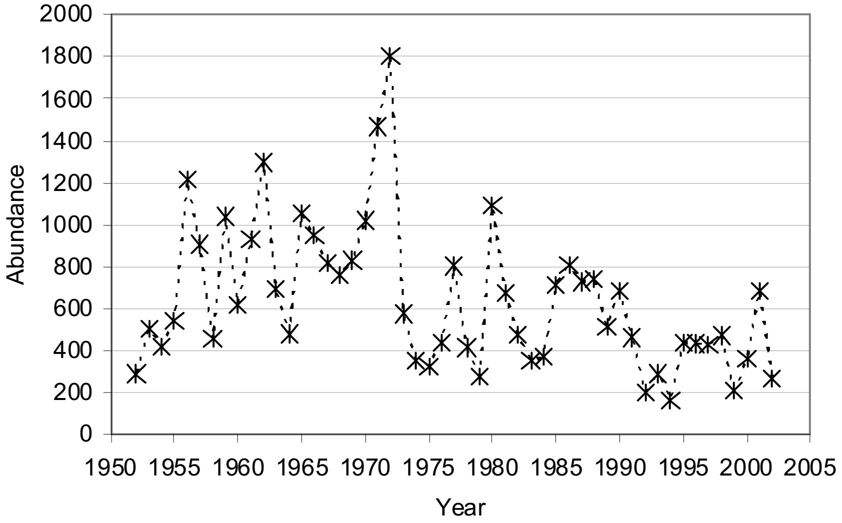

Figure 39. Total spawner abundance estimates versus year for the Suiattle River population of Chinook salmon, 1952–2002.

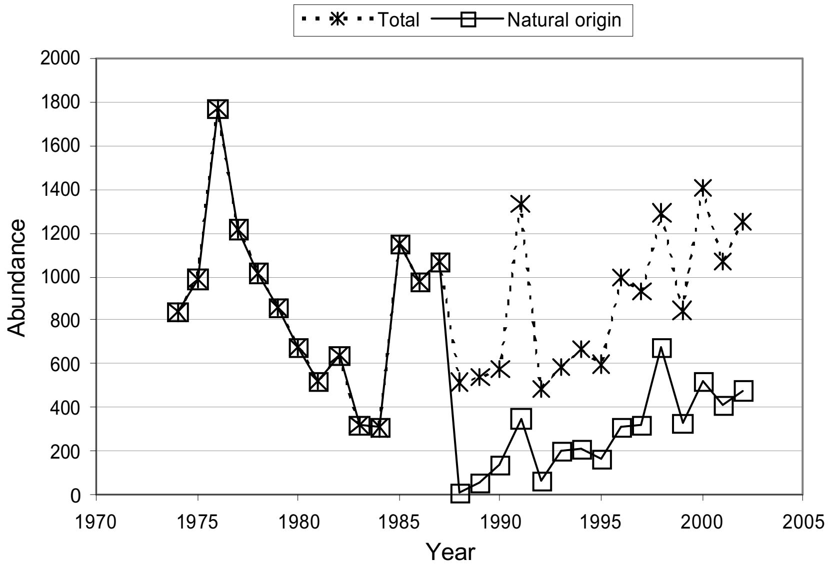

Figure 40. Total and natural-origin spawner abundance estimates versus year for the North Fork Stillaguamish River population of Chinook salmon, 1974–2002.

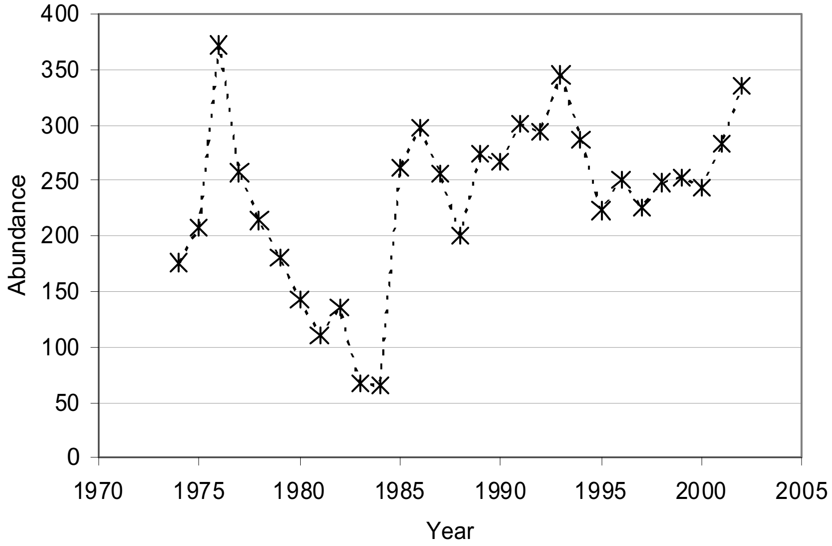

Figure 41. Total spawner abundance estimates versus year for the South Fork Stillaguamish River population of Chinook salmon, 1974–2003.

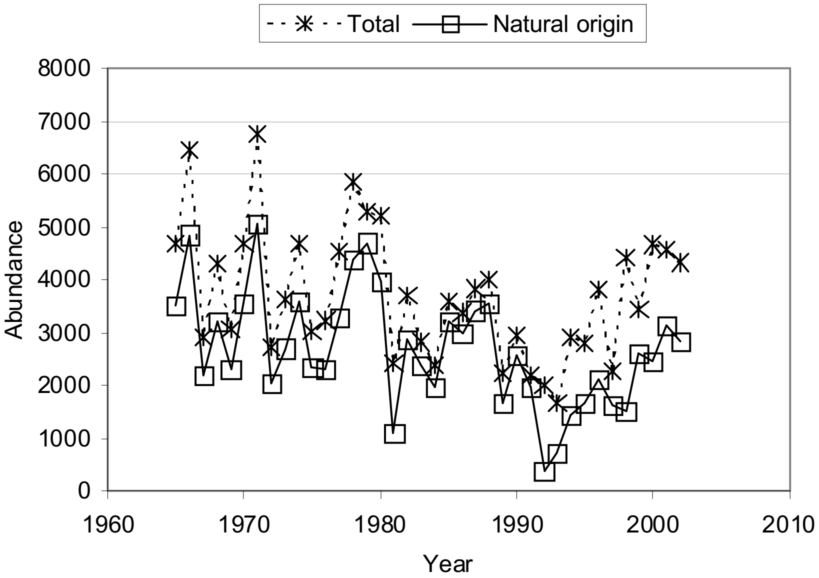

Figure 42. Total and natural-origin spawner abundance estimates versus year for the Skykomish River population of Chinook salmon, 1965–2002.

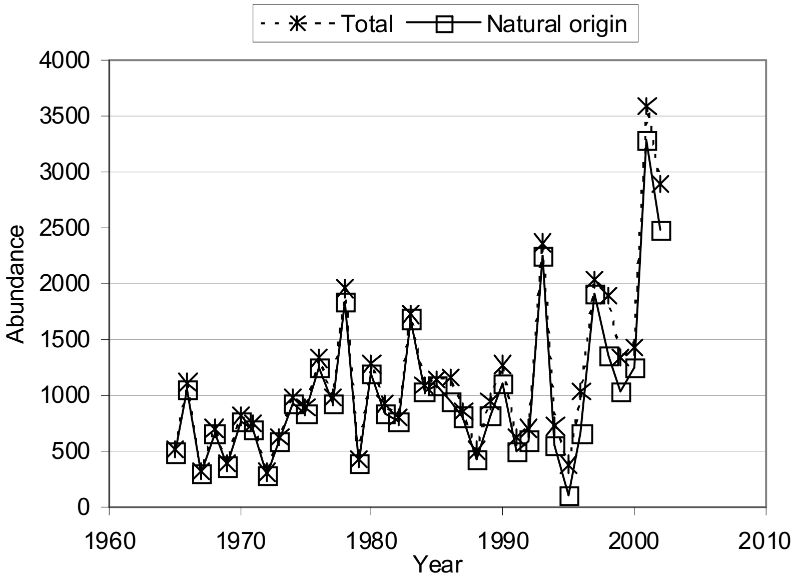

Figure 43. Total and natural-origin spawner abundance estimates versus year for the Snoqualmie River population of Chinook salmon, 1965–2003.

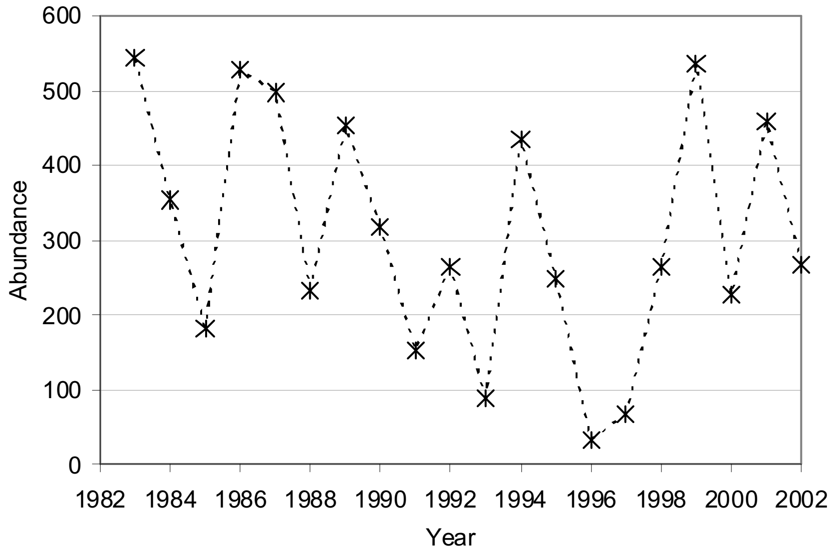

Figure 44. Total spawner abundance estimates versus year for the north Lake Washington tributaries population of Chinook salmon, 1983–2002.

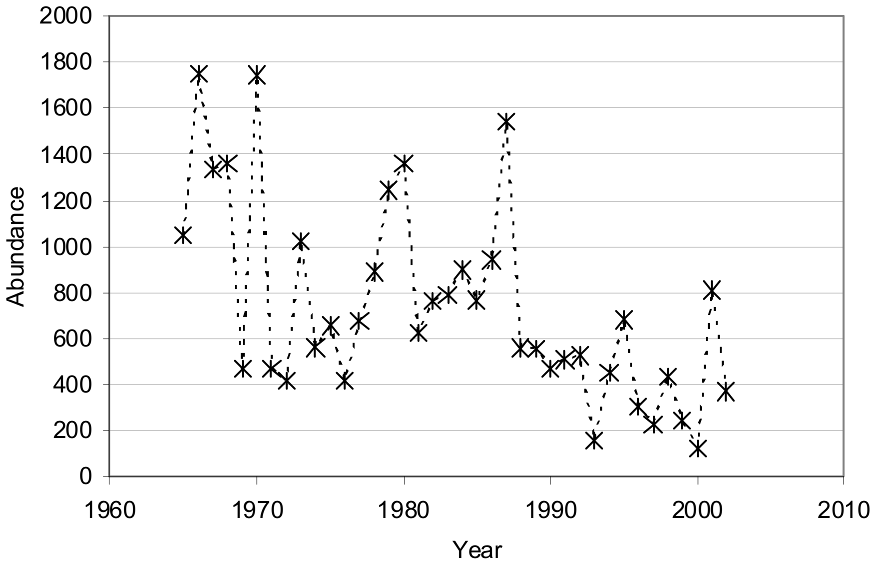

Figure 45. Total spawner abundance estimates versus year for the Cedar River population of Chinook salmon, 1965–2002.

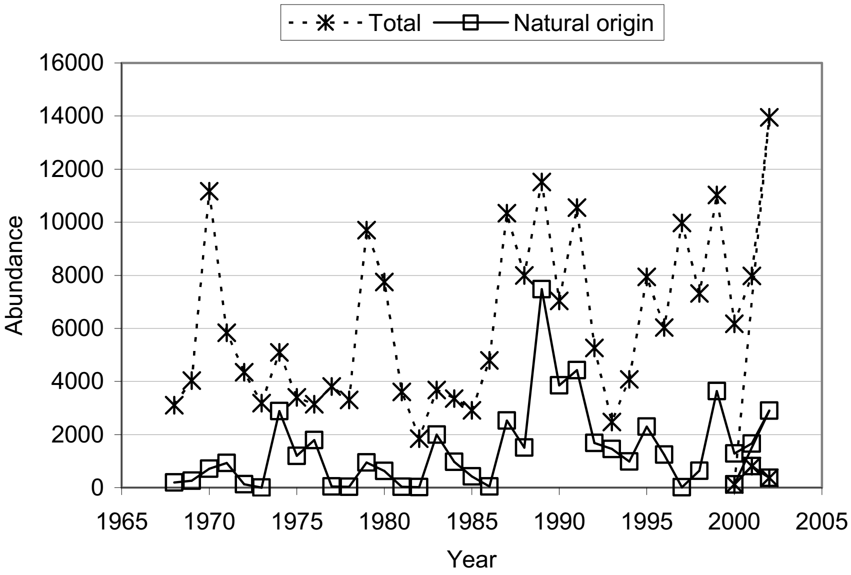

Figure 46. Total and natural-origin spawner abundance estimates versus year for the Green/Duwamish rivers population of Chinook salmon, 1967–2002.

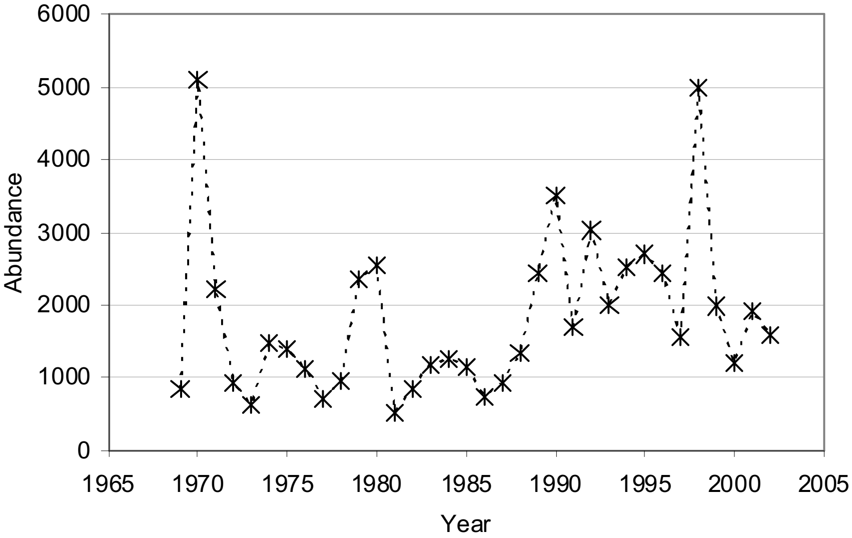

Figure 47. Total spawner abundance estimates versus year for the Puyallup River population of Chinook salmon, 1969–2002.

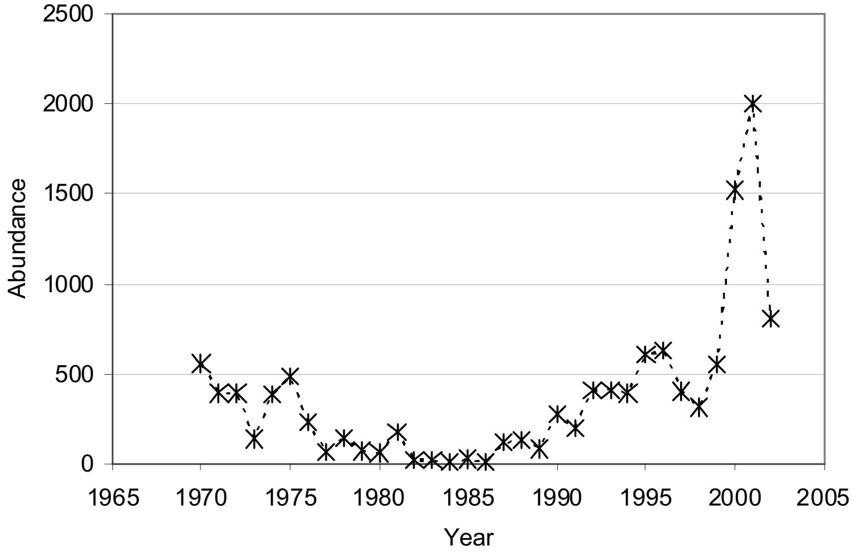

Figure 48. Total spawner abundance estimates versus year for the White River population of Chinook salmon, 1970–2002.

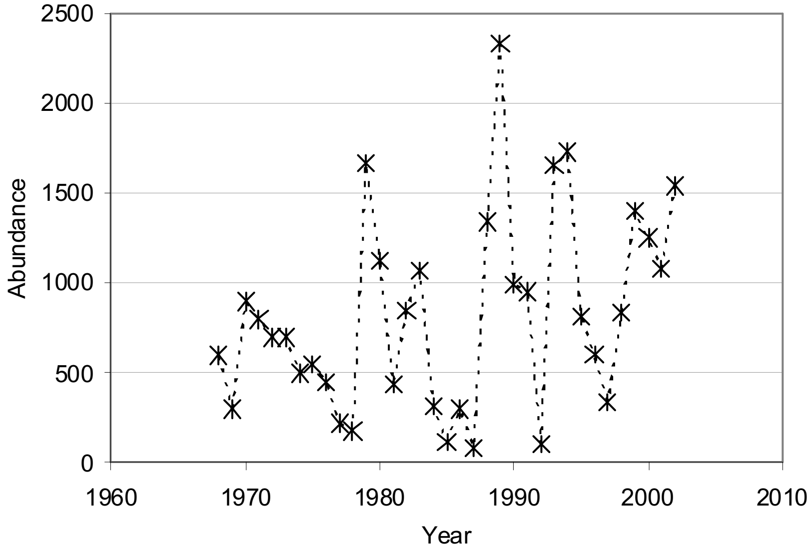

Figure 49. Total spawner abundance estimates versus year for the Nisqually River population of Chinook salmon, 1968–2002.

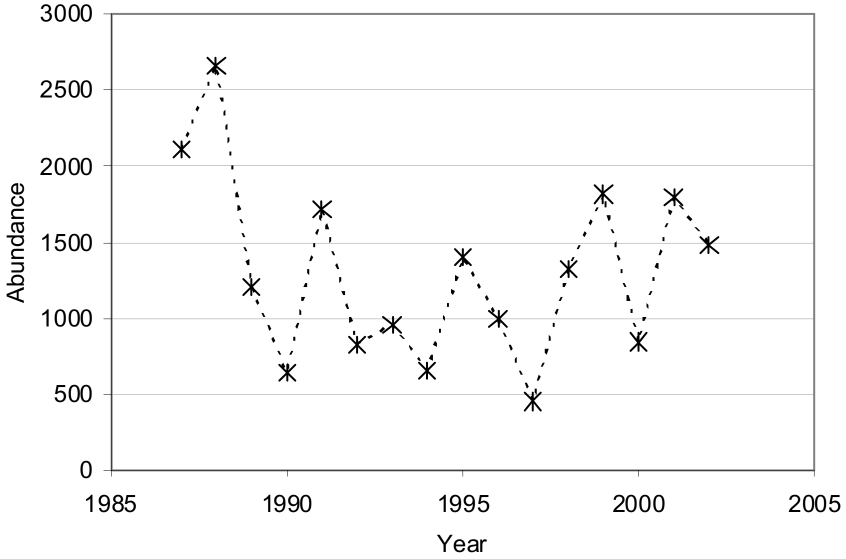

Figure 50. Total spawner abundance estimates versus year for the Skokomish River population of Chinook salmon, 1987–2003.

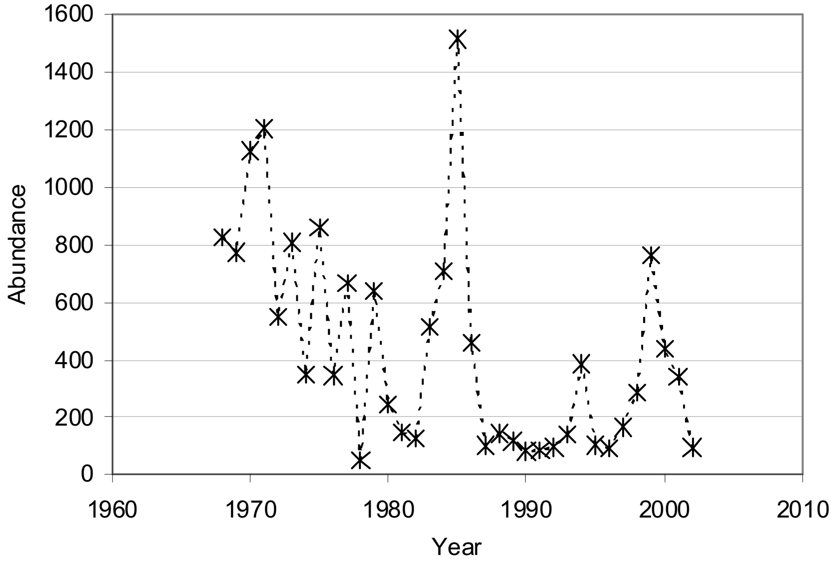

Figure 51. Total spawner abundance estimates versus year for the Dosewallips/Hamma Hamma/Duckabush rivers population of Chinook salmon, 1967–2002.

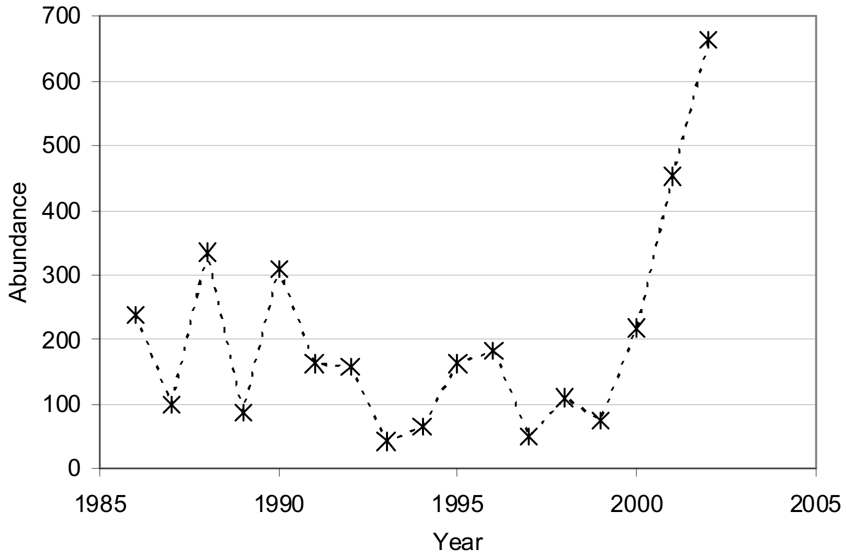

Figure 52. Total spawner abundance estimates versus year for the Dungeness River population of Chinook salmon, 1986–2002.

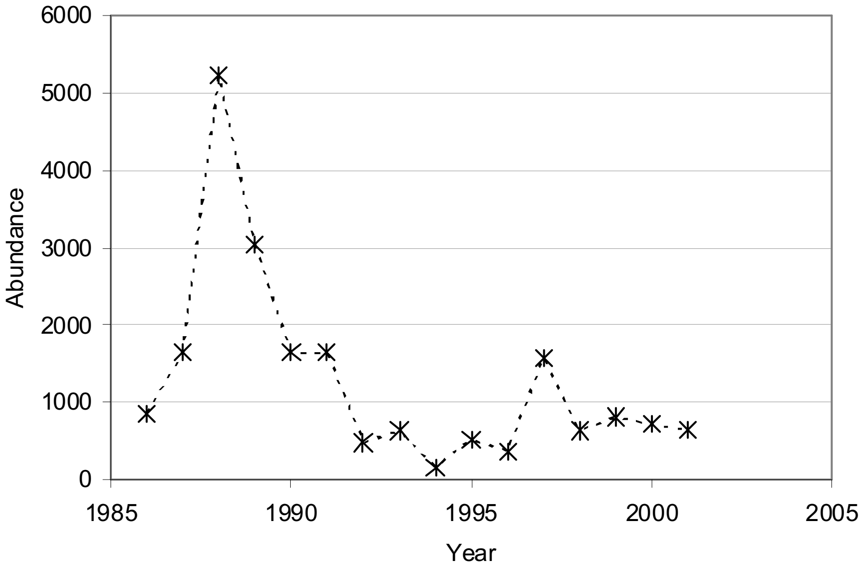

Figure 53. Total spawner abundance estimates versus year for the Elwha River population of Chinook salmon, 1986–2001.

Trends in Natural Spawners

Long-term trends in abundance for naturally spawning populations of Chinook salmon in Puget Sound indicate that approximately half the populations are declining, and half are increasing in abundance over the length of available time series (Table 10 and Figures 32–53). The median over all populations of long-term trend in abundance is 1.0 (range 0.92–1.2), indicating that most populations are just replacing themselves. Over the long term, the most extreme declines in natural spawning abundance have occurred in the combined Dosewallips and Elwha populations. Those populations with the greatest long-term population growth rates are the North Fork Nooksack and White rivers. All populations reported above are likely to have a moderate to high fraction of naturally spawning hatchery fish, so it is not possible to say what the trends in naturally spawning, natural-origin Chinook salmon might be in those populations.

Table 10. Estimates of long- and short-term trends, and the short-term median population growth rate (λ), and their 95% confidence intervals (CI) for spawners in Puget Sound Chinook salmon populations.

Population	**Data years**	**Long-term trend (CI)[a]**	**Short-term trend (CI) (1990–2002)[b]**	**ST λ (± lnSE) (1990–2002)[b]**
North Fork Nooksack	1984–2001	1.16 (1.04–1.30)	1.42 (1.18–1.70)	0.75 (0.07)
South Fork Nooksack	1984–2001	1.00 (0.96–1.05)	1.07 (0.98–1.15)	0.94 (0.05)
Lower Skagit	1952–2002	0.99 (0.97–1.00)	1.06 (0.94–1.18)	1.05 (0.09)
Upper Skagit	1952–2002	1.00 (0.99–1.01)	1.06 (0.98–1.14)	1.05 (0.06)
Upper Cascade	1984–2002	1.04 (1.00–1.08)	1.05 (0.98–1.14)	1.06 (0.05)
Lower Sauk	1952–2002	0.99 (0.98–1.00)	1.03 (0.91–1.17)	1.01 (0.12)
Upper Sauk	1952–2002	0.97 (0.96–0.99)	0.97 (0.89–1.06)	0.96 (0.06)
Suiattle	1952–2002	0.99 (0.98–0.99)	1.00 (0.92–1.08)	0.99 (0.06)
North Fork Stillaguamish	1974–2002	1.01 (0.99–1.03)	1.06 (1.01–1.11)	0.92 (0.04)
South Fork Stillaguamish[c]	1974–2002	1.02 (1.00–1.04)	1.00 (0.97–1.02)	0.99 (0.02)
Skykomish	1965–2002	0.99 (0.98–1.00)	1.07 (1.03–1.11)	0.87 (0.03)
Snoqualmie	1965–2002	1.03 (1.01–1.04)	1.10 (1.01–1.21)	1.00 (0.04)
North Lake Washington[c]	1983–2002	0.97 (0.91–1.03)	1.04 (0.91–1.19)	1.07 (0.07)
Cedar[c]	1965–2002	0.97 (0.95–0.98)	0.97 (0.89–1.07)	0.99 (0.07)
Green[c]	1968–2002	1.02 (1.01–1.04)	1.05 (0.98–1.13)	0.67 (0.06)
White[c]	1970–2002	1.05 (1.00–1.10)	1.14 (1.06–1.22)	1.16 (0.06)
Puyallup[c]	1968–2002	1.02 (1.00–1.04)	0.96 (0.91–1.02)	0.95 (0.06)
Nisqually[c]	1968–2002	1.02 (0.99–1.05)	1.06 (0.93–1.20)	1.04 (0.07)
Skokomish[c]	1987–2002	0.99 (0.93–1.05)	1.04 (0.97–1.12)	1.04 (0.04)
Combined Dosewallips[c]	1968–2002	0.96 (0.93–0.98)	1.11 (0.99–1.20)	1.17 (0.10)
Dungeness[c]	1986–2002	1.02 (0.94–1.10)	1.07 (0.94–1.20)	1.09 (0.11)
Elwha[c]	1986–2001	0.92 (0.84–1.00)	0.97 (0.86–1.10)	0.95 (0.11)

[a] Long- and short-term trends are calculated on all spawners.

[b] Short-term λ is calculated assuming the reproductive success of naturally spawning hatchery fish is equivalent to that of natural-origin fish (for those populations where information on the fraction of hatchery fish in natural spawning abundance is available).

[c] Estimate of the fraction of hatchery fish in time series is not available for use in λ calculation, so trend represents that in hatchery-origin + natural-origin spawners.

Fewer populations exhibit declining trends in abundance over the short term than over the long term—4 of 22 populations in the ESU declined from 1990 to 2002 (median = 1.06, range = 0.96–1.4) (Table 10). In contrast, estimates of short-term population growth rates suggest a very different picture when the reproductive success of hatchery fish is assumed to be 1. As discussed in Section 2, Methods, short-term population growth rates (λ) were calculated under two assumptions about the reproductive success of naturally spawning hatchery fish: the reproductive success was 0 (H0), or the reproductive success was equivalent to that of natural-origin fish (H1). Short-term λ estimates, assuming the reproductive success of hatchery fish was 0, are very similar to estimates of short-term trend, so they are not reported here. The median short-term λ over all populations (when the reproductive success of hatchery fish is assumed to be 1) is

$$\lambda - \mathrm{H1} = 1.0 \text{ (range} = 0.67 - 1.2) \tag{21}$$

The median estimate of short-term population growth would be even lower if the estimates of the fraction of naturally spawning hatchery fish were available for all populations in the ESU. As mentioned earlier, the 10 populations in the ESU for which no hatchery fraction information is available are all suspected to have a moderate to high fraction of hatchery-origin adults in natural escapements. In those cases where hatchery information is available and the fraction of hatchery-origin natural spawners is significant (e.g., North Fork Nooksack and Green rivers), the effect of the reproductive success of hatchery fish assumption on estimates of λ is dramatic. The most extreme short-term declines in natural spawner abundance have occurred in the upper Sauk, Cedar, Puyallup, and Elwha populations. Of these populations, only the upper Sauk is likely to have a low fraction of hatchery fish in escapements. When λ is calculated assuming the reproductive success of hatchery fish is equivalent to that of natural-origin fish, the biggest estimated short-term population declines are in the Green, Skykomish, North Fork Stillaguamish, and North Fork Nooksack populations (Table 10). Again, if hatchery fraction data were available for the additional 10 populations in the ESU for which such data are missing, more examples of significant short-term declines in population growth rate surely would emerge. The populations with the most positive short-term trends and population growth rates are the combined Dosewallips and White river populations. Both of these populations are thought to have a moderate fraction of naturally spawning hatchery fish, but because such estimates are not available, estimating the trends in natural-origin spawners is not possible.

Another indicator of the productivity of Chinook salmon populations is presented in the time-series figures showing the total number of spawners (natural and hatchery origin) and the number of preharvest recruits produced by those spawners against time (Figures 54–75). Dividing the number of preharvest recruits by the number of spawners for the same time period would yield an estimate of the preharvest recruits per spawner. Generating this type of figure requires harvest and age structure information and therefore could be produced for only a limited number of years in some populations. Representing information this way can indicate whether there have been changes in preharvest recruitment and the degree to which harvest management has the potential to recover populations. If the preharvest recruitment line is consistently below the spawner line, it indicates that the population would not be replacing itself, even in the absence of all harvest. In most populations, the preharvest recruits exceeded spawners in all but a few years for which data are available (Figures 54–75).

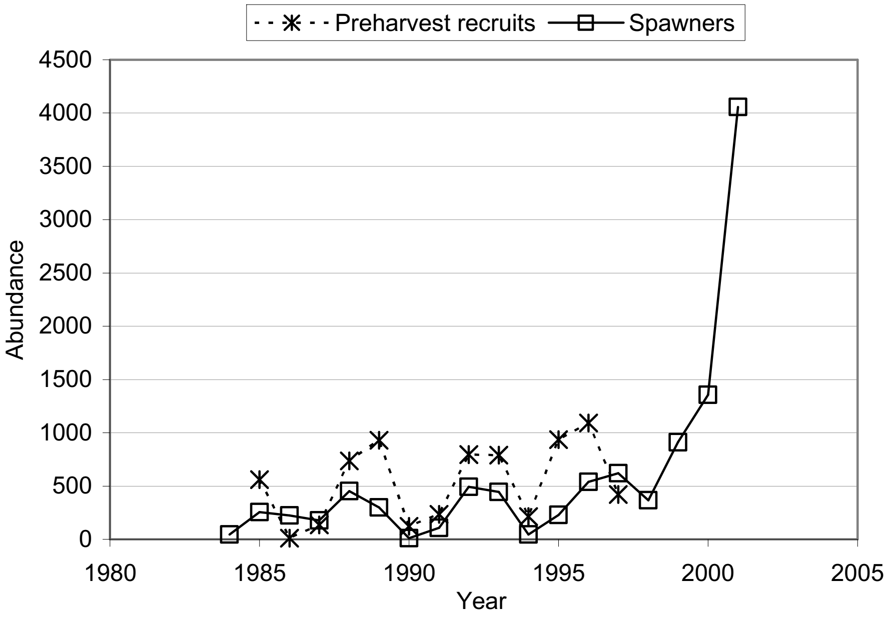

Figure 54. Preharvest recruits and spawners versus broodyear for the North Fork Nooksack River Chinook salmon population, 1984–2001.

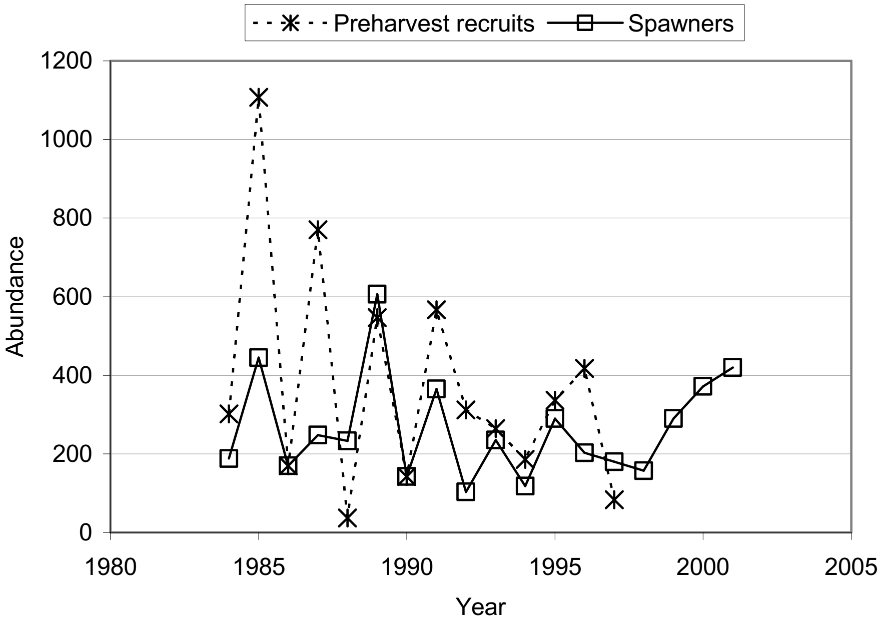

Figure 55. Preharvest recruits and spawners versus broodyear for the South Fork Nooksack River Chinook salmon population, 1984–2001.

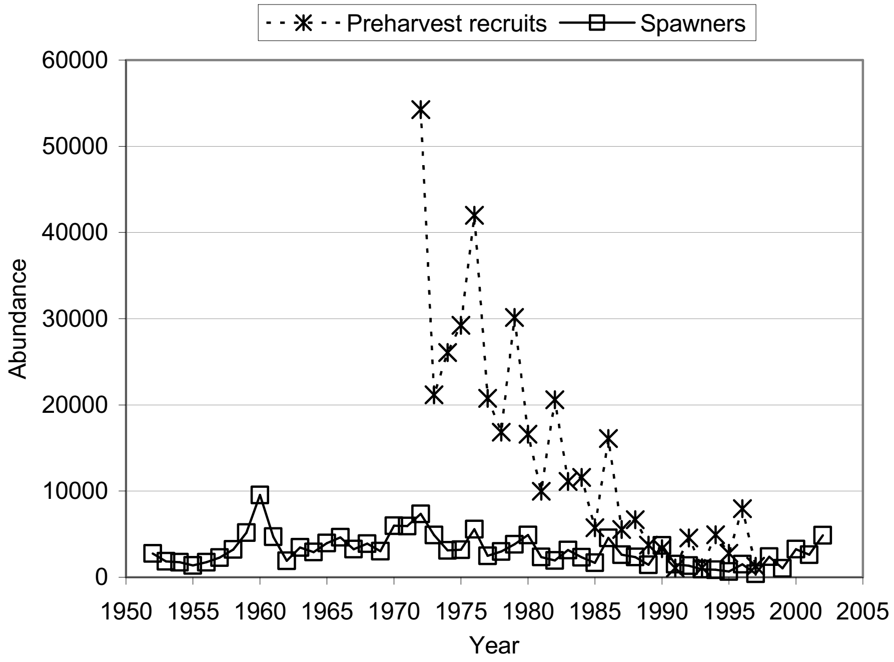

Figure 56. Preharvest recruits and spawners versus broodyear for the lower Skagit River Chinook salmon population, 1951–2002.

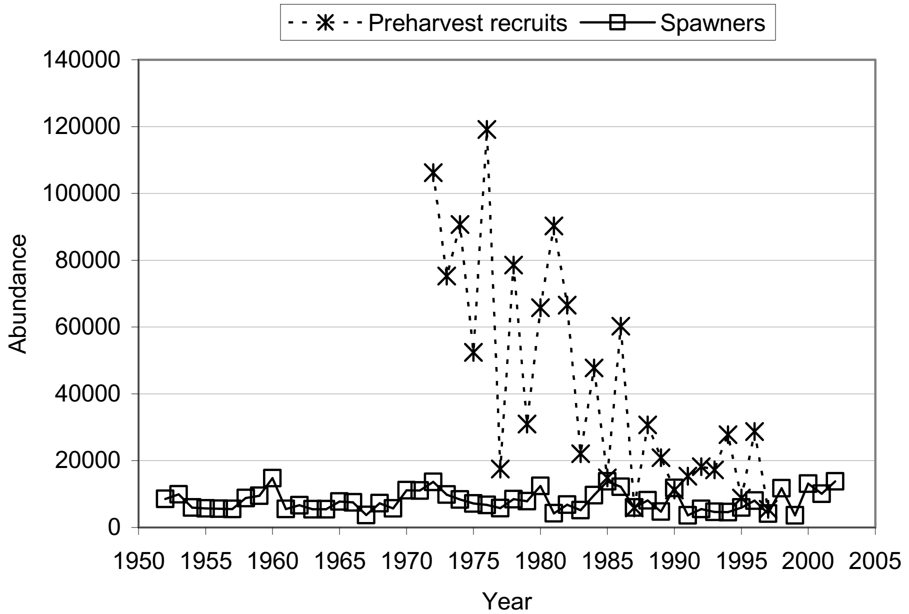

Figure 57. Preharvest recruits and spawners versus broodyear for the upper Skagit River Chinook salmon population, 1951–2002.

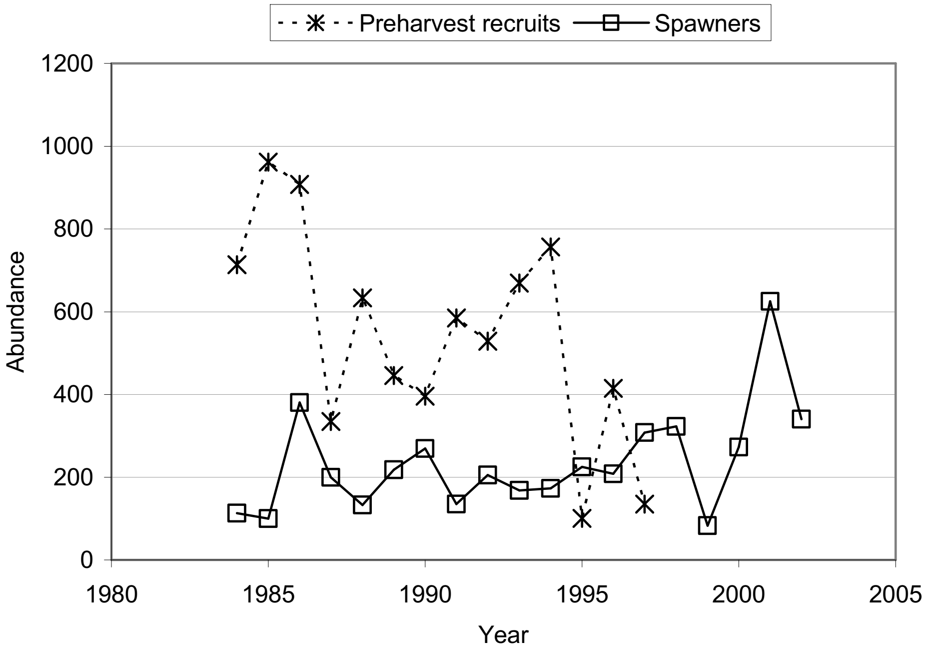

Figure 58. Preharvest recruits and spawners versus broodyear for the upper Cascade River Chinook salmon population, 1984–2002.

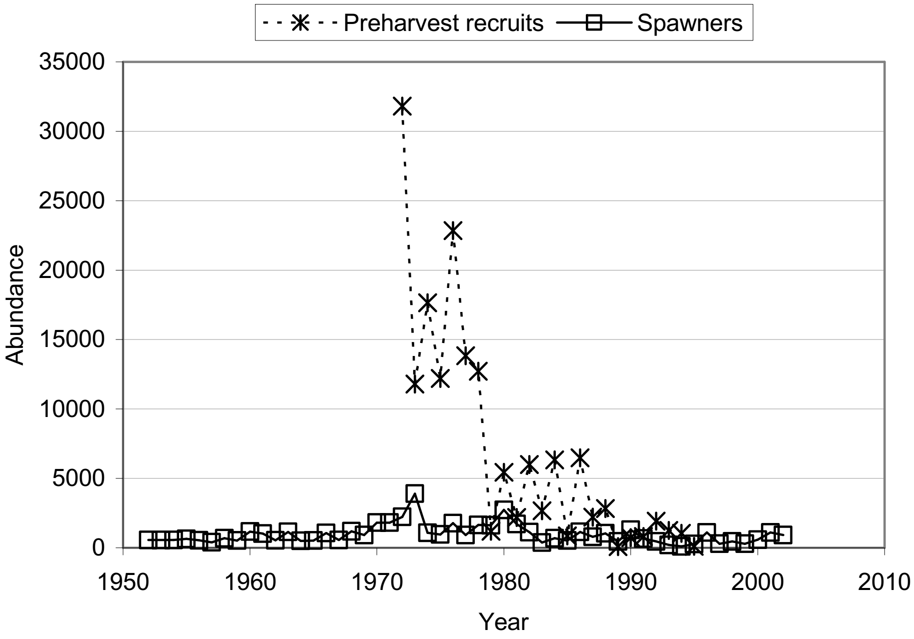

Figure 59. Preharvest recruits and spawners versus broodyear for the lower Sauk Chinook salmon population, 1951–2002.

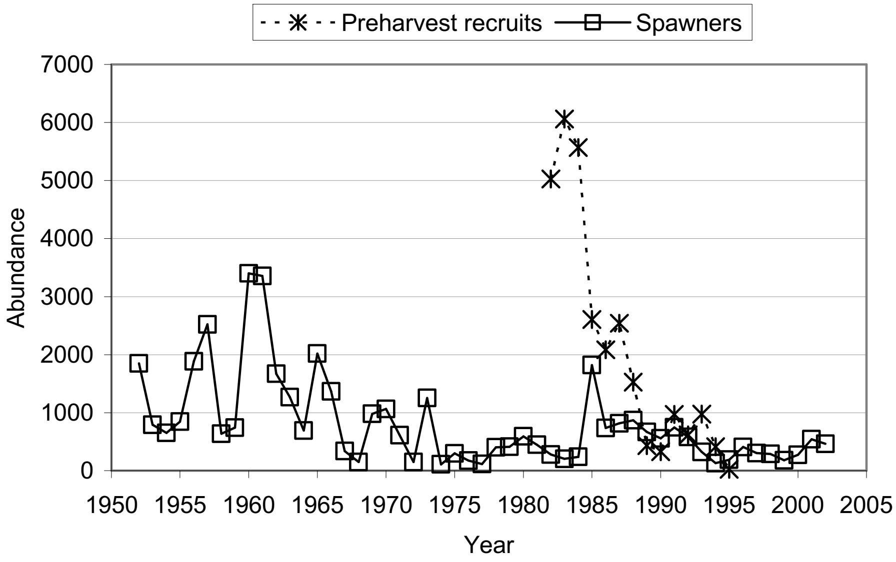

Figure 60. Preharvest recruits and spawners versus broodyear for the upper Sauk River Chinook salmon population, 1951–2002.

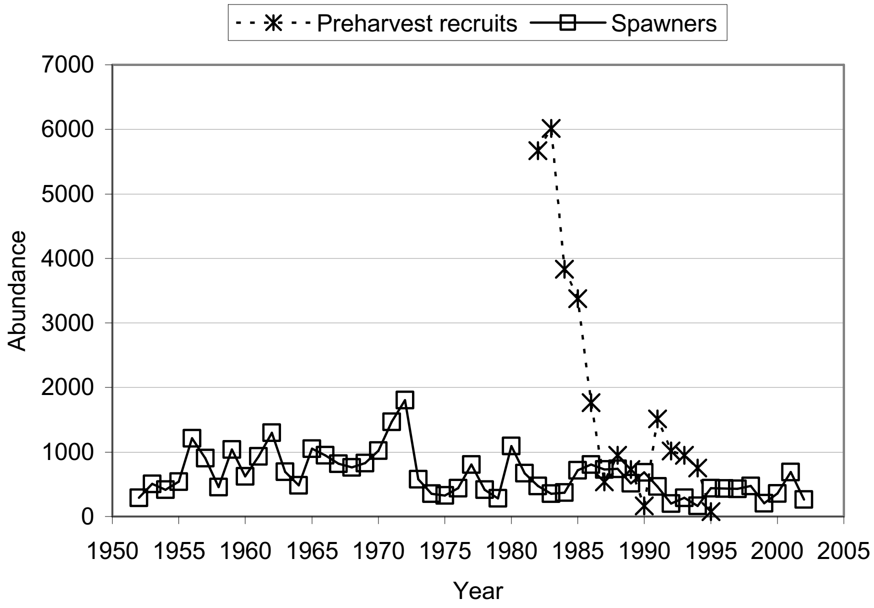

Figure 61. Preharvest recruits and spawners versus broodyear for the Suiattle River Chinook salmon population, 1951–2002.

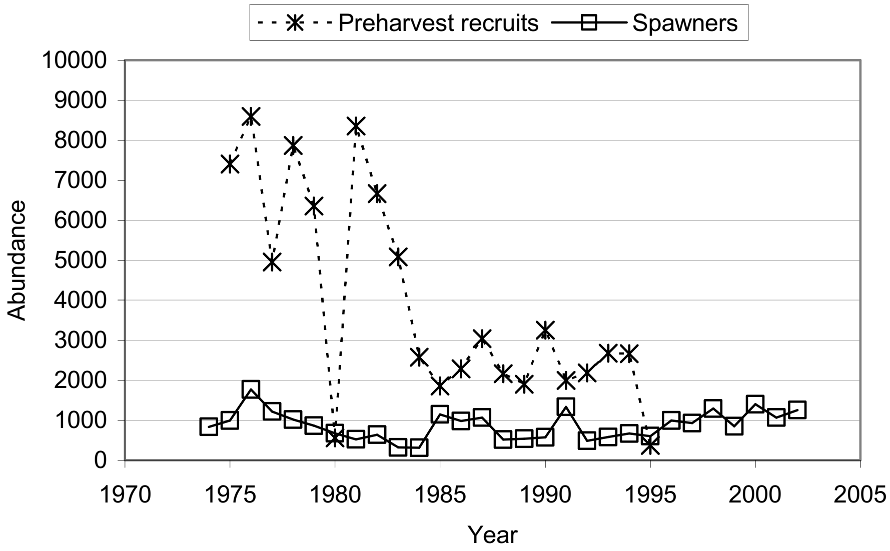

Figure 62. Preharvest recruits and spawners versus broodyear for the North Fork Stillaguamish River Chinook salmon population, 1974–2002.

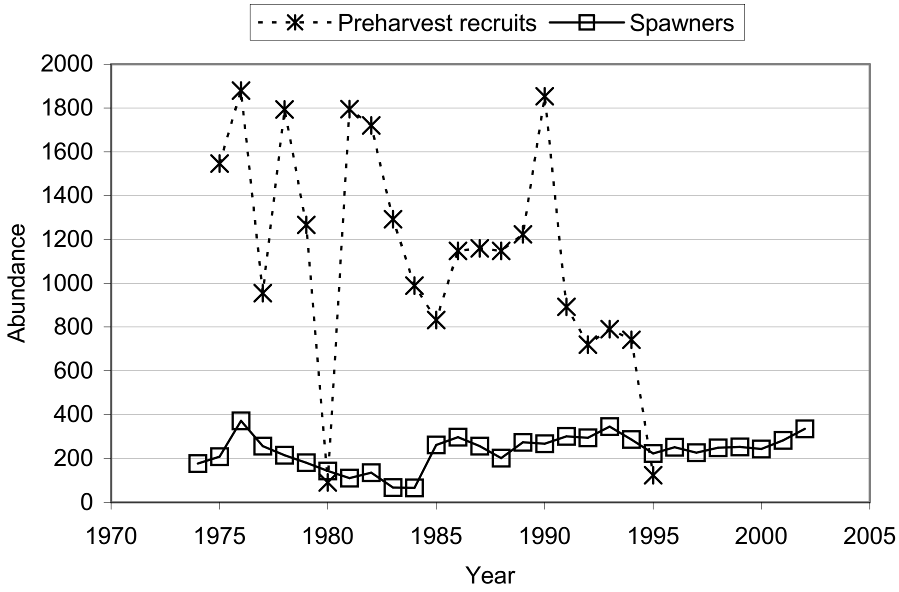

Figure 63. Preharvest recruits and spawners versus broodyear for the South Fork Stillaguamish River Chinook salmon population, 1974–2002.

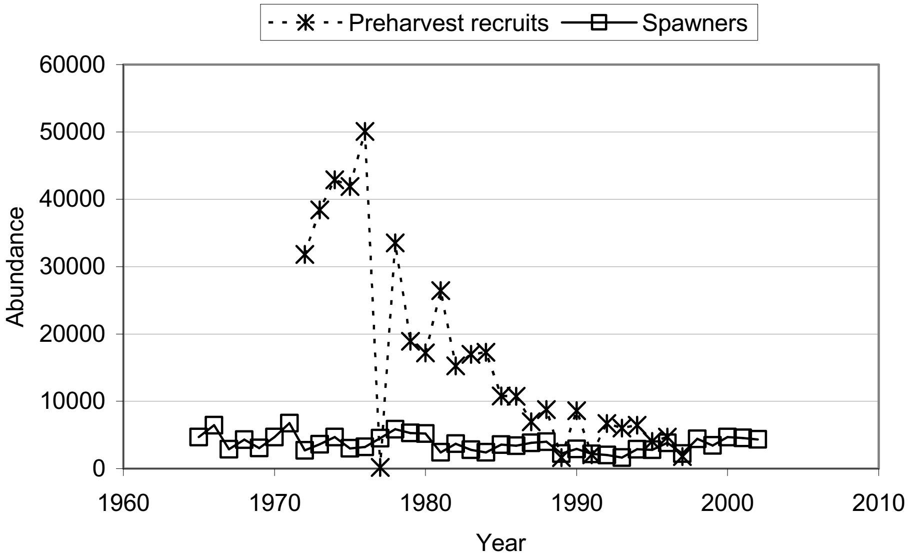

Figure 64. Preharvest recruits and spawners versus broodyear for the Skykomish River Chinook salmon population, 1965–2002.

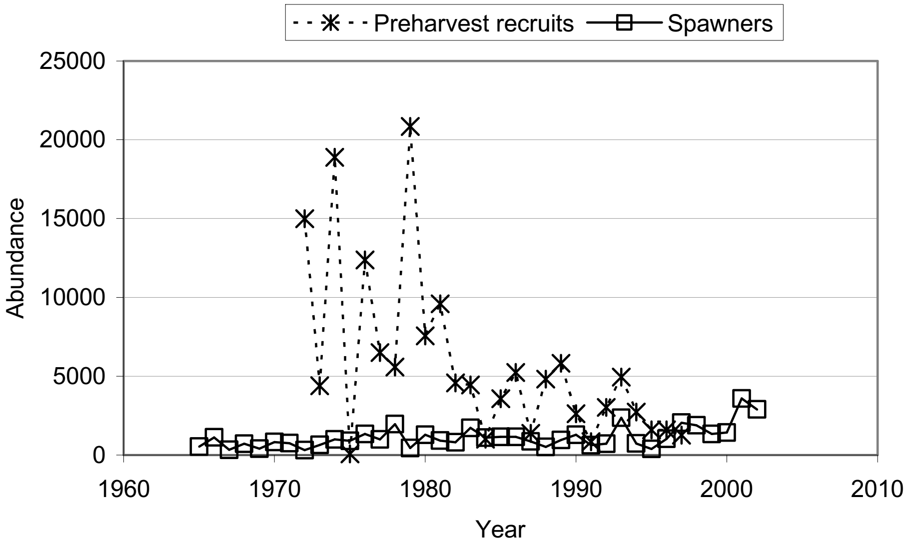

Figure 65. Preharvest recruits and spawners versus broodyear for the Snoqualmie River Chinook salmon population, 1965–2002.

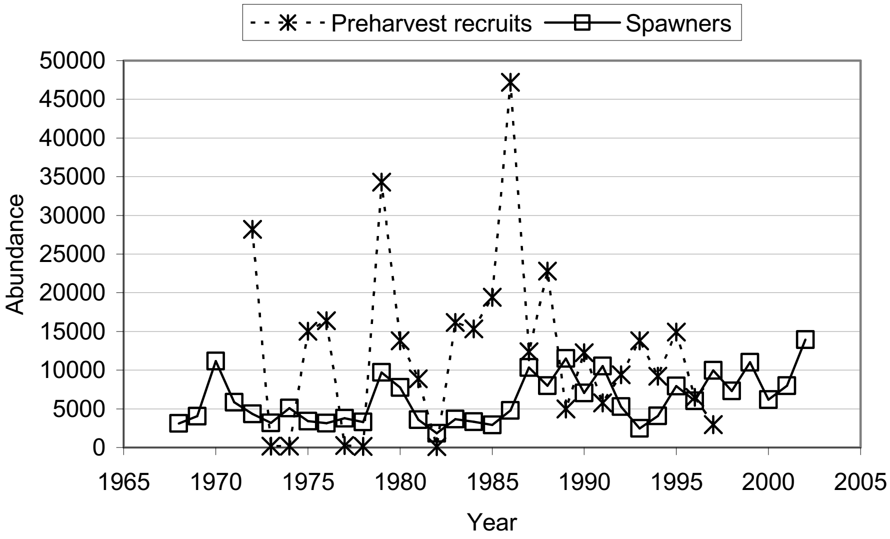

Figure 66. Preharvest recruits and spawners versus broodyear for the north Lake Washington tributaries Chinook salmon population, 1983–2002.

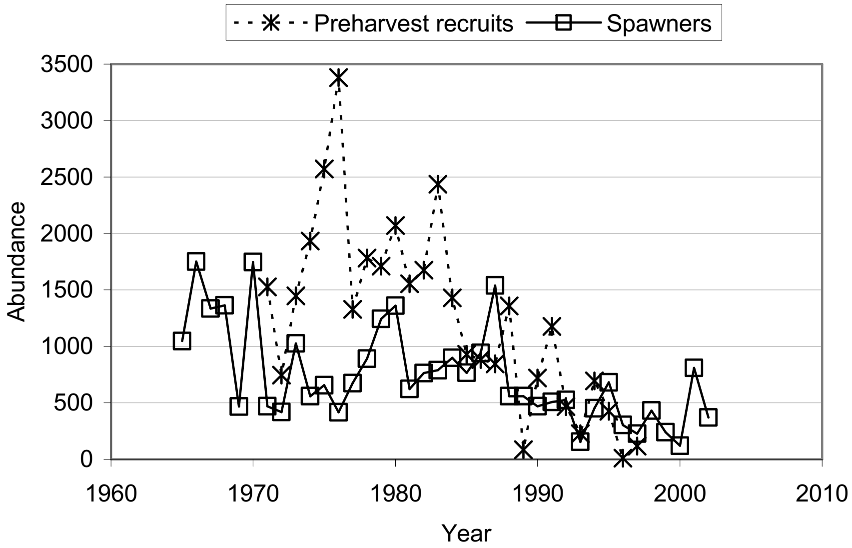

Figure 67. Preharvest recruits and spawners versus broodyear for the Cedar River Chinook salmon population, 1965–2002.

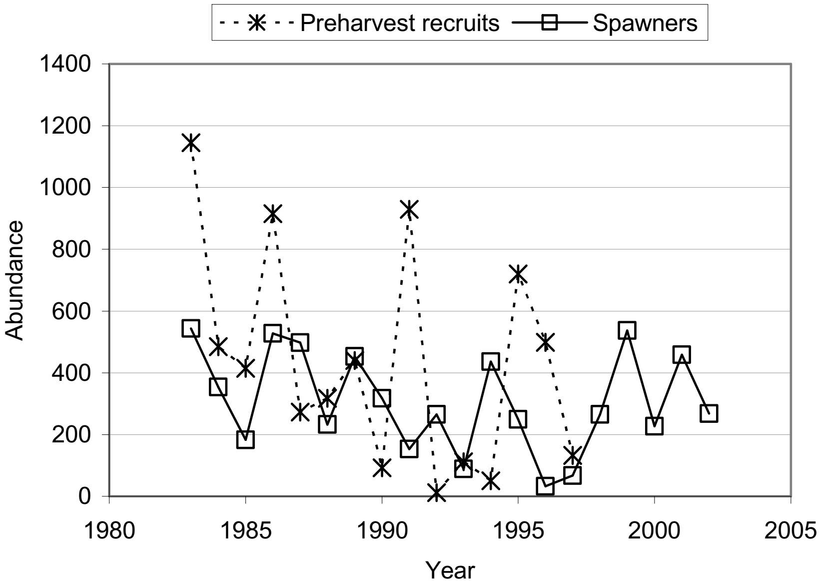

Figure 68. Preharvest recruits and spawners versus broodyear for the Green River Chinook salmon population, 1967–2002.

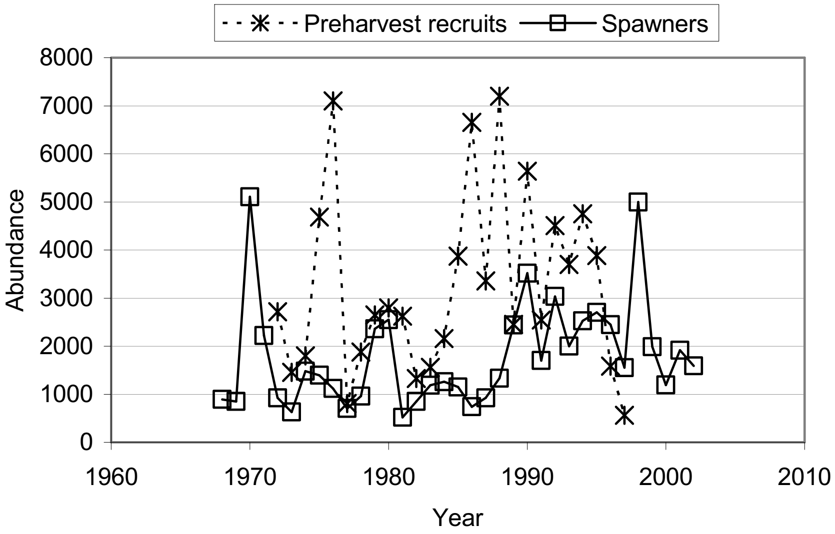

Figure 69. Preharvest recruits and spawners versus broodyear for the Puyallup River Chinook salmon population, 1968–2002.

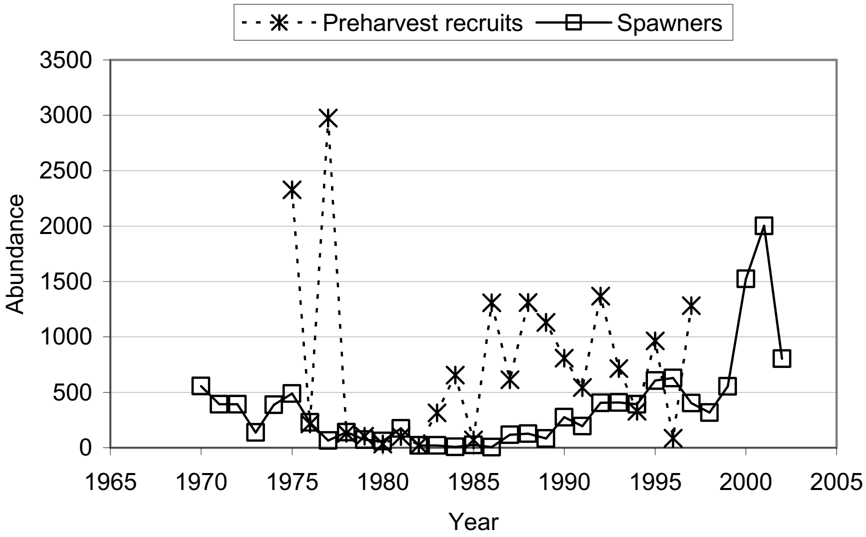

Figure 70. Preharvest recruits and spawners versus broodyear for the White River Chinook salmon population, 1970–2002.

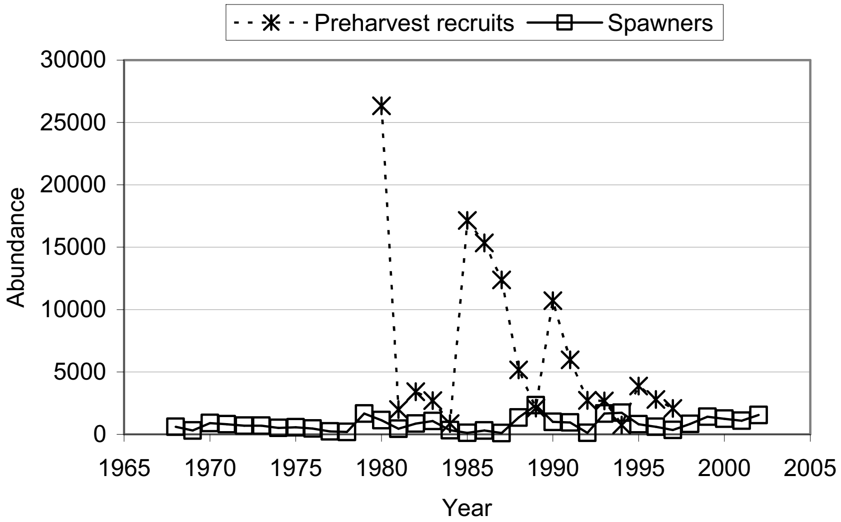

Figure 71. Preharvest recruits and spawners versus broodyear for the Nisqually River Chinook salmon population, 1968–2002.

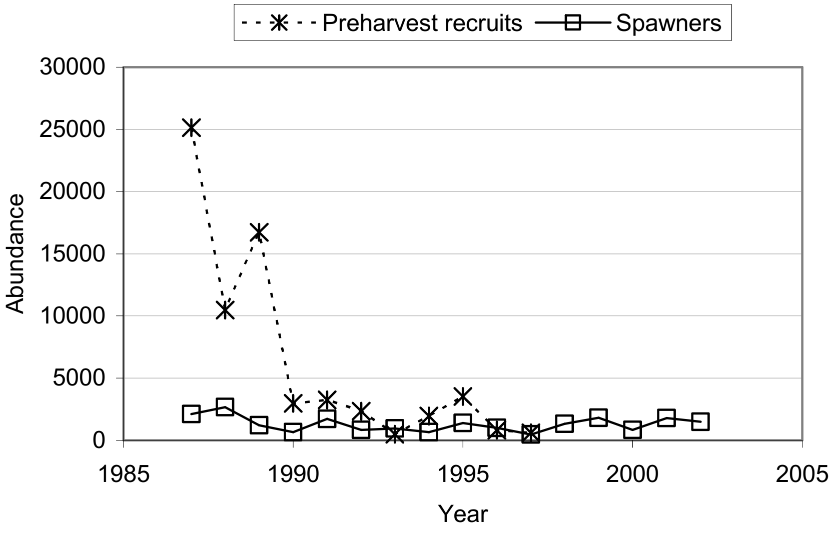

Figure 72. Preharvest recruits and spawners versus broodyear for the Skokomish River Chinook salmon population, 1987–2002.

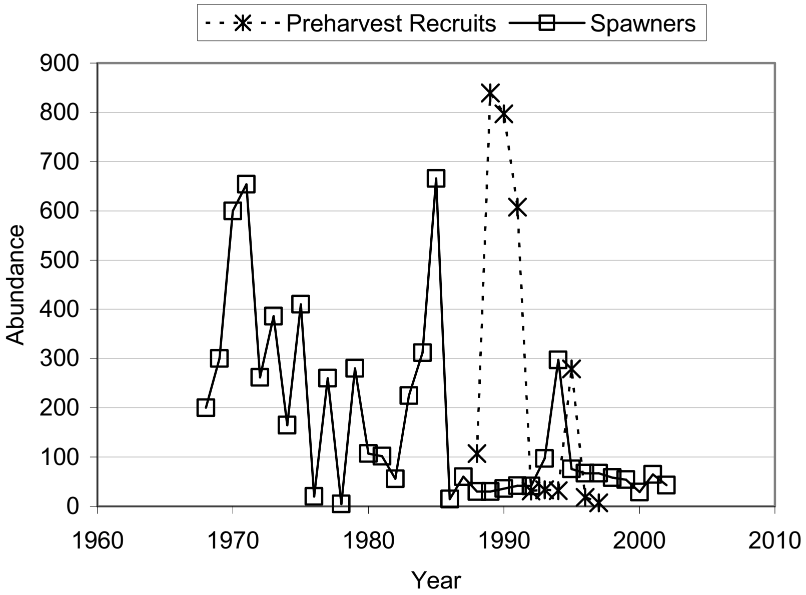

Figure 73. Preharvest recruits and spawners versus broodyear for the Dosewallips River Chinook salmon population, 1967–2002.

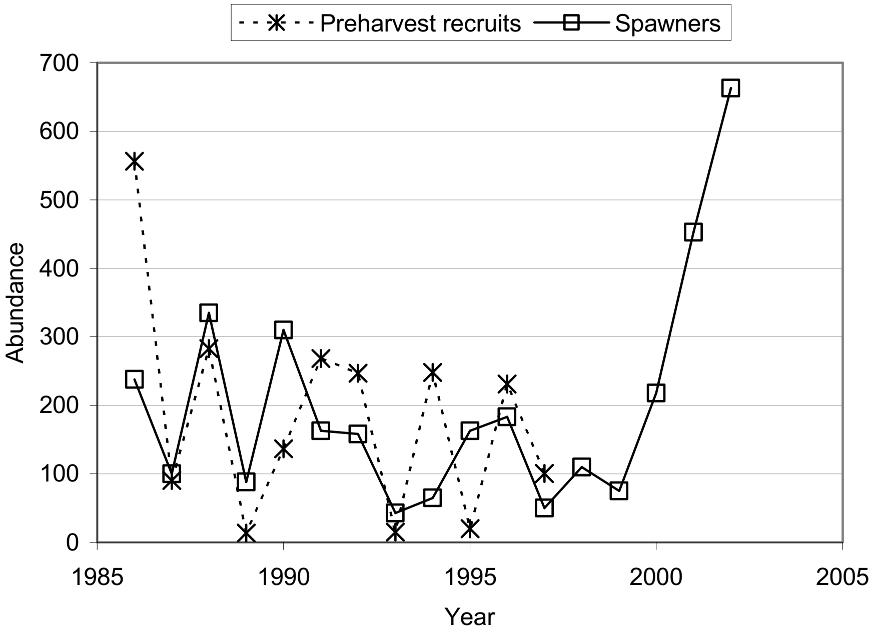

Figure 74. Preharvest recruits and spawners versus broodyear for the Dungeness River Chinook salmon population, 1986–2002.

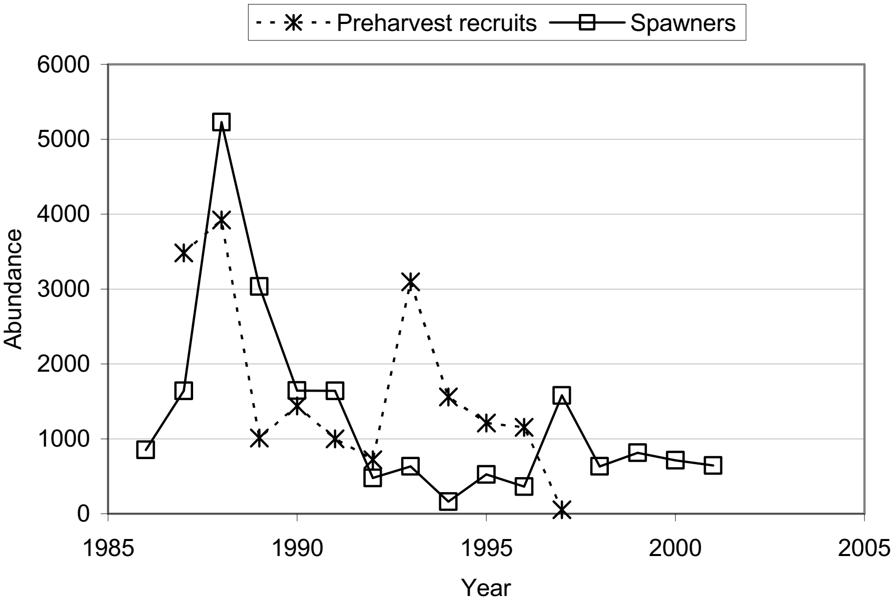

Figure 75. Preharvest recruits and spawners versus broodyear for the Elwha River Chinook salmon population, 1986–2001.

Updated Threats Information

The Puget Sound TRT has estimated adult equivalent exploitation rates for each population of Chinook salmon in the ESU (Table 11). Exploitation rates are the proportion of the returning population that are caught in fisheries or are killed as a result of fishing activities (e.g., nonretention mortality). These harvest estimates include mortality from sport and commercial fisheries in the ocean, Puget Sound, and in rivers. Exploitation rate estimates are a function of coded-wire tag recoveries, escapement estimates, and estimates of incidental mortalities provided by the Chinook Technical Committee of the Pacific Salmon Commission (PSC 2001a, 2001b). These harvest rates are equivalent to exploitation rates provided by the CTC, but they are different from exploitation rates estimated by the Fishery Regulation Assessment Model (FRAM).

Exploitation rates on Puget Sound Chinook salmon populations averaged 75% (median = 85%; range 31–92%) in the earliest 5 years of data availability and have dropped to an average of 44% (median = 45; range 26–63%) in the most recent 5-year period.

Table 11. Estimated broodyear adult-equivalent exploitation rates on populations of Puget Sound Chinook salmon.

Population	Data years (broodyear)	Earliest 5-year mean exploitation rate (%)	Most recent 5-year mean exploitation rate (%)
North Fork Nooksack	1982–1998	43	26
South Fork Nooksack	1982–1998	44	26
Lower Skagit*	1969–1998	86	61
Upper Skagit*	1969–1998	88	63
Upper Cascade*	1982–1998	80	56
Lower Sauk*	1969–1998	88	63
Upper Sauk*	1979–1998	72	56
Suiattle*	1979–1998	73	58
North Fork Stillaguamish	1972–1998	89	40
South Fork Stillaguamish	1972–1998	89	40
Skykomish	1969–1998	86	49
Snoqualmie	1969–1998	85	45
North Lake Washington	1981–1998	40	27
Cedar	1969–1998	52	31
Green	1969–1998	82	57
White	1972–1998	90	26
Puyallup	1971–1998	53	30
Nisqually	1977–1998	92	62
Skokomish	1985–1998	90	31
Dosewallips	1985–1998	92	38
Dungeness	1984–1998	31	32
Elwha	1984–1998	64	44

* The population-specific harvest rates for the Skagit River basin are in dispute; Puget Sound TRT, NOAA Fisheries Northwest Regional Office, and the Puget Sound comanagers are working to resolve different estimates resulting from the Pacific Salmon Commission (Chinook Technical Committee) and FRAM.

The Puget Sound TRT has amassed estimates of the total number of hatchery-origin Chinook salmon returning to streams (Table 12). For each population, these estimates include the total return—returns to natural spawning grounds and to hatchery racks within a population's

Table 12. Total estimated recent annual average returns of hatchery-produced Chinook salmon (adults returning to hatchery racks and to spawning grounds) and total releases of juvenile Chinook salmon in streams containing independent populations of Chinook salmon in Puget Sound. Sources: Puget Sound TRT (2002) and Waknitz (2002).

Population	Average annual return to stream 1987–2001 (minimum–maximum)[a]	Previous (1990–1994) average annual releases of Chinook salmon hatchery juveniles by life stage (in thousands)	Most recent (1995–2001) average annual releases of Chinook salmon hatchery juveniles by life stage (in thousands)
North Fork Nooksack	1,720 (0–9,179)	5,500 (4,763 fall; 737 spring/summer)	3,081 fall
South Fork Nooksack	1,254 (0–5,515)		
Lower Skagit	1,171 (70–4,110)	2,251 (1,292 fall; 491 spring, 468 summer)	754 (32 fall; 423 spring; 299 summer)
Upper Skagit			
Upper Cascade			
Lower Sauk			
Upper Sauk			
Suiattle			
North Fork Stillaguamish	318 (2–777)	NA	178 summer
South Fork Stillaguamish[b]	NA		
Skykomish	3,666 (824–8,530)	1,926 (1,316 fall; 610 summer)	2,574 (1,401 fall; 1,173 summer)
Snoqualmie	2,921 (19–6,514)		
North Lake Washington[b]	NA	2,349 fall	2,077 fall
Cedar	NA		
Green	13,565 (3,211–23,014)	4,413 fall	3,681 fall
White[b]	NA	1,686 (1,672 fall, 14 spring) 70 fall in south Sound general	1,695 (1,669 fall; 26 spring)
Puyallup[b]	2,048 (762–3,484)		
Nisqually[b]	2,559 (0–13,481)	NA	NA
Miscellaneous South Puget Sound streams	NA	6,947 fall	6,411 fall
Eastern Kitsap streams	NA	2,851 (2,519 fall; 332 spring)	3,771 (3,447 fall; 324 spring)
Skokomish[b]	3,621 (294–8,816)	4,928 (4,637 fall; 291 spring)	6,856 (6,793 fall; 63 spring)
Combined Dosewallips[b]	NA		
Dungeness[b]	NA	NA	1,283 spring
Elwha	634 (97–2,089)	1,831 fall	2,482 fall

[a] Hatchery rack-return data are not available for all streams.

[b] Estimates of hatchery-origin Chinook salmon returning to spawn are not available.

geographic boundaries. These estimates do not account for possible strays of hatchery fish from outside the population's boundaries. It is apparent from Table 12 that even populations of Chinook salmon in northern Puget Sound (not a hatchery production management area for comanagers) receive significant numbers of adult hatchery fish returning each year. The numbers of hatchery-origin juvenile Chinook salmon released into Puget Sound streams each year also are reported in Table 12. Average annual numbers of juvenile releases have declined since the time of the last status review (1990–1994 versus 1995–2001) in the Nooksack, Skagit, and Green river basins, and releases have remained roughly the same in the North Lake Washington/Cedar, White/Puyallup rivers, and south Puget Sound streams. In contrast, juvenile Chinook salmon releases have increased in the Snohomish and Elwha river basins, in eastern Kitsap Peninsula streams, and in Hood Canal. With the exception of the Skagit and Stillaguamish river basins, all major watersheds in Puget Sound receive annual releases of over a million (close to 7 million in Hood Canal) juvenile Chinook salmon. Hatchery stocks of Chinook salmon in Puget Sound have been categorized (SSHAG 2003) and are in Appendix A, Table A-1.

Comparison with Previous Data

Overall, the natural spawning escapement estimates for Puget Sound Chinook salmon populations are improved relative to those at the time of the previous status review of Puget Sound Chinook salmon conducted with data through 1997. The differences between population escapement estimates based on status assessments using data from 1997 and the present assessment using data through 2002 could be due to 1) revised pre-1997 data, 2) differences in which fish are counted as part of a population, 3) new information on the fraction of natural spawners that are hatchery fish, or 4) true differences reflected in new data on natural spawners obtained over the most recent 5 years. The median across populations of the most recent 5-year geometric mean of natural escapement for the same 22 populations through 1997 was $N = 438$ (compared to $N = 771$ through 2002), and the range was 1–5,400. As was the case at the time of the previous status review, it is not possible to determine the status of the natural-origin, natural spawners in half the populations of Chinook salmon in Puget Sound. The most dramatic change in recent natural escapement estimates from the previous status assessment was in the Green River—the recent natural-origin escapement estimate is lower than the previous one by almost 5,000 spawners. This apparent drop in natural escapement is probably due primarily to new information about the fraction of hatchery fish that are spawning naturally.

Throughout the ESU, the estimates of trends in natural spawning escapements for Puget Sound Chinook salmon populations are similar to the previous status review of Puget Sound Chinook salmon conducted with data through 1997. Some populations exhibit improvements in trends relative to the last status assessment, and others show more significant declines. As stated above for escapement estimates, the differences in trend estimates between the previous status assessments using data from 1997 and the present assessment using data through 2002 could be due to 1) revised pre-1997 data, 2) differences in which fish are counted as part of a population, 3) new information on the fraction of natural spawners that are hatchery fish, or 4) true differences reflected in new data on natural spawners obtained over the most recent 5 years. The median across populations of the long-term trend in natural spawners was a 1.1% decline per year through 1997, compared to a median estimate indicating a flat trend through 2002. Twelve populations had declining long-term trends through 1997, and 10 populations have declining long-term trends through 2002. Short-term trends are generally more positive in recent years—the median trend across 22 populations through 1997 was a 4% decline per year, and the median trend through 2002 was a 1.1% increase per year. Fourteen populations showed declining short-term trends at the time of the previous status reviews, and only four populations exhibit declining short-term trends in recent years. Nevertheless, as stated above for interpreting abundance estimates, we lack information on the fraction of naturally spawning, hatchery-origin fish for 10 of the 22 populations of Chinook salmon in Puget Sound, so our understanding of the trend in natural-origin spawners among populations across the ESU is incomplete. An illustration of how misleading trend estimates on total natural spawners can be for estimating trends in natural-origin spawners can be found comparing the λ calculations assuming naturally spawning hatchery fish do (i.e., λ – H1) or do not (i.e., λ – H0) contribute naturally spawning offspring. For those 12 populations with information on the hatchery fraction of natural spawners in the ESU, 7 populations switched from an estimated positive short-term population growth rate to a negative rate when hatchery fish were assumed to contribute naturally spawning offspring.

The spatial distribution of Chinook salmon populations with a strong component of natural-origin spawners in the Puget Sound ESU has not changed since the last status assessment. Populations containing significant numbers of natural-origin spawners whose status can be reliably estimated occur in the Skagit River basin, the South Fork Stillaguamish, and the Snohomish River basin. The remaining populations in mid- and south Puget Sound, Hood Canal, and the Strait of Juan de Fuca have significant (but nonquantifiable) fractions of hatchery-origin spawners, so their contribution to spatial structure in the ESU is not possible to estimate.

The change in diversity in the ESU from historical conditions also has not changed since the last status review. An estimated 31 independent populations of Chinook salmon occurred historically in the ESU, and 22 remain extant. All but one of the nine putatively extinct Chinook salmon stocks is an early run population (or component of a population). The loss of early run Chinook salmon stocks in Puget Sound represents an important loss of part of the evolutionary legacy of the historical ESU.

8. Lower Columbia River Chinook Salmon ESU

Summary of Previous BRT Conclusions

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

Listing status: Threatened.

New Data and Updated Analyses

New data acquired for this report includes spawner abundance estimates through 2001, new estimates of the fraction of hatchery spawners, and harvest estimates. In addition, WDFW provided estimates of historical abundance. Information on recent hatchery releases was also obtained. New analyses include the designation of relatively demographically independent populations, recalculation of previous BRT metrics with additional years of data, estimates of median annual growth rate (λ) under different assumptions about the reproductive success of hatchery fish, and estimates of current and historically available kilometers of streams.

Historical Population Structure

As part of its effort to develop viability criteria for Lower Columbia River ESU Chinook salmon, the Willamette/Lower Columbia Technical Recovery Team (WLC-TRT) has identified historically demographically independent populations (Myers et al. 2002). Population boundaries are based on an application of VSPs defined in McElhany et al. (2000). Myers et al.

hypothesized that the ESU historically consisted of 20 fall-run populations (tules), 2 late-fall-run populations (brights), and 9 spring-run populations for a total of 31 populations (Figures 76 and 77). The populations identified in Myers et al. 2002 are used as the units for the new analyses in this report.

The WLC-TRT partitioned Lower Columbia River ESU Chinook salmon populations into a number of strata based on major life history characteristics and ecological zones (McElhany et al. 2003). The WLC-TRT concluded that a viable ESU would need multiple viable populations in each strata. The strata and associated populations are identified in Table 13.

Abundance and Trends

Data sources for abundance time series and related data are in Appendix A, Table A-2. The recent abundance of both total and natural-origin spawners, and recent fraction of hatchery-origin spawners, for Lower Columbia River ESU Chinook salmon populations are summarized

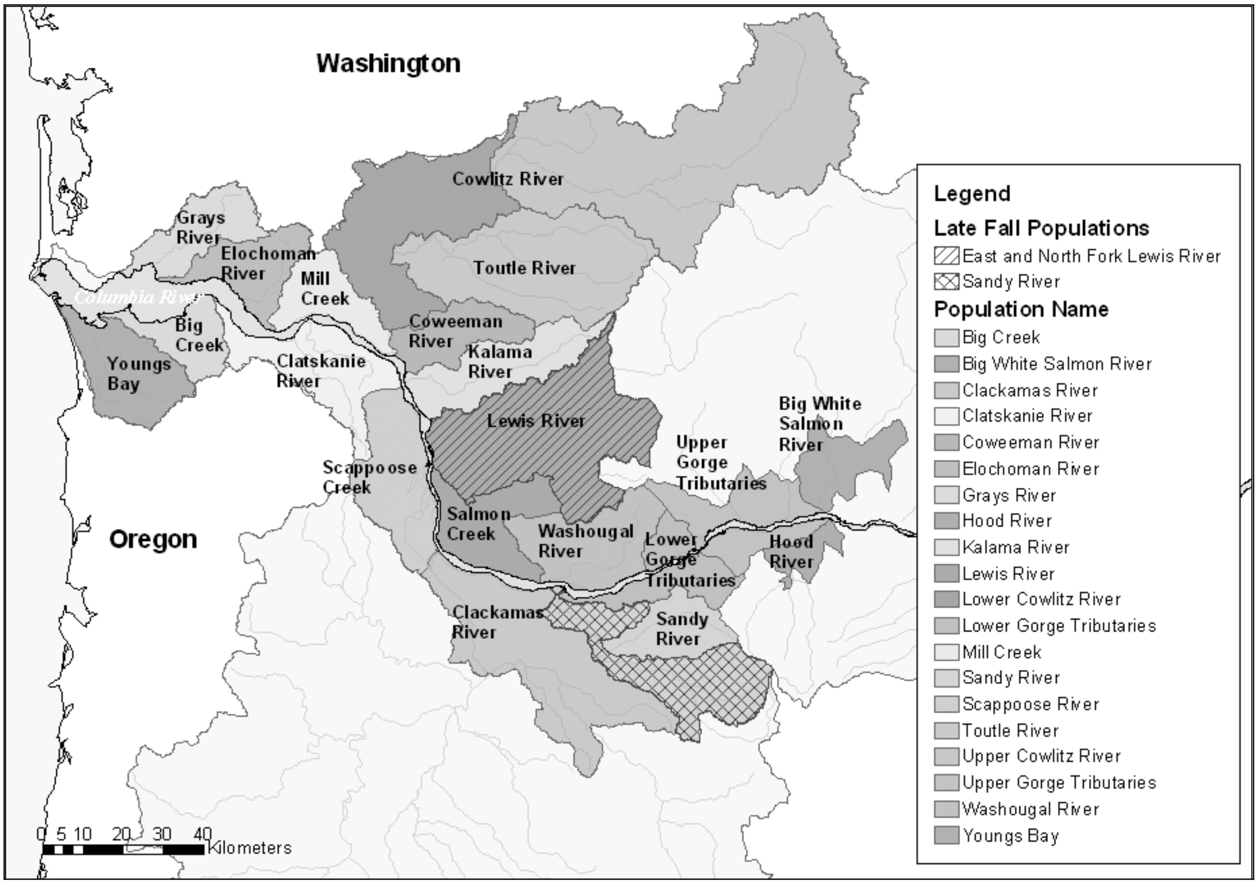

Figure 76. Historical independent Lower Columbia River ESU early and late-fall-run Chinook salmon populations. Source: Myers et al. (2002).

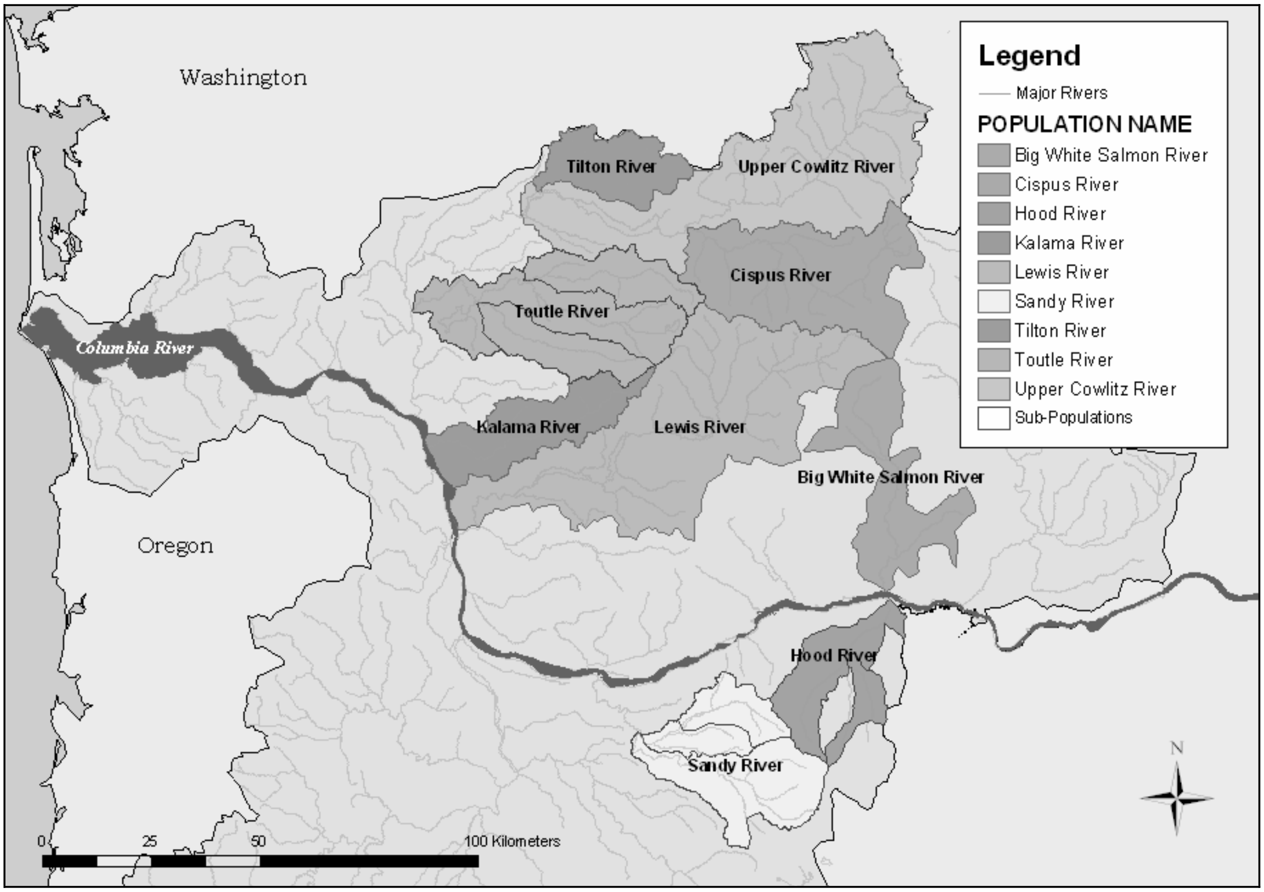

Figure 77. Historical, independent, Lower Columbia River ESU spring-run Chinook salmon populations. Source: Myers et al. (2002).

in Table 13. Natural-origin fish had parents that spawned in the wild, as opposed to hatchery-origin fish, whose parents were spawned in a hatchery. The abundances of natural-origin spawners range from near extirpation for most of the spring-run populations to over 7,841 for the Lewis River bright population. The majority of the fall-run tule populations have a substantial fraction of hatchery-origin spawners in the spawning areas and may be sustained largely by hatchery production. Exceptions are the Coweeman population and the East Fork Lewis portion of the Lewis River/Salmon Creek population, which have few hatchery fish spawning on the natural spawning areas. These two populations have recent geometric mean natural-origin abundance estimates of 274 and 256 spawners respectively. Although quantitative information is not yet available, preliminary examination of scales indicates that almost all current spring-run spawners in the Washington part of this ESU are of hatchery origin.[8] The majority of the spring-run populations have been extirpated, largely as the result of dams blocking access to their high-elevation habitat. The two bright Chinook populations (i.e., Lewis and Sandy) have relatively high abundances, particularly the Lewis.

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[8] D. Rawding, Washington Department of Fish and Wildlife, Vancouver, WA. Pers. commun., 18 March 2003.

Table 13. Historical population structure and abundance statistics for Lower Columbia ESU Chinook salmon populations, by life history and ecological zone.

			Total spawners		**Natural-origin spawners**		
Life history[a] ecological zone[b]	**Population**	**Years for recent means[c]**	**Recent geometric mean**	**Recent arithmetic mean**	**Recent geometric mean**	**Recent arithmetic mean**	**Recent average hatchery-origin[d] spawners (%)**
Fall run							
Coastal	Youngs Bay			No data			
	Grays River	1997–2001	99	152	59	89	38
	Big Creek			No data			
	Elochoman River	1997–2001	676	1,074	186	289	68
	Clatskanie River			No data			
	Mill, Abernathy, Germany creeks	1997–2001	734	1,197	362	626	47
	Scappoose Creek			No data			
Cascade	Coweeman River	1997–2001	274	469	274	469	0
	Lower Cowlitz River	1996–2000	1,562	1,626	463	634	62
	Upper Cowlitz River	2001		5,682			No data (assumed high)
	Toutle River			No data			
	Kalama River	1997–2001	2,931	3,138	655	1,214	67
	Salmon Creek/Lewis River	1997–2001 (East Fork data only	256	294	256	294	0
	Clackamas River	1998–2001	40	56		No data	
	Washougal River	1997–2001	3,254	3,364	1,130	1,277	58
	Sandy River	1997–2001	183	216		No data	
Columbia Gorge	Lower gorge tributaries			No data			
	Upper gorge tributaries	1997–2001 (Wind River data only)	136	216	109	198	13
	Hood River	1994–1998	18	21		No data	
	Big White Salmon River	1997–2001	334	602	218	462	21

Table 13 continued. Historical population structure and abundance statistics for Lower Columbia ESU Chinook salmon populations, by life history and ecological zone.

Life history[a] ecological zone[b]	Population	Years for recent means[c]	Total spawners Recent geometric mean	Total spawners Recent arithmetic mean	Natural-origin spawners Recent geometric mean	Natural-origin spawners Recent arithmetic mean	Recent average hatchery-origin[d] spawners (%)
Late fall (bright)							
Cascade	Sandy River	1997–2001	504	773	778	750	3
	North Fork Lewis River	1997–2001	7,841	8,834	6,818	7,828	13
Spring run							
Cascade	Upper Cowlitz River						
	Cispus River	2001		1,787		No data	
	Tilton River						
	Toutle River	No data					
	Kalama River	1997–2001	98	185		No data	
	Lewis River	1997–2001	347	363		No data	
	Sandy River	No data					
Columbia Gorge	Big White Salmon River	No data (no fish?)					
	Hood River	1994–1998	51	61		No data	

[a] Life history types are based on traits related to run timing.

[b] Ecological zones are based on ecological community and hydrodynamic patterns.

[c] Time series used for the summary statistics are referenced in Appendix A, Table A-2.

[d] Natural-origin spawners had parents that spawned in the wild, as opposed to hatchery-origin fish, whose parents were spawned in a hatchery.

Access to the habitat of the historical upper Cowlitz, Cispus, and Tilton populations is blocked by the Mayfield, Mossy Rock, and Cowlitz Falls dams. A relatively large number of both spring- and fall-run Chinook salmon are currently released as part of a reintroduction program to establish Chinook above Cowlitz Falls Dam (Serl and Morrill 2002). The adults for the reintroduction program are collected at the Cowlitz Salmon Hatchery, and the vast majority of the Chinook trucked above Cowlitz Falls are believed to be of hatchery origin, though marking of hatchery fish is not complete and a quantitative assessment has not been undertaken. Downstream survival of juvenile Chinook through the dams and reservoirs is considered negligible, so juveniles are collected at Cowlitz Falls and trucked downstream. The current collection efficiency of juveniles at Cowlitz Falls is considered too low for the reintroduction to be self-sustaining.[9]

Where data are available, the abundance time-series information for each population is presented in Figures 78–105. Three types of time-series figures are presented. The first type plots abundance against time (Figures 78–81, 83, 85, 87, 89, 91, 93, 95–97, and 99–102). Where possible, two lines are presented on the abundance figure: one line is the estimated total number

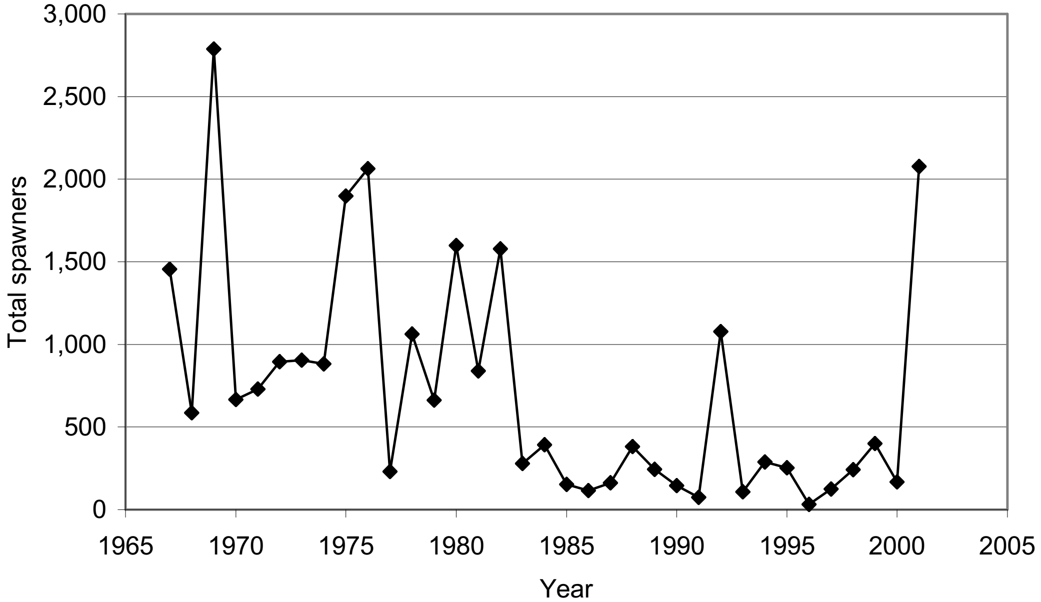

Figure 78. Big White Salmon River fall-run Chinook salmon total spawner abundance (hatchery and natural origin), 1967–2001.

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[9] D. Rawding, Washington Department of Fish and Wildlife, Vancouver, WA. Pers. commun., 28 March 2003.

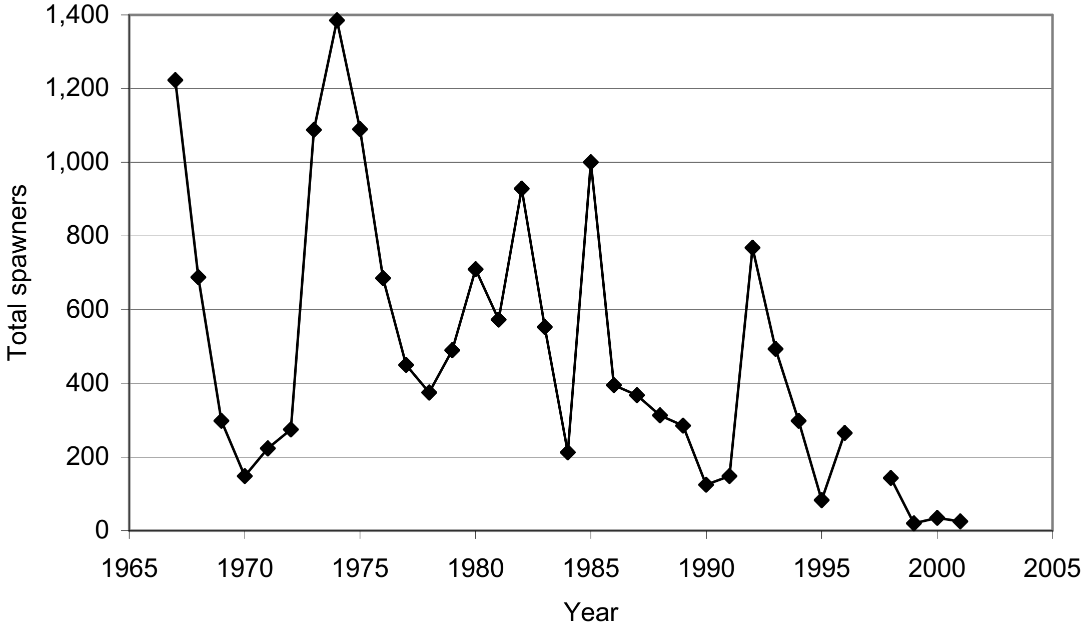

Figure 79. Clackamas River fall-run Chinook salmon total spawner abundance (hatchery and natural origin), 1967–2001.

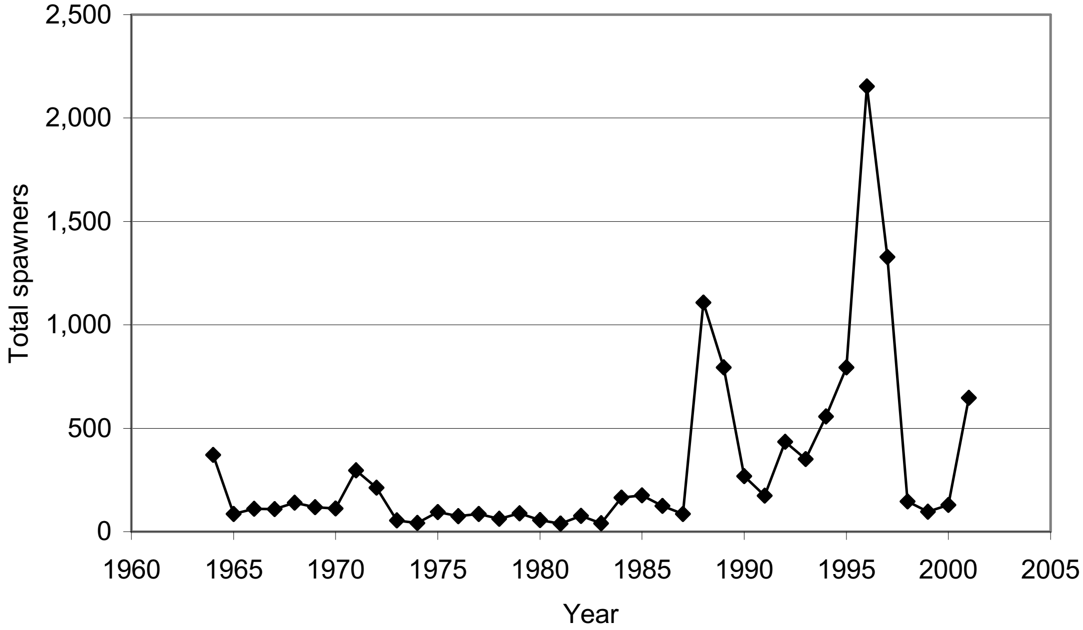

Figure 80. Coweeman River fall-run Chinook salmon total spawner abundance (almost all spawners are of natural origin), 1964–2001.

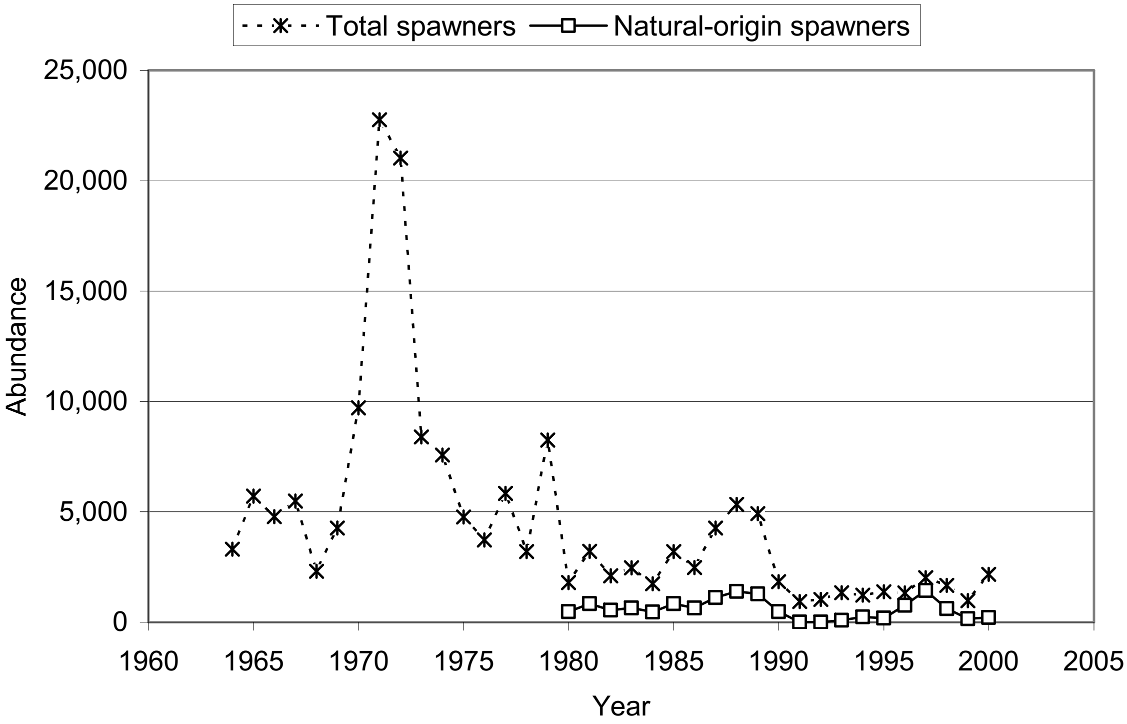

Figure 81. Lower Cowlitz River fall-run Chinook salmon spawner abundance, 1964–2000.

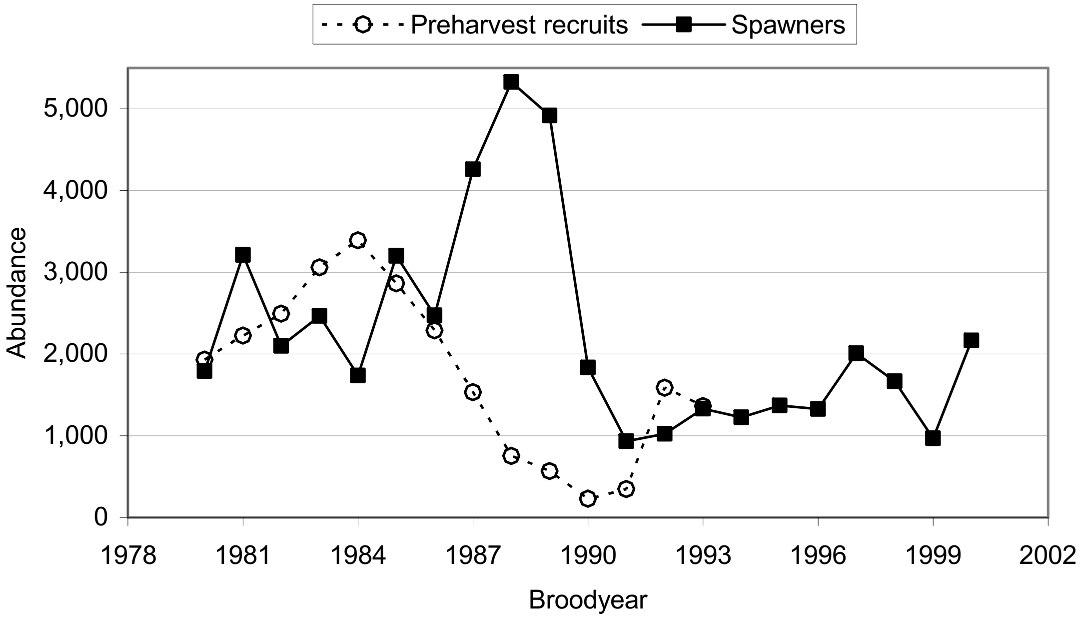

Figure 82. Estimate of fall-run Chinook preharvest recruits and spawners in the Cowlitz River, 1980–2001.

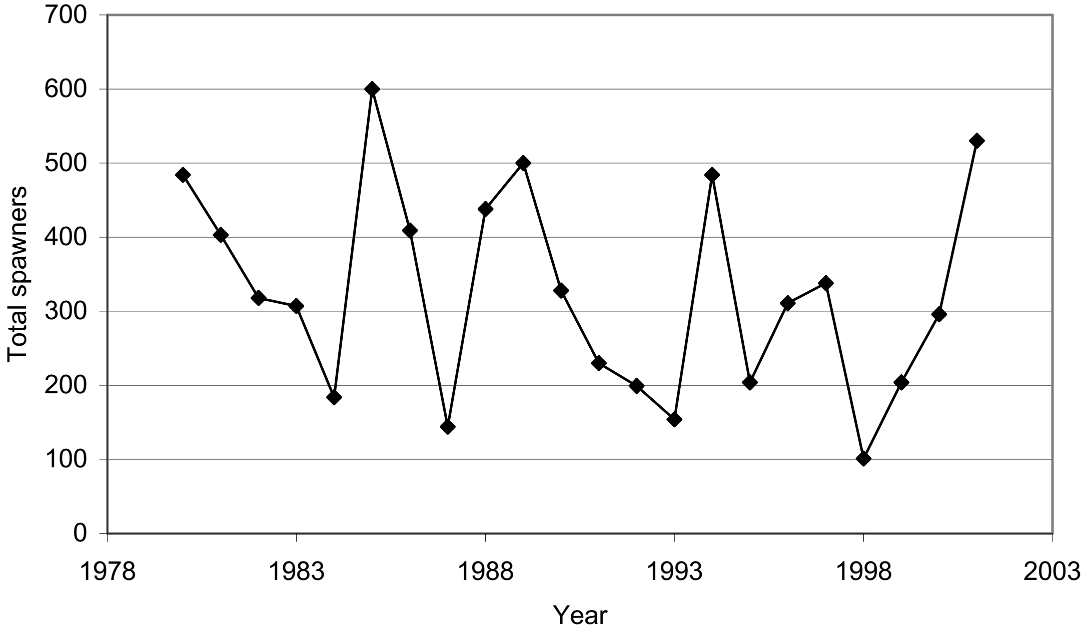

Figure 83. East Fork Lewis River fall-run Chinook salmon total spawner abundance (almost all spawners are of natural origin), 1980–2001.

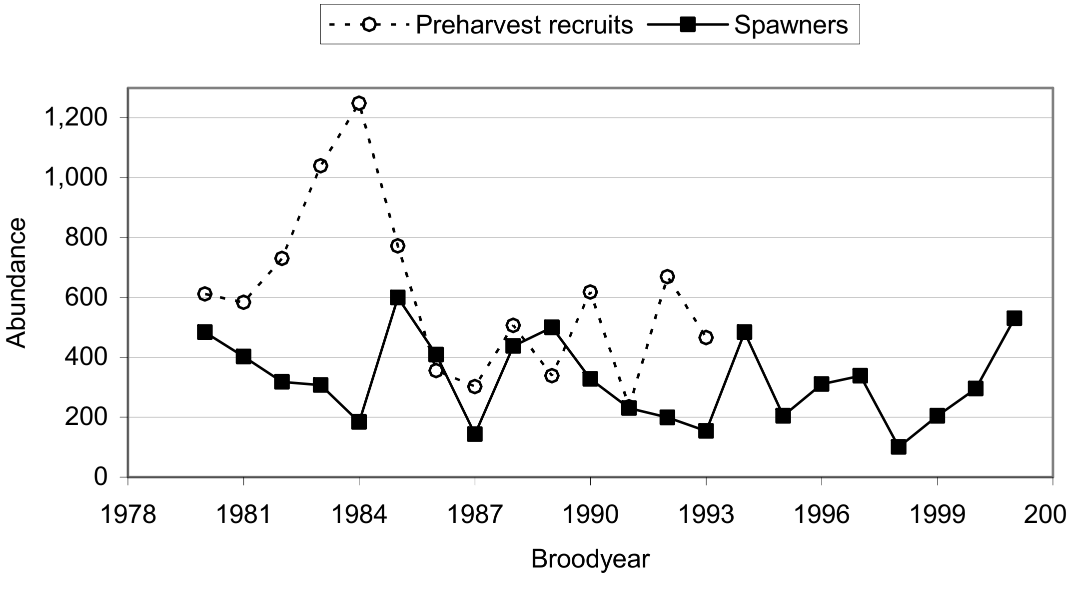

Figure 84. Estimate of fall-run Chinook salmon spawner abundance preharvest recruits and spawners in the East Fork Lewis River, 1980–2001.

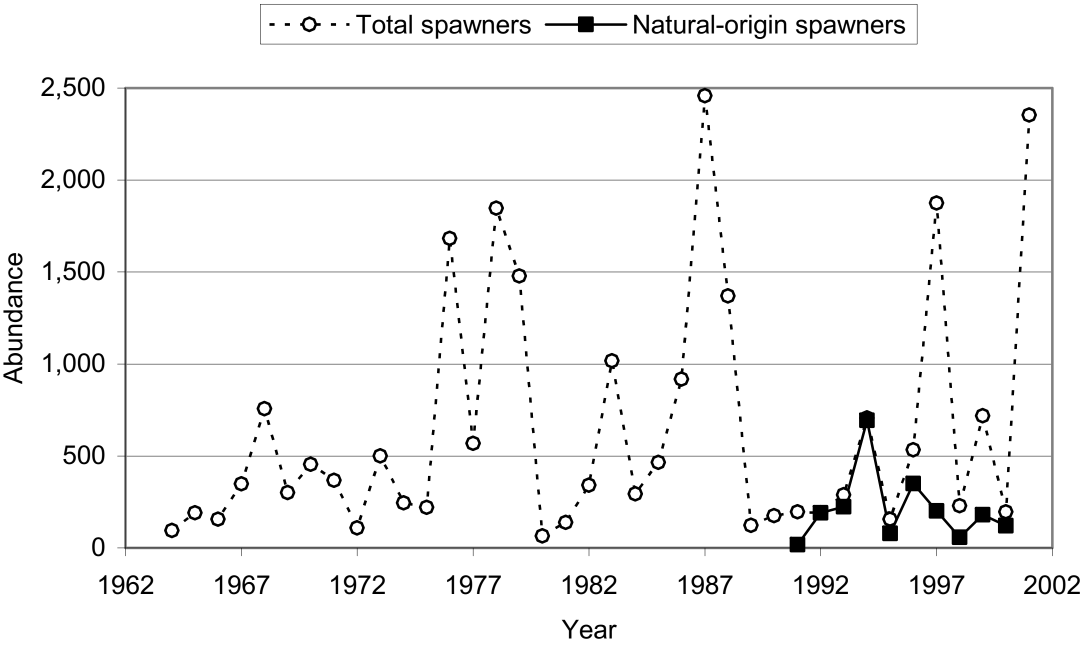

Figure 85. Elochoman River fall-run Chinook salmon spawner abundance, 1964–2001.

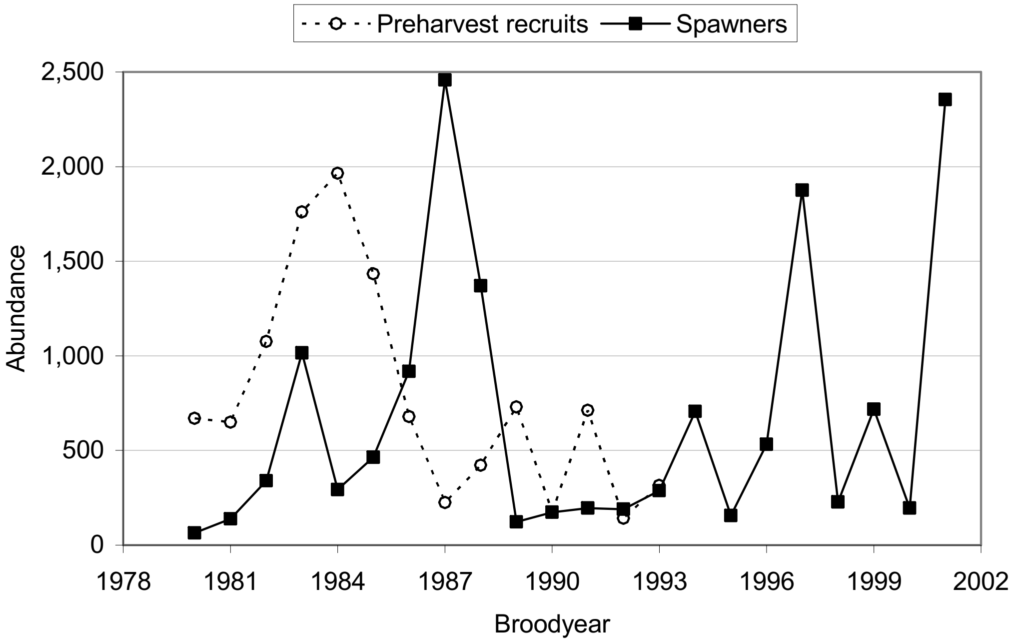

Figure 86. Estimate of fall-run Chinook salmon preharvest recruits and spawners in the Elochoman River, 1980–2001.

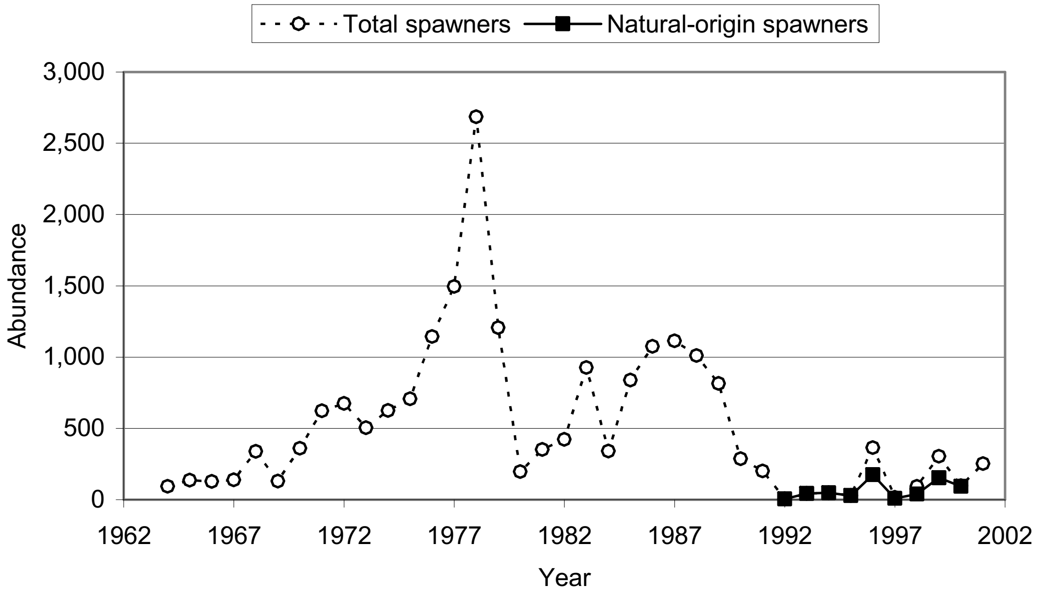

Figure 87. Grays River fall-run Chinook salmon spawner abundance, 1964–2001.

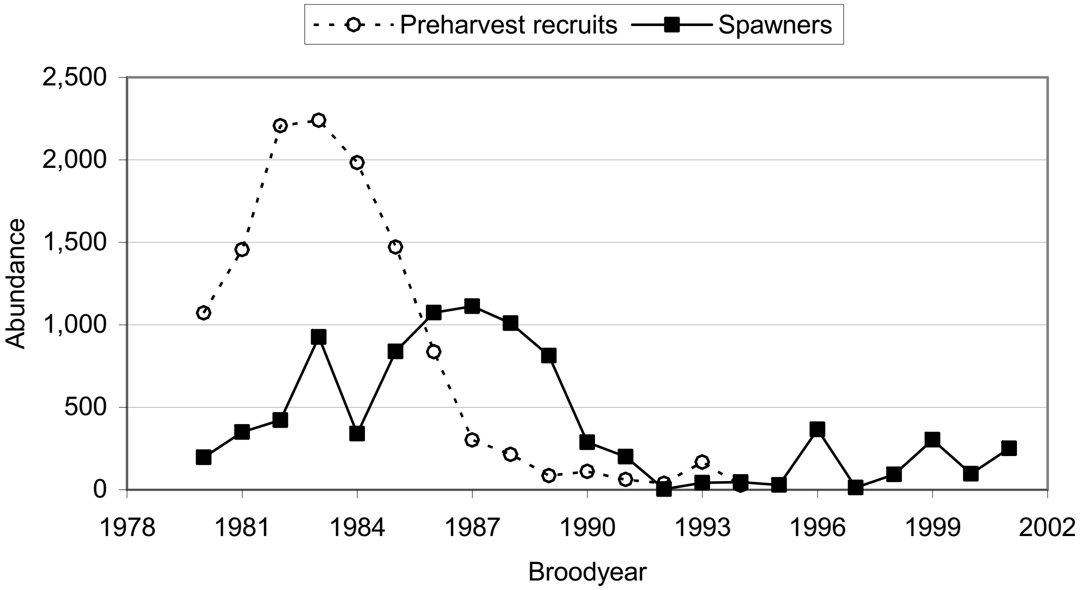

Figure 88. Estimate of Grays River fall-run Chinook salmon preharvest recruits and spawners, 1980–2001.

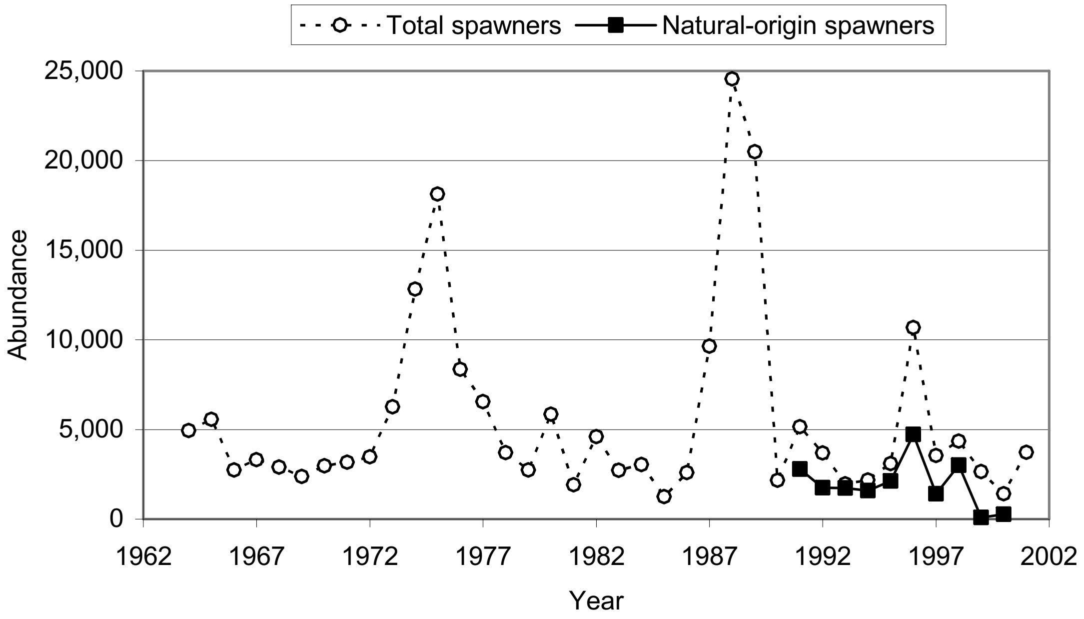

Figure 89. Kalama River fall-run Chinook salmon spawner abundance, 1964–2001.

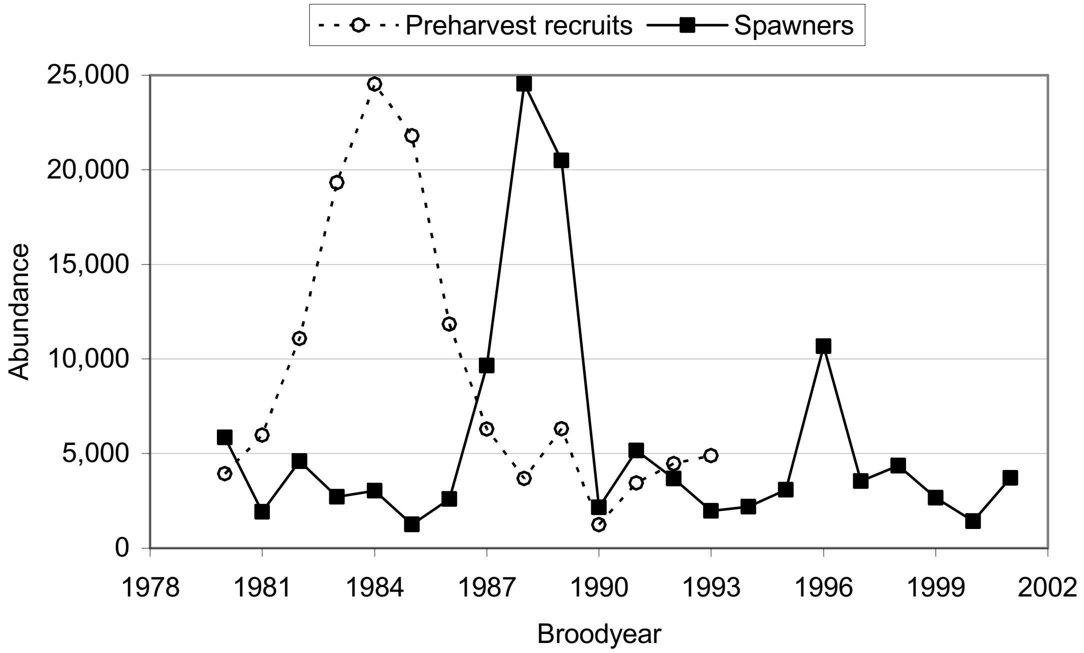

Figure 90. Estimate of Kalama River fall-run Chinook salmon preharvest recruits and spawners, 1980–2001.

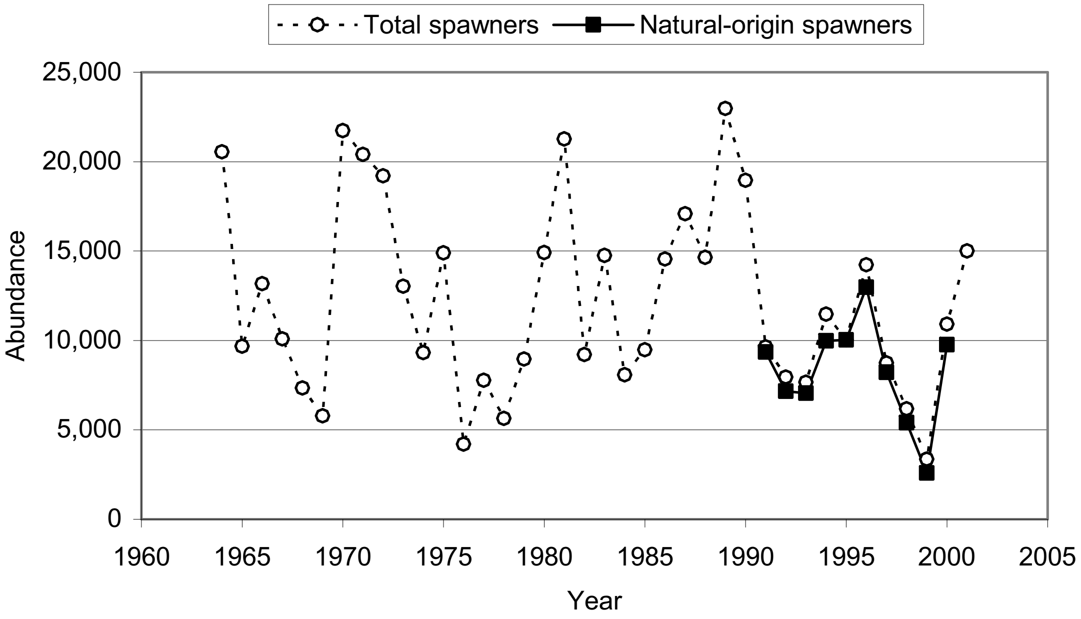

Figure 91. Lewis River late-fall-run (bright) Chinook salmon spawner abundance, 1964–2001.

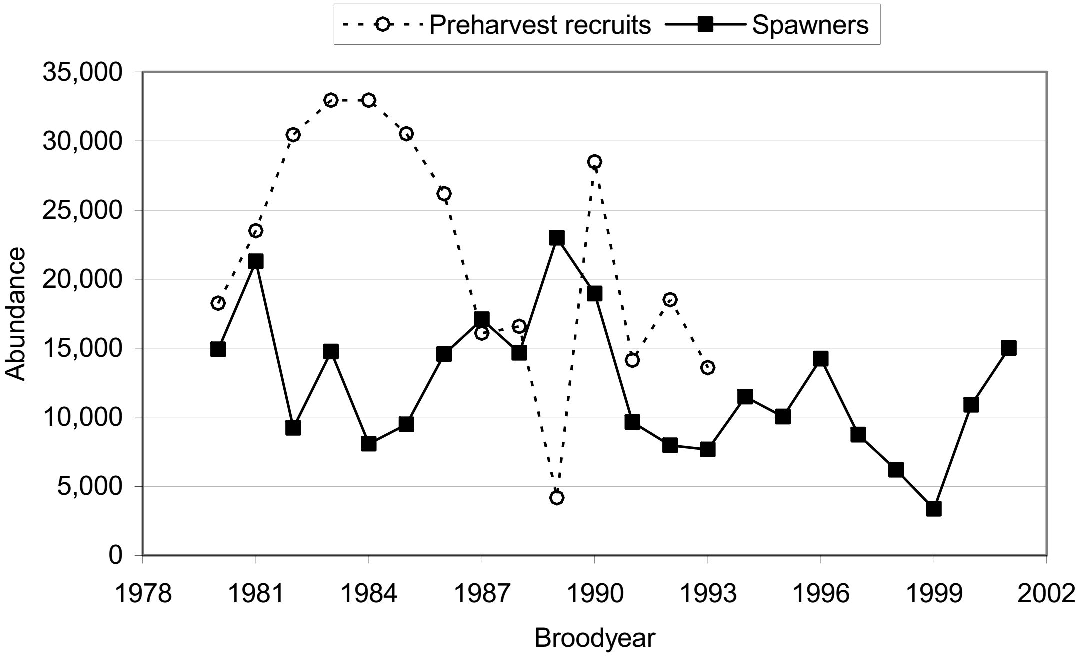

Figure 92. Estimate of Lewis River late-fall-run (bright) Chinook salmon preharvest recruits and spawners, 1980–2001.

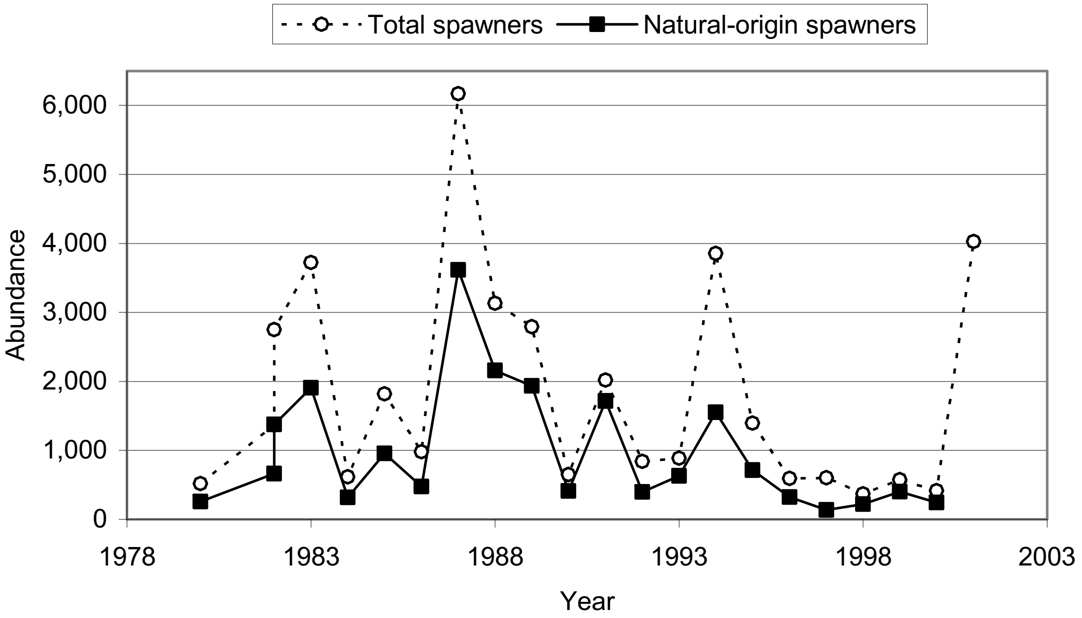

Figure 93. Mill, Germany, and Abernathy creeks fall-run Chinook salmon spawner abundance, 1980–2001.

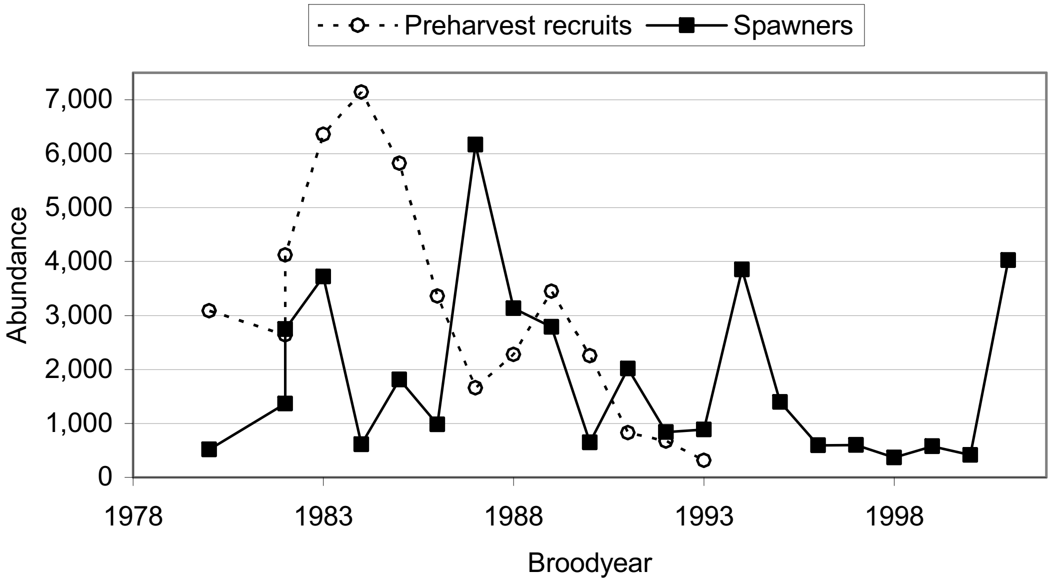

Figure 94. Estimate of Mill, Germany, and Abernathy creeks fall-run Chinook salmon preharvest recruits and spawners, 1980–2001.

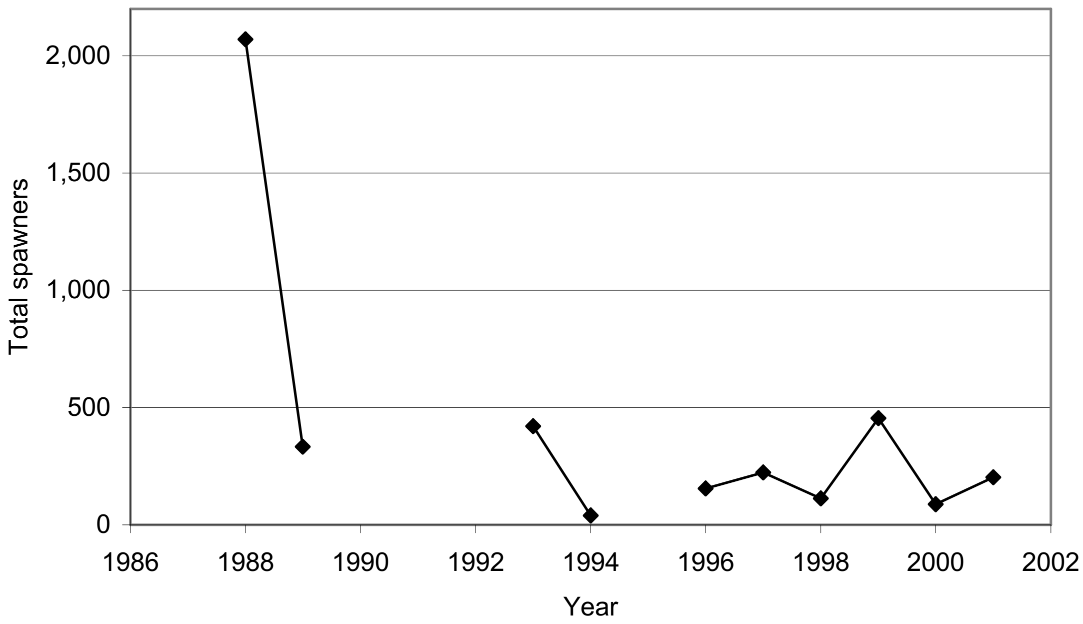

Figure 95. Sandy River fall-run Chinook salmon spawner abundance, 1988–2001.

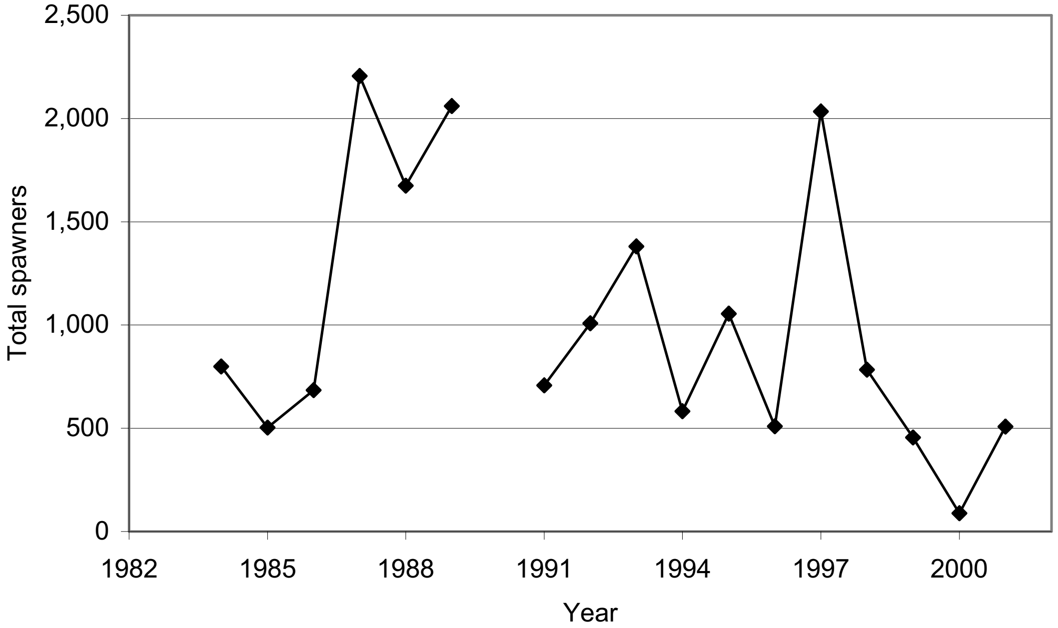

Figure 96. Sandy River late-fall-run (bright) Chinook salmon spawner abundance, 1984–2001.

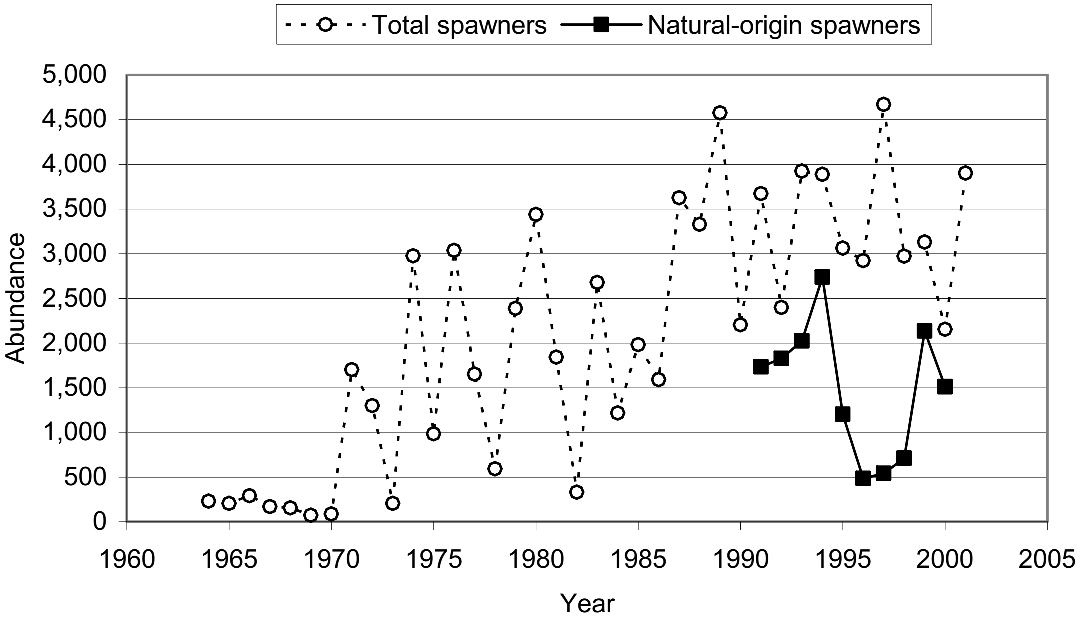

Figure 97. Washougal River fall-run Chinook salmon spawner abundance, 1964–2001.

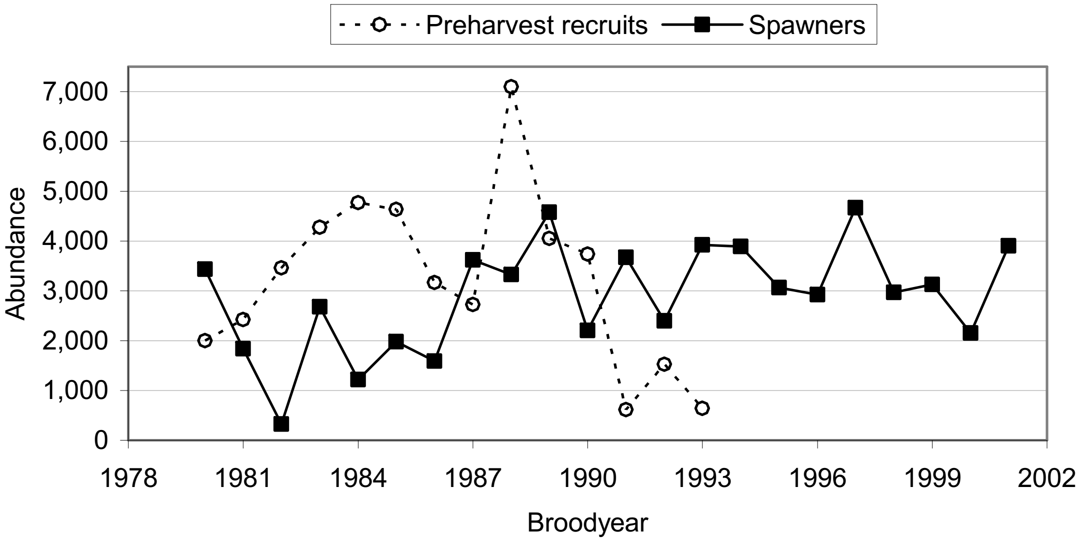

Figure 98. Estimate of Washougal River fall-run Chinook salmon preharvest recruits and spawners 1980–2001.

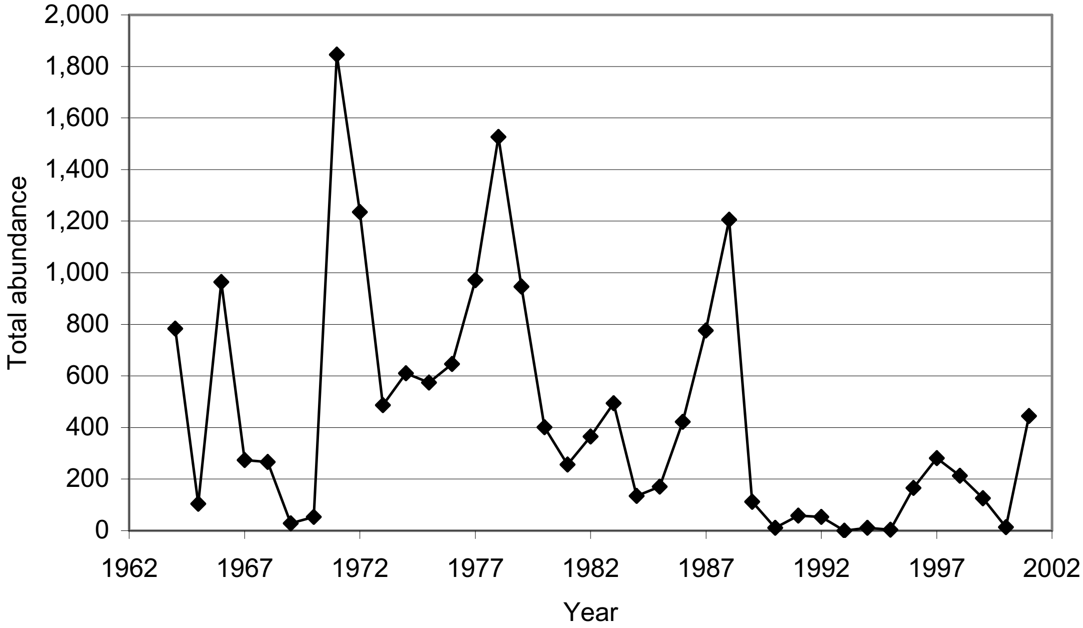

Figure 99. Wind River fall-run Chinook salmon total spawner abundance (hatchery and natural origin), 1964–2001.

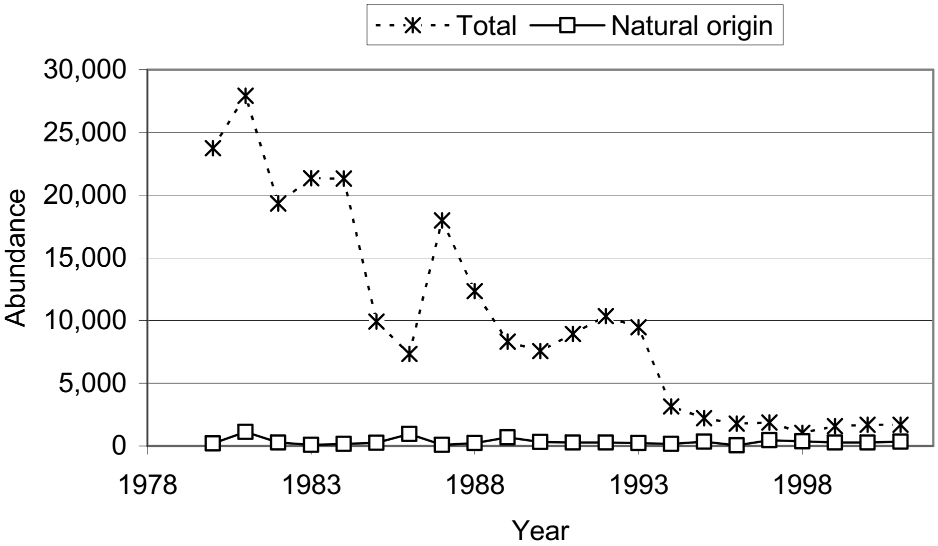

Figure 100. Cowlitz River spring-run Chinook salmon total spawner abundance below Mayfield Dam (the majority of spawners are of hatchery origin), 1980–2001.

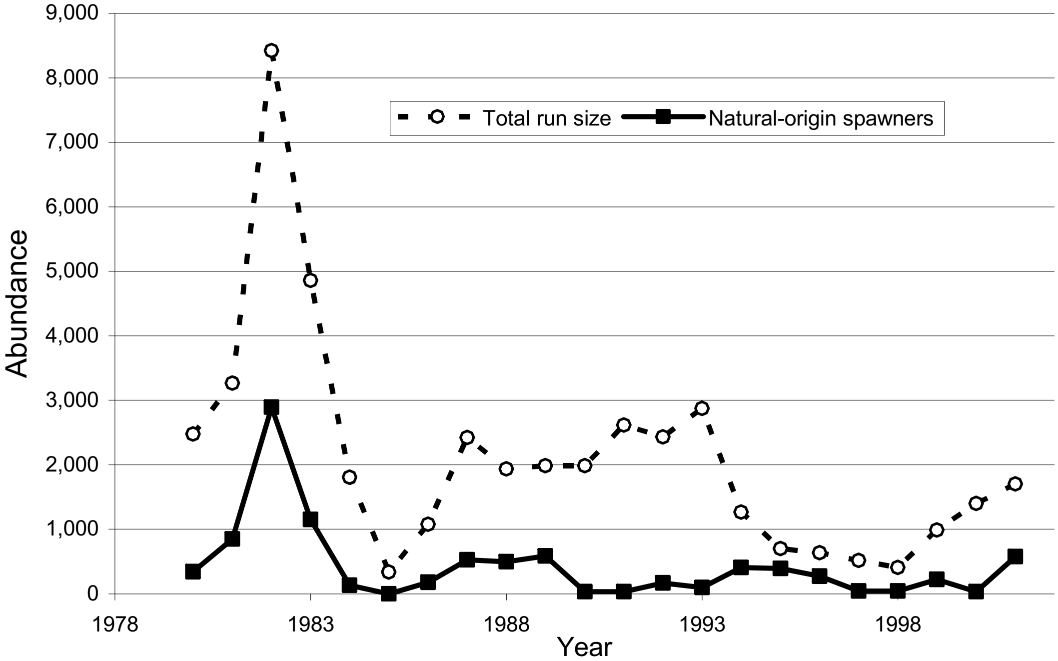

Figure 101. Kalama River spring-run Chinook salmon total spawners (the majority of spawners are of hatchery origin), 1980–2001.

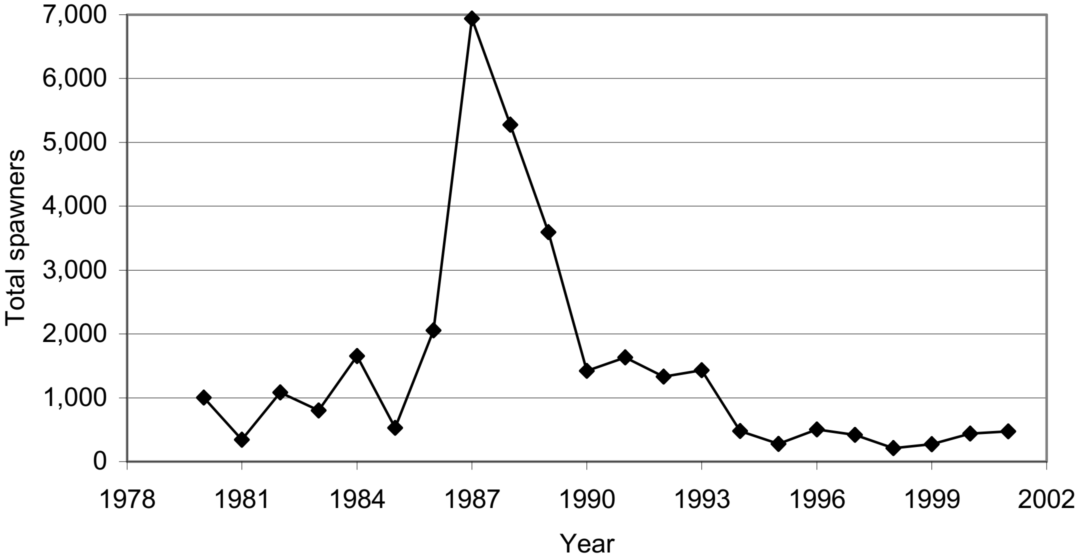

Figure 102. Lewis River spring-run Chinook salmon total spawner abundance below Merwin Dam (the majority of spawners are of hatchery origin), 1980–2001.

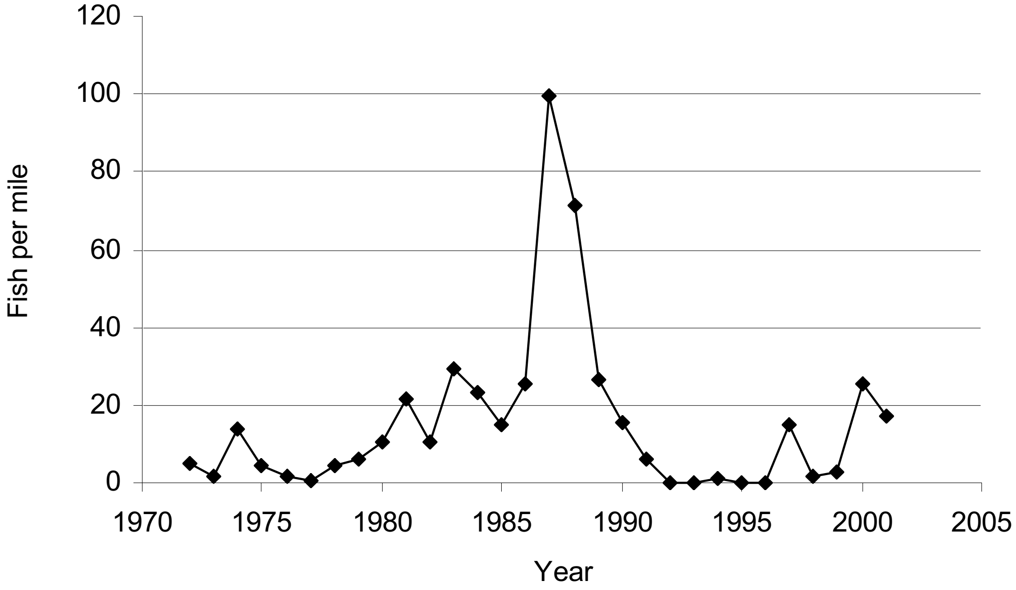

Figure 103. Youngs Bay Chinook salmon per mile, 1972–2001.

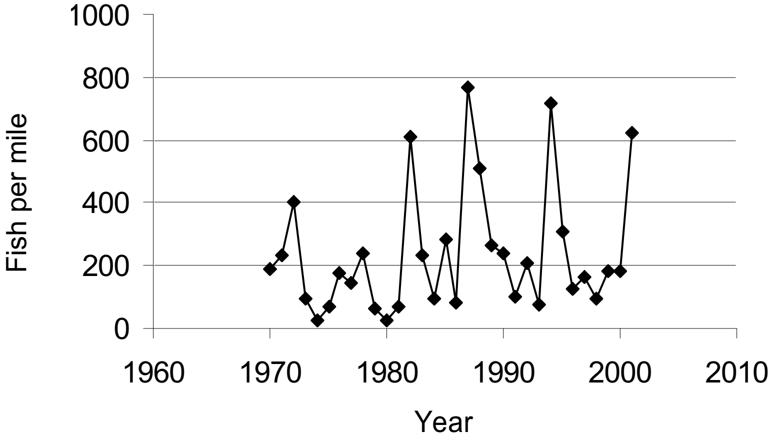

Figure 104. Big Creek Chinook salmon per mile, 1970–2001.

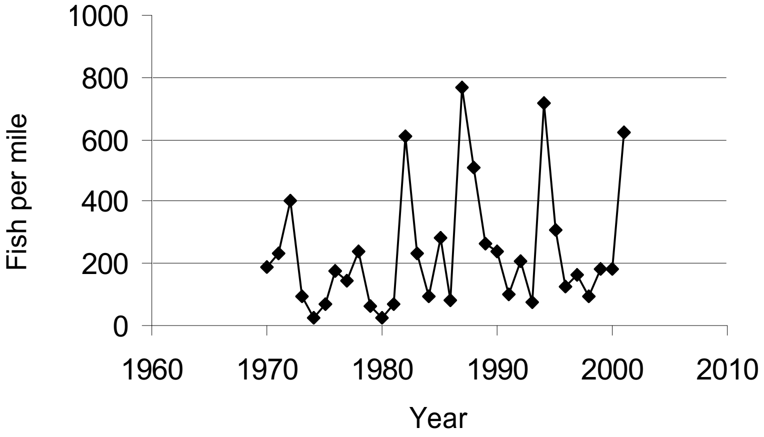

Figure 105. Clatskanie River Chinook salmon per mile, 1970–2001.

of spawners, the other is the estimated number of fish of natural origin. In many cases, data were not available to distinguish between natural- and hatchery-origin spawners, so only total spawner information is presented. This type of figure can give a sense of the abundance levels, overall trend, variability patterns, and fraction of hatchery-origin spawners. A high fraction of hatchery-origin spawners indicates that the population may potentially be sustained by hatchery production, not the natural environment. It is important to note that estimates of fraction of hatchery-origin fish are highly uncertain because the hatchery marking rate for Lower Columbia River ESU fall-run Chinook salmon is generally only a few percent, and expansion to population hatchery fraction is based on only a handful of recovered marked fish (WLC-TNT 2002).[10]

The second type of time series figure displays fish-per-mile data. For three fall-run Chinook populations in Oregon watersheds, total abundance estimates are not available, but a fish-per-mile time series exists (Figures 103–105). There are no estimates of the fraction of hatchery-origin spawners in these fish-per-mile time series, but the percentage may be high given the large number of hatchery fish released and the high fraction of hatchery-origin spawners estimated in Washington watersheds, directly across the Columbia River. The lack of information on hatchery fraction reduces the value of these time series for evaluating extinction risk.

The third type of time-series figure presents the total number of spawners (natural and hatchery origin) and the estimated number of preharvest recruits produced by those spawners against time (Figures 82, 84, 86, 88, 90, 92, and 94). Dividing the number of preharvest recruits by the number of spawners for the same time period would yield an estimate of the preharvest recruits per spawner for the broodyear. Spawners are taken as the sum of hatchery- and natural-origin spawners. This type of figure requires harvest and age structure information and therefore could be produced for only a limited number of populations. This type of figure can indicate whether preharvest recruitment has changed and the degree to which harvest management has

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[10] P. McElhany, NMFS, Northwest Fisheries Science Center, Seattle, WA.

the potential to recover populations. If the preharvest recruitment line is consistently below the spawner line, the population would not be replacing itself, even in the absence of all harvest.

Summary statistics on population trends and growth rate are presented in Tables 14–16. The methods for estimating trends and growth rate (λ) are described in Section 2, Methods. Trends are calculated on total spawners, both hatchery and natural origin. The λ estimate is calculated using two different assumptions about the reproductive success of hatchery-origin spawners. In one analysis, hatchery-origin spawners are assumed to have zero reproductive success; in the other analysis, hatchery-origin spawners are assumed to have a reproductive success equal to that of natural-origin spawners. Because λ is only calculated for time series for which the fraction of hatchery-origin spawners is known, most of the long-term trend estimates use data dating from 1980, even though the abundance time series of total spawners may extend earlier than 1980. The majority of populations have a long-term trend of less than 1, indicating the population is in decline. In addition, for most populations there is a high probability that the true trend/growth rate is less than 1 (Table 16). However, in general there is a great deal of uncertainty about the growth rate, as the large confidence intervals indicate. The uncertainty about growth rate is generally higher for Chinook salmon than for other lower Columbia River anadromous salmonids because of the high variability observed in the time series. Assuming that hatchery-origin fish have a reproductive success equal to natural-origin fish, analysis indicates a negative long-term growth rate for all of the populations except the Coweeman River fall run. The Coweeman fall run had very few hatchery-origin spawners (Table 14). Potential reasons for these declines were cataloged in previous status reviews: they include habitat degradation, overharvest, deleterious hatchery practices, and climate-driven changes in marine survival.

The Lewis River bright population is considered the healthiest in the ESU. The population is significantly larger than any other population in the ESU; in fact, it is larger than any salmon population in the Columbia River basin except for Hanford Reach Chinook. The Lewis bright Chinook harvest has been managed to an escapement target of 5,700, which has been met every year for which data are available except 1999 (Figure 91). The preharvest recruits exceeded spawners in all years for which data are available except two (Figure 92). There has been a hatchery program for Lewis River brights, but hatchery-origin spawners have generally comprised less than 10% of the spawning population over the time series. These indicators all suggest a relatively healthy population. However, the long-term population trend estimate is negative (Table 14), and it is not clear the extent to which this reflects management decisions to harvest closer to the escapement goal, as compared to declining productivity over the time series. The population is also geographically confined to a reach that is only a few kilometers long and located immediately below Merwin Dam, where it is affected by the flow management of the hydrosystem. This limited spatial distribution is a potential risk factor.

Table 14. Long-term trend and growth rate for a subset of Lower Columbia River ESU Chinook salmon populations for which adequate data are available (95% confidence intervals are in parentheses).

Run population	Years for long-term trend[a]	Long-term trend of total spawners[b]	Years for long-term λ[c]	Long-term median growth rate (λ)	
				Hatchery = 0[d]	**Hatchery = wild[e]**
Fall run					
Grays River	1964–2001	0.965 (0.928–1.003)	1980–2001	0.944 (0.739–1.204)	0.844 (0.660–1.081)
Elochoman River	1964–2001	1.019 (0.990–1.048)	1980–2001	1.037 (0.813–1.323)	0.800 (0.625–1.024)
Mill, Abernathy, Germany creeks	1980–2001	0.965 (0.909–1.024)	1980–2001	0.981 (0.769–1.252)	0.829 (0.648–1.006)
Coweeman River	1964–2001	1.046 (1.018–1.075)	1980–2001	1.092 (0.855–1.393)	1.091 (0.852–1.396)
Lower Cowlitz River	1964–2000	0.951 (0.933–0.968)	1980–2000	0.998 (0.776–1.282)	0.682 (0.529–0.879)
Kalama River	1964–2001	0.994 (0.973–1.016)	1980–2001	0.973 (0.763–1.242)	0.818 (0.639–1.048)
Salmon Creek/Lewis River	1980–2001	0.981 (0.949–1.014)	1980–2001	0.984 (0.771–1.256)	0.979 (0.765–1.254)
Clackamas River	1967–2001	0.937 (0.910–0.965)	No hatchery fraction data		
Washougal River	1964–2001	1.088 (1.002–1.115)	1980–2001	1.025 (0.803–1.308)	0.815 (0.637–1.045)
Upper gorge tributaries	1964–2001 (Wind only)	0.935 (0.892–0.979)	1980–2001	0.959 (0.751–1.224)	0.955 (0.746–1.223)
Big White Salmon River	1967–2001	0.941 (0.912–0.971)	1980–2001	0.963 (0.755–1.229)	0.945 (0.738–1.210)
Late-fall run (brights)					
Sandy River	1984–2001	0.946 (0.880–1.014)	1984–2001	0.943 (0.715–1.243)	0.935 (0.706–1.237)
North Fork Lewis River	1964–2001	0.992 (0.980–1.008)	1980–2001	0.968 (0.756–1.204)	0.948 (0.741–1.214)
Spring run					
Upper Cowlitz River	1980–2001	0.994 (0.942–1.064)	No hatchery fraction data (presumed high)		
Kalama River	1980–2001	0.945 (0.840–1.064	No hatchery fraction data (presumed high)		
Lewis River	1980–2001	0.935 (0.879–0.995)	No hatchery fraction data (presumed high)		

[a] The long-term analysis used the entire data set.

[b] The trend estimate is for total spawners and includes both natural- and hatchery-origin fish.

[c] The λ calculation is an estimate of what the natural growth rate would have been after accounting for hatchery-origin spawners. The λ estimate is calculated under two hypotheses about the reproductive success of hatchery-origin spawners.

[d] Hatchery fish are assumed to have zero reproductive success.

[e] Hatchery fish are assumed to have the same relative reproductive success as natural-origin fish.

Table 15. Short-term trend and growth rate for a subset of Lower Columbia River ESU Chinook salmon populations for which adequate data are available (95% confidence intervals are in parentheses).

Run population	Years for short-term trend[a]	Short-term trend of total spawners[b]	Years for short-term λ	Short-term median growth rate (λ)[c]	
				Hatchery = 0[d]	Hatchery = wild[e]
Fall run					
Grays River	1990–2001	1.086 (0.840–1.405)	1990–2001	1.004 (0.787–1.282)	0.898 (0.701–1.150)
Elochoman River	1990–2001	1.154 (0.988–1.347)	1990–2001	1.119 (0.877–1.428)	0.869 (0.679–1.113)
Mill, Abernathy, Germany creeks	1990–2001	0.974 (0.833–1.139)	1990–2001	0.993 (0.778–1.268)	0.823 (0.643–1.054)
Coweeman River	1990–2001	0.985 (0.816–1.139)	1990–2001	0.977 (0.765–1.247)	0.977 (0.763–1.251)
Lower Cowlitz River	1990–2000	1.031 (0.969–1.097)	1990–2000	1.231 (0.873–1.443)	0.782 (0.607–1.009)
Kalama River	1990–2001	0.996 (0.898–1.104)	1990–2001	0.944 (0.740–1.205)	0.799 (0.624–1.022)
Salmon Creek/ Lewis River	1990–2001	1.017 (0.929–1.114)	1990–2001	1.027 (0.805–1.311)	1.027 (0.802–1.315)
Clackamas River	1990–2001	0.799 (0.677–0.945)	1990–2001	No hatchery fraction data	
Washougal River	1990–2001	1.009 (0.961–1.058)	1990–2001	0.985 (0.722–1.257)	0.769 (0.600–0.989)
Upper gorge tributaries	1990–2001	1.291 (0.943–1.769)	1990–2001	1.246 (0.976–1.590)	1.235 (0.964–1.581)
Big White Salmon River	1990–2001	1.106 (0.899–1.361)	1990–2001	1.057 (0.828–1.348)	1.013 (0.791–1.297)
Late-fall run (brights)					
Sandy River	1990–2001	0.915 (0.796–1.052)	1990–2001	0.919 (0.697–1.212)	0.912 (0.689–1.207)
North Fork Lewis River	1990–2001	0.969 (0.889–1.056)	1990–2001	0.966 (0.754–1.236)	0.945 (0.738–1.210)
Spring run					
Upper Cowlitz River	1990–2001	1.011 (0.891–1.148)	1990–2001	No hatchery fraction data	
Kalama River	1990–2001	1.080 (0.880–1.326)	1990–2001	No hatchery fraction data	
Lewis River	1990–2001	0.857 (0.783–0.937)	1990–2001	No hatchery fraction data	

[a] Short-term data sets include data from 1990 to the most recent available year.

[b] The trend estimate is for total spawners and includes both natural- and hatchery-origin fish.

[c] The λ calculation is an estimate of what the natural growth rate would have been after accounting for hatchery-origin spawners. The λ estimate is calculated under two hypotheses about the reproductive success of hatchery-origin spawners.

[d] Hatchery fish are assumed to have zero reproductive success.

[e] Hatchery fish are assumed to have the same relative reproductive success as natural-origin fish.

Table 16. Probability that the long-term abundance trend or growth rate is less than 1 for a subset of Lower Columbia River ESU Chinook salmon populations.

	Long-term analysis			**Short-term analysis**		
		Probability $\lambda < 1$			**Probability $\lambda < 1$**	
Run population	**Probability trend < 1**	**Hatchery = 0**	**Probability trend < 1**	**Probability Trend < 1**	**Hatchery = 0[a]**	**Hatchery = wild[b]**
Fall run						
Grays River	0.965	0.715	0.947	0.245	0.491	0.710
Elochoman River	0.099	0.373	0.967	0.033	0.270	0.765
Mill, Abernathy, Germany creeks	0.887	0.581	0.973	0.643	0.514	0.833
Coweeman River	0.001	0.194	0.196	0.570	0.556	0.556
Lower Cowlitz River	1.000	0.510	0.510	0.148	0.216	0.952
Kalama River	0.710	0.612	0.612	0.536	0.704	0.962
Salmon Creek/Lewis River	0.876	0.663	0.663	0.340	0.331	0.331
Clackamas River	1.000	No hatchery fraction data		0.993	No hatchery fraction data	
Washougal River	0.000	0.323	0.323	0.350	0.556	0.989
Upper gorge tributaries	0.997	0.612	0.612	0.050	0.137	0.148
Big White Salmon River	1.000	0.623	0.623	0.151	0.405	0.476
Late-fall run (brights)						
Sandy River	0.994	0.833	0.833	0.906	0.828	0.849
North Fork Lewis River	0.817	0.800	0.800	0.785	0.733	0.841
Spring run						
Upper Cowlitz River	0.591	No hatchery fraction data		0.423	No hatchery fraction data	
Kalama River	0.834	No hatchery fraction data		0.210	No hatchery fraction data	
Lewis River	0.993	No hatchery fraction data		0.998	No hatchery fraction data	

[a] Hatchery-origin fish are assumed to have zero reproductive success.

[b] Hatchery-origin fish are assumed to have reproductive success equivalent to that of natural-origin fish.

EDT-Based Estimates of Historical Abundance

The WDFW has conducted analyses of the Lower Columbia River ESU Chinook salmon populations using the EDT (ecosystem and diagnosis treatment) model (Busack and Rawding 2003). The EDT model attempts to predict fish population performance based on input information about reach-specific habitat attributes (http://www.olympus.net/community/dungenesswc/EDT-primer.pdf). WDFW populated this model with estimates of historical habitat conditions that produced the estimates of average historical abundance shown in Table 17. There is a great deal of unquantified uncertainty in the EDT historical abundance estimates, which should be considered when interpreting these data. In addition, the habitat scenarios

Table 17. Estimate of historical abundance based on the WDFW's EDT analysis of equilibrium abundance under historical habitat conditions. Source: Busack and Rawding (2003).

Population	**EDT estimate of historical abundance**
Grays River fall run	2,477
Coweeman River fall run	4,971
Lower Cowlitz River fall run	53,956
Toutle River fall run	25,392
Kalama River fall run	2,455
Lewis River fall run (East Fork only)	4,220
Lewis River brights	43,371
Washougal River fall run	7,518
Upper gorge tributaries fall run (Wind River only)	2,363
Toutle River spring run	2,901
Kalama River spring run	4,178

evaluated as "historical" may not reflect historical distributions, because some areas that were historically accessible, but are currently blocked by large dams, are omitted from the analyses; and some areas that were historically inaccessible, but are recently passable because of human intervention, are included.

The EDT outputs are provided here to give a sense of the historical abundance of populations relative to each other and an estimate of the historical abundance relative to the current abundance.

Loss of Habitat from Barriers

Steel and Sheer (2003) conducted an analysis to assess the number of stream kilometers historically and currently available to salmon populations in the lower Columbia River (Table 18). Stream kilometers usable by salmon are determined based on simple gradient cutoffs and the presence of impassable barriers. This approach will overestimate the number of usable stream kilometers, because it does not consider habitat quality (other than gradient). However, the analysis does indicate that for some populations (particularly spring run) currently accessible stream habitat kilometers are greatly reduced from historical conditions.

New Hatchery and ESU Information

Recent Hatchery Releases

Updated information on Chinook hatchery releases in the ESU is provided in Appendix A, Table A-3. These data indicate a high level of Chinook salmon hatchery production in the lower Columbia River. Categorizations of Lower Columbia River ESU hatchery stocks (SSHAG 2003) can be found in Appendix A, Table A-1.

Table 18. Loss of habitat due to barriers in the Lower Columbia River Chinook salmon ESU.

Population	**Potential current habitat (km)**[a]	**Potential historical habitat (km)**[b]	**Current to historical habitat ratio (%)**[c]
Youngs Bay fall run	178	195	91
Grays River fall run	133	133	100
Big Creek fall run	92	129	71
Elochoman River fall run	85	116	74
Clatskanie River fall run	159	159	100
Mill, Abernathy, and Germany creeks fall run	117	123	96
Scappoose Creek fall run	122	157	78
Coweeman River	61	71	86
Lower Cowlitz River fall run	418	919	45
Upper Cowlitz River fall run			
Toutle River fall run	217	313	69
Kalama River fall run	78	83	94
Salmon Creek/Lewis River fall run	438	598	73
Clackamas River fall run	568	613	93
Washougal River fall run	84	164	51
Sandy River fall run	227	286	79
Lower gorge tributaries fall run	34	35	99
Upper gorge tributaries fall run	23	27	84
Hood River fall run	35	35	100
Big White Salmon River fall run	0	71	0
Sandy River late fall run (bright)	217	225	96
North Fork Lewis River late fall run (bright)	87	166	52
Upper Cowlitz spring run	4	276	1
Cispus River spring run	0	76	0
Tilton River spring run	0	93	0
Toutle River spring run	217	313	69
Kalama River spring run	78	83	94
Lewis River spring run	87	365	24
Sandy River spring run	167	218	77
Big White Salmon spring run	0	232	0
Hood River spring run	150	150	99
Total	4,075	6,421	63

[a] The potential current habitat is the kilometers of stream with a gradient between 0.5% and 4%, below all currently impassable barriers.

[b] The potential historical habitat is stream kilometers with a gradient between 0.5% and 4%, below historically impassable barriers.

[c] The current to historical habitat ratio is the percent of the historical habitat that is currently available.

Comparison with Previous Data

The ESU exhibits three major life history types: fall run (tules), late-fall run (brights), and spring run. The ESU spans three ecological zones: coastal (rain-driven hydrograph), western Cascade (snow- or glacial-driven hydrograph), and Columbia Gorge (transitioning to drier interior Columbia River basin ecological zones). The fall-run Chinook salmon populations are currently dominated by large-scale hatchery production, relatively high harvest, and extensive habitat degradation (discussed in previous status reviews). The Lewis River late-fall-run Chinook salmon population is the healthiest in the ESU and has a reasonable probability of being self-sustaining. The spring-run populations are largely extirpated as the result of dams, which block access to their high-elevation habitat. Abundances have largely declined since the last status review update (1998), and trend indicators for most populations are negative, especially if hatchery fish are assumed to have a reproductive success equivalent to that of natural-origin fish. However, 2001 abundance estimates increased over the previous few years for most Lower Columbia River ESU Chinook salmon populations, and preliminary indications are that 2002 abundance also increased.[11] Many salmon populations in the Pacific Northwest have shown increases in abundance over the last few years, and the relationship of these increases to potential changes in marine survival are discussed in the introduction to this report.

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[11] See Footnote 9.

9. Upper Willamette River Chinook Salmon ESU

Summary of Previous BRT Conclusions

NMFS reviewed the status of the Upper Willamette River Chinook salmon ESU initially in 1998 (Myers et al. 1998) and updated it that same year (NMFS 1998a). In the 1998 update, the BRT noted several concerns for this ESU. The previous BRT was concerned about the few remaining populations of spring-run Chinook salmon in the Upper Willamette River ESU, and the high proportion of hatchery fish in the remaining runs. The BRT noted with concern that the Oregon Department of Fish and Wildlife (ODFW) was able to identify only one remaining naturally reproducing population in this ESU, the spring-run Chinook salmon in the McKenzie River. The previous 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 previous BRT partially attributed the declines in spring-run Chinook salmon in the Upper Willamette River ESU to the extensive habitat blockages caused by dam construction. The previous BRT was encouraged by efforts to reduce harvest pressure on naturally produced spring-run Chinook salmon in upper Willamette River tributaries, and the increased focus on selective marking of hatchery fish should help managers targeting specific populations of wild or hatchery Chinook salmon. A majority of the previous (1998) BRT concluded that the Upper Willamette River Chinook salmon ESU was likely to become endangered in the foreseeable future. A minority of BRT members felt that Chinook salmon in this ESU were not presently in danger of extinction, nor were they likely to become so in the foreseeable future.

Listing status: Threatened.

New Data and Updated Analyses

New data for this update include spawner abundance through 2002 in the Clackamas River, 2001 in the McKenzie River, and 2001 at Willamette Falls. In addition, new data include updated redd surveys in the upper Willamette River basin, new estimates of the fraction of hatchery-origin spawners in the McKenzie and North Santiam rivers from an otolith-marking study, the first estimate of hatchery fraction in the Clackamas River (2002 data), and information on recent hatchery releases. New analyses for this update include the designation of relatively demographically independent populations, recalculation of previous BRT metrics in the McKenzie River with additional years of data, estimates of current and historically available stream kilometers, and updates on current hatchery releases.

Historical Population Structure

As part of its effort to develop viability criteria for upper Willamette River Chinook salmon, the WLC-TRT identified historical demographically independent populations (Myers et al. 2002). Population boundaries are based on an application of the VSP definition (McElhany et al. 2000). Myers et al. (2002) hypothesized that the ESU historically consisted of seven spring-run populations (Figure 106). The populations identified in Myers et al. (2002) are used as the units for the new analyses in this report.

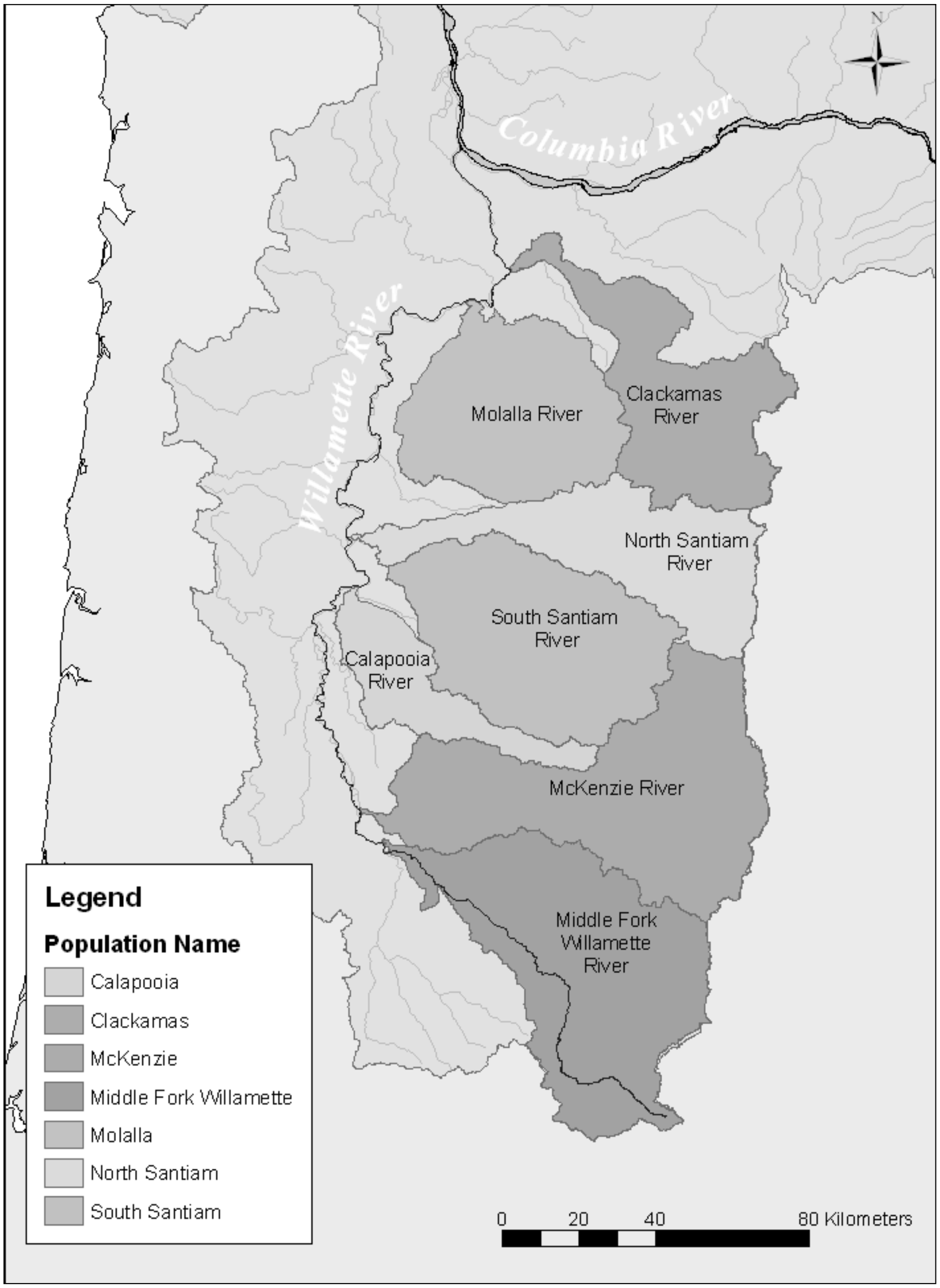


Figure 106. Historical populations of spring-run Chinook salmon in the Upper Willamette River ESU. Source: Myers et al. (2002).

Abundance and Trends

References for abundance time series and related data are presented in Appendix A, Table A-3. Recent abundance of natural-origin spawners, recent fraction of hatchery-origin spawners, and recent harvest rates for Upper Willamette River ESU Chinook salmon populations are summarized in Table 19. The total number of spring-run Chinook spawners passing Willamette Falls from 1953 to 2001 is shown in Figure 107. All spring-run Chinook in the ESU, except those entering the Clackamas River, must pass Willamette Falls. There is no assessment of the ratio of hatchery- to natural-origin Chinook passing the falls, but the majority of fish are undoubtedly of hatchery origin. (Natural-origin fish are defined has having had parents that spawned in the wild, as opposed to hatchery-origin fish, whose parents spawned in a hatchery.) The status of individual populations follows.

Clackamas

The count of spring-run Chinook salmon passing the North Fork Dam on the Clackamas from 1958 to 2002 is shown in Figure 108 (Cramer 2002a). The total number of Chinook passing above the dam exceeded 1,000 in most years since 1980, and the last several years show large increases. However, the majority of these fish are likely of hatchery origin. The only year for which hatchery-origin estimates are available is 2002, and the estimate is 64% of hatchery origin. Although the majority of spring-run Chinook spawning habitat is above North Fork Dam,

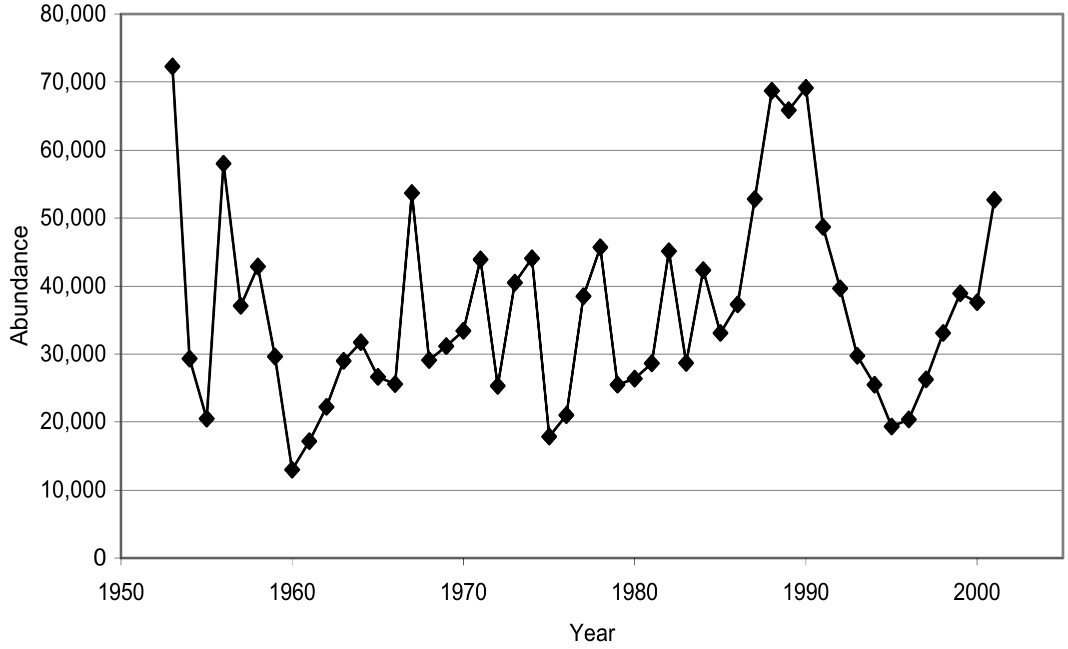


Figure 107. Number of spring-run Chinook salmon passing Willamette Falls, 1953–2001. The count is of mixed natural and hatchery origin, with the majority of fish likely of hatchery origin.

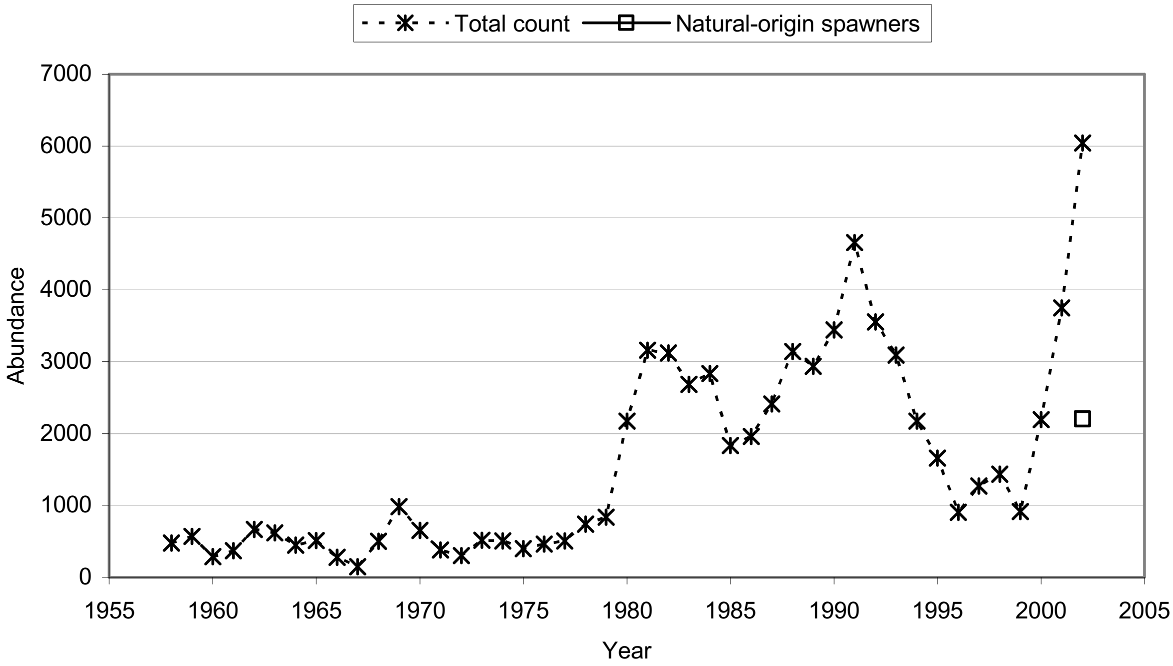


Figure 108. Number of spring-run Chinook salmon passing North Fork Dam on the Clackamas River (Cramer 2002a), 1958–2002. The total count is all fish passing above the dam. There is only one estimate (in 2002) of the number of fish passing above the dam that are of natural origin.

spawning is observed below the dam. The majority of spawning below the dam is also considered to be by hatchery-origin spawners. The population has shown substantial increases in total abundance (mixed hatchery and natural origin) in the last couple years.

Molalla

A 2002 survey of 16.3 miles (26.2 km) of stream in the Molalla found 52 redds. However, 93% of the carcasses recovered in the Molalla in 2002 were fin-clipped and of hatchery origin (Schroeder et al. 2002). Fin-clip recovery fractions for spring-run Chinook in the Willamette tend to underestimate the proportion of hatchery-origin spawners (Schroeder et al. 2002), so the true fraction is likely in excess of 93% (i.e., near 100%). The Molalla natural-origin spring-run Chinook population is believed to be extirpated, or nearly so.

North Santiam

Survey estimates of redds per mile in the North Santiam River are shown in Figure 109 (from Schroeder et al. 2002). The number of stream miles surveyed varies between 26.8 and 43.5. The total redds counted in a year varies between 116 and 310. Schroeder et al. (2002) estimate an escapement of 94 natural-origin spawners above Bennett Dam in 2000 and 151 in 2001. These natural-origin spawners were greatly outnumbered by hatchery-origin spawners (2,192 and 6,635 in 2000 and 2001, respectively). This resulted in an estimate of 94% hatchery-origin spawners in 2000 and 98% in 2001. This population is not considered self-sustaining.

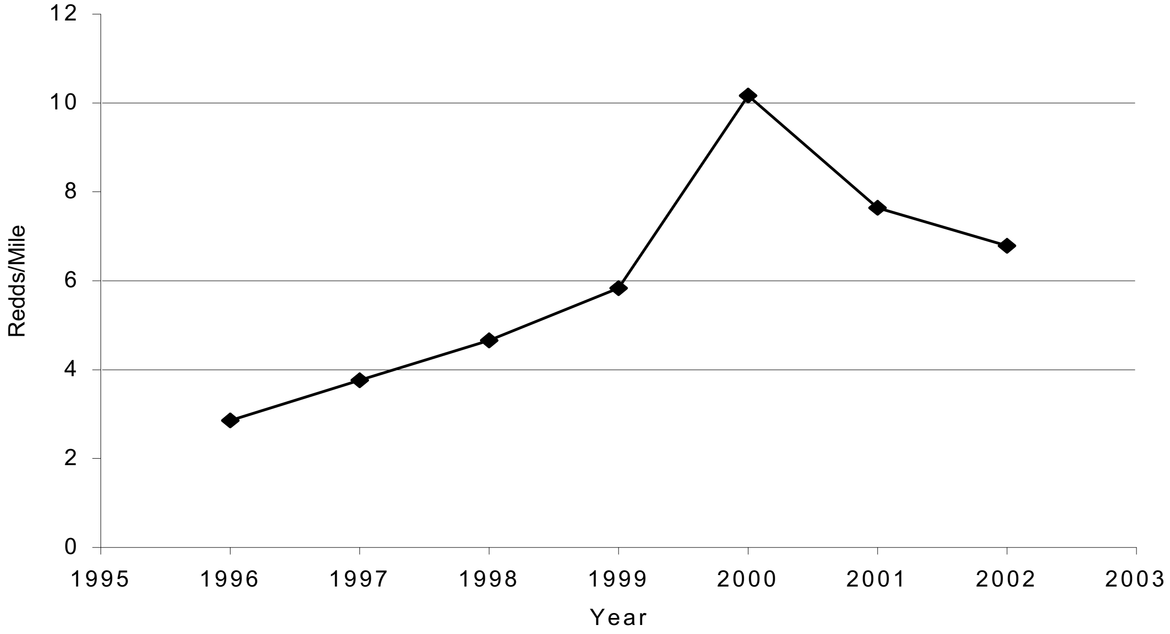


Figure 109. North Santiam River Chinook salmon redds per mile, 1996–2002. The number of stream miles surveyed varies between 26.8 and 43.5 miles. The total redds counted in a year varies between 116 and 310. Over 95% of the spawners are estimated to be of hatchery origin. Source: Data from Schroeder et al. (2002).

South Santiam

A 2002 survey of 50.8 miles (81.7 km) of stream in the South Santiam River below Foster Dam found 982 redds. However, 84% of the carcasses recovered in the South Santiam in 2002 were fin-clipped and of hatchery origin (Schroeder et al. 2002). Fin-clip recovery fractions for spring-run Chinook in the Willamette River tend to underestimate the proportion of hatchery-origin spawners (Schroeder et al 2002), so the true fraction is likely in excess of 84%. This population is not considered self-sustaining.

Calapooia

A 2002 survey of 11.1 miles (17.8 km) of stream in the Calapooia River above Brownsville found 16 redds (Schroeder et al. 2002). The carcasses recovered in the Calapooia in 2002 were too decomposed to determine the presence or absence of fin clips. However, it was assumed that all the fish were surplus hatchery fish outplanted from the South Santiam Hatchery (Schroeder et al. 2002). The Calapooia natural-origin spring-run Chinook population is believed to be extirpated, or nearly so.

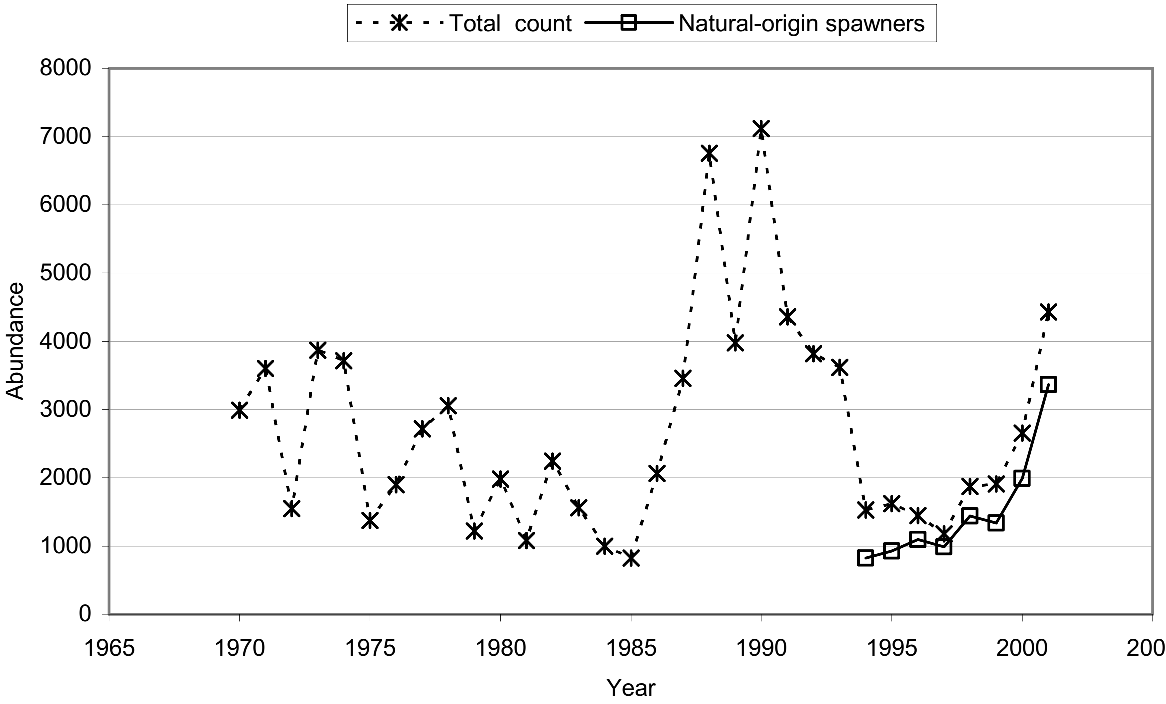


Figure 110. Number of McKenzie River spring-run Chinook salmon at Leaburg Dam, 1970–2001.

McKenzie

The time series of total spring-run Chinook counts and natural-origin fish passing Leaburg Dam on the McKenzie River is shown in Figure 110. The average fraction of hatchery-origin fish passed above the dam from 1998 to 2001 was estimated to be 26%. Redds are observed below Leaburg Dam, but the fraction of hatchery-origin fish is higher (Schroeder et al. 2002). The fraction of fin-clipped spring-run Chinook carcasses recovered below Leaburg Dam was 72% in 2000 and 67% in 2001. Again, fin-clip recoveries tend to underestimate the fraction of hatchery-origin spawners. The spring-run Chinook population above Leaburg Dam in the McKenzie River is considered the best in the ESU, but with over 20% of the fish of hatchery origin, it is difficult to determine whether this population would be naturally self-sustaining. The population has shown substantial increases in total abundance (mixed hatchery and natural origin) in the last couple years.

Middle Fork Willamette

A 2002 survey of 17 miles (27.4 km) of the mainstem Middle Fork Willamette River found 64 redds. However, 77% of the carcasses recovered in the Middle Fork in 2002 were fin-clipped and of hatchery origin (Schroeder et al. 2002). In Fall Creek, a tributary of the Middle Fork, 171 redds in 13.3 miles were found in 2002. The 2002 carcass survey found that 39% of fish were fin-clipped. Fin-clip recovery fractions for spring-run Chinook in the Willamette River tend to underestimate the proportion of hatchery-origin spawners. This population is not considered to be self-sustaining.

No formal trend analyses were conducted on any Upper Willamette River ESU Chinook salmon populations. The two populations with long time series of abundance (Clackamas and McKenzie) have insufficient information on the fraction of hatchery-origin spawners to permit a meaningful analysis.

Loss of Habitat from Barriers

Steel and Sheer (2003) conducted an analysis was conducted to assess the number of stream kilometers historically and currently available to salmon populations in the upper Willamette River basin (Table 19). Stream kilometers usable by salmon are determined based on simple gradient cutoffs and on the presence of impassable barriers. This approach will overestimate the number of usable stream kilometers, because it does not consider habitat quality (other than gradient). However, the analysis does indicate that, for some populations, the number of stream habitat kilometers currently accessible is significantly reduced from the historical condition.

Hatchery Releases

A large number of spring-run Chinook salmon are released into the upper Willamette River as mitigation for the loss of habitat above federal hydroprojects (Table 20). This hatchery production is considered a potential risk because it masks the productivity of the natural population, interbreeding of hatchery and natural fish poses genetic risks, and the incidental take from the fishery promoted by hatchery production can increase adult mortality. Harvest retention is only allowed for hatchery-marked fish, but take from hooking mortality and noncompliance is still a potential issue.

Table 19. Historical populations of Upper Willamette River spring-run Chinook salmon ESU.

Population	**Hatchery fraction (%)**	**Potential current habitat[a] (%)**	**Potential historical habitat[a] (km)**	**Current to historical habitat ratio (%)**
Clackamas River	64[b]	369	475	78
Molalla River	>93[c]	432	688	63
North Santiam River	97	173	269	64
South Santiam River	>84[c]	445	658	68
Calapooia River	Estimated @100	163	253	65
McKenzie River	26[d]	283	382	74
Middle Fork Willamette River	>77[c]	197	425	46
Total		2,063	3,150	65

[a] The current and historical habitat estimates are based on Steel and Sheer's analysis (2003).

[b] For the Clackamas River population, only one year (2002) of hatchery fraction estimate is available (Cramer 2002a).

[c] Hatchery fraction in the Molalla, South Santiam, and Middle Fork Willamette rivers are minimum estimates based on the ratio of adipose-marked versus unmarked fish recovered in 2001 (Schroeder et al. 2002).

[d] For the McKenzie River population, hatchery fraction is the average percent of spawners of hatchery origin over the last 4 years.

Table 20. Upper Willamette River spring-run Chinook salmon ESU hatchery releases. Source: Compiled by Waknitz (2002).

Watershed	Years	Hatchery	Stock	Release site	Total
Willamette River	1994	Dexter Pond	McKenzie	Lower Willamette River	73,028
	1995	Dexter Pond	Willamette	Lower Willamette River	137,573
	1995	Lowerone Star	Clackamas	Lower Willamette River	59,654
	1995	Marion Forks	North Santiam	Lower Willamette River	40,320
	1993–1994	McKenzie	McKenzie	Lower Willamette River	344,089
	1992–1993	Step	Clackamas	Lower Willamette River	70,193
	1993–1994	Step	McKenzie	Lower Willamette River	331,446
	1993–1995	McKenzie	Clackamas	Lower Willamette River	125,585
	1996–1999	Willamette	McKenzie	Lower Willamette River	225,122
	1995–1996	Willamette	North Santiam	Lower Willamette River	81,513
	1995–1999	McKenzie	McKenzie	Lower Willamette River	574,117
Clackamas River	1991–1994	Clackamas	Clackamas	Clackamas River	4,358,092
	1995–2002	Clackamas	Clackamas	Clackamas River	9,182,916
	1996–2001	McKenzie	McKenzie	Clackamas River	1,332,542
	1991	Eagle Creek	Clackamas	Eagle Creek	556,814

Fall-run Chinook salmon are not native to the upper Willamette River and are not part of the Upper Willamette River Chinook salmon ESU. Fall-run Chinook hatchery fish are no longer released into the upper Willamette River, though there have been substantial releases in the past (Figure 111).

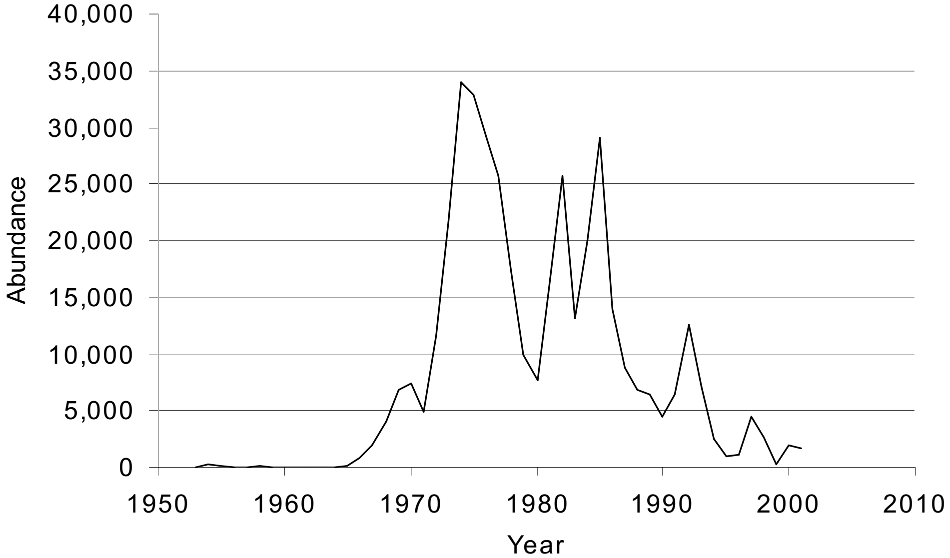


Figure 111. Number of fall-run Chinook salmon at Willamette Falls, 1952–2001. Fall-run Chinook salmon are not native in the upper Willamette River and are not found in the Upper Willamette River Chinook salmon ESU.

ESU Summary

The updated information provided in this memorandum, the information contained in previous Upper Willamette River ESU Chinook salmon status reviews, and WLC-TRT's preliminary analysis indicate that most natural-origin spring-run Chinook populations are likely extirpated, or nearly so. The only population considered potentially self-sustaining is the McKenzie River population. However, its abundance has been relatively low (low thousands), with a substantial number of these fish being of hatchery origin. The McKenzie River population has shown a substantial increase in the last couple years, hypothesized to be a result of increased ocean survival. What ocean survival will be in the future is unknown, and the long-term sustainability of the McKenzie River population is uncertain.

10. California Coastal Chinook Salmon ESU

Summary of Previous BRT Conclusions

The status of Chinook salmon throughout California and the Pacific Northwest was formally assessed in 1998 (Myers et al. 1998). Substantial scientific disagreement about the biological data and its interpretation persisted for some ESUs, which were reconsidered in a subsequent status review update (NMFS 1999a). Information from those reviews regarding ESU structure, analysis of extinction risk, risk factors, and hatchery influences is summarized in the subsections that follow.

ESU Structure

The initial status review proposed a single ESU of Chinook salmon inhabiting coastal basins south of Cape Blanco, Oregon, and the tributaries to the Klamath River downstream of its confluence with the Trinity River in California (Myers et al. 1998). Subsequent review of an augmented genetic data set and further consideration of ecological and environmental information led to the division of the originally proposed ESU into the Southern Oregon and Northern California Coastal Chinook salmon ESU and the California Coastal Chinook salmon ESU (NMFS 1999a). The California Coastal Chinook salmon ESU currently includes Chinook salmon from Redwood Creek to the Russian River (inclusive).

Summary of Risk Factors and Status

The California Coastal Chinook salmon ESU is listed as threatened. Primary causes for concern were low abundance, reduced distribution (particularly in the southern portion of the ESU's range), and generally negative trends in abundance; all of these concerns were especially strong for spring-run Chinook salmon in this ESU (Myers et al. 1998). Data for this ESU are sparse and in general of limited quality, which contributes to substantial uncertainty in estimates of abundance and distribution. The BRT considered degradation of the genetic integrity of the ESU to be of minor concern and to present less risk for this ESU than for other ESUs.

Previous reviews of conservation status for Chinook salmon in this area exist. Nehlsen et al. (1991) identified three putative populations (Humboldt Bay tributaries, Mattole River, and Russian River) as being at high risk of extinction and three other populations (Redwood Creek, Mad River, and lower Eel River) as being at moderate risk of extinction. Higgins et al. (1992) identified seven "stocks of concern," of which two populations (tributaries to Humboldt Bay and the Mattole River) were considered to be at high risk of extinction. Some reviewers indicate that Chinook salmon native to the Russian River have been extirpated.

Table 21. Historical estimates of abundance of Chinook salmon in the California Coastal Chinook salmon ESU.

Selected watersheds	CDFG[a] (1965)	Wahle and Pearson (1987)
Redwood Creek	5,000	1,000
Mad River	5,000	1,000
Eel River	55,000	17,000
Mainstem Eel River[b]	13,000	–
Van Duzen River[b]	2,500	–
Middle Fork Eel River[b]	13,000	–
South Fork Eel River[b]	27,000	–
Bear River	–	100
Small Humboldt County rivers	1,500	–
Miscellaneous rivers north of Mattole River	–	600
Mattole River	5,000	1,000
Noyo River	50	–
Russian River	500	50
Total	72,550	20,750

[a] CDFG = California Department of Fish and Game.

[b] Entries for subbasins of the Eel River basin are not included separately in the total.

Historical estimates of escapement are presented in Table 21. These estimates are based on professional opinion and evaluation of habitat conditions, and thus do not represent rigorous estimates based on field sampling. Historical time series of counts of upstream migrating adults are available for Benbow Dam (South Fork Eel River 1938–1975), Sweasy Dam (Mad River 1938–1964), and Cape Horn Dam (Van Arsdale Fish Station, Eel River); the latter represent a small, unknown, and presumably variable fraction of the total run to the Eel River. Data from cursory, nonsystematic stream surveys of two tributaries to the Eel River (Tomki and Sprowl creeks) and one tributary to the Mad River (Canon Creek) were also available; these data provide crude indices of abundance.

Previous status reviews considered the following to pose significant risks to the California Coastal Chinook salmon ESU: degradation of freshwater habitats due to a variety of agricultural and forestry practices, water diversions, urbanization, mining, and severe recent flood events (exacerbated by land use practices). Special concern was noted regarding the more precipitous declines in distribution and abundance in spring-run Chinook salmon. Many of these factors are particularly acute in the southern portion of the ESU and were compounded by uncertainty stemming from the general lack of population monitoring in California (Myers et al. 1998).

In previous status reviews, the effects of hatcheries and transplants on the ESU's genetic integrity elicited less concern than other risk factors for this ESU, and were less of a concern compared to other ESUs.

Listing status: Threatened.

New Data and Updated Analyses

The TRT for the North-Central California Coast (NCCC) recovery domain proposed a set of plausible hypotheses, based largely on geography, regarding the population structure of the California Coastal Chinook salmon ESU (Table 22), but concluded that information to discriminate among these hypotheses is insufficient (Bjorkstedt et al. in prep.). Data are not available for all potential populations; only those for which data are available are considered below.

Abundance and Trends

New or updated time series for Chinook salmon in this ESU include 1) counts of adults reaching Van Arsdale Fish Station near the effective headwater terminus of the Eel River; 2) cursory, quasi-systematic spawner surveys on Canon Creek (tributary to the Mad River), Tomki Creek (tributary to the Eel River), and Sprowl Creek (tributary to the Eel River); and 3) counts of

Table 22. Plausible hypotheses for independent populations considered by the North-Central California Coast TRT. This information is summarized from a working draft report and should be considered as preliminary and subject to revision.

Lumped	Split
Redwood Creek	
Mad River	
Humboldt Bay tributaries	
Eel River[a]	
	South Fork Eel River
	Van Duzen River
	Middle Fork Eel River
	North Fork Eel River
	Upper Eel River
Bear River	
Mattole River	
Tenmile to Gualala[b]	
Russian River	

[a] Plausible hypotheses regarding the population structure of Chinook salmon in the Eel River basin include scenarios ranging from five independent populations (South Fork Eel River, Van Duzen River, upper Eel River, Middle Fork Eel River, and North Fork Eel River) to a single, strongly structured independent population.

[b] This stretch of the coast comprises numerous smaller basins that drain directly into the Pacific Ocean, some of which appear sufficiently large to support independent populations of Chinook salmon. The following hypotheses span much of the range of plausible scenarios: 1) independent populations exist in all basins that exceed a minimum size; 2) independent populations exist only in basins between the Tenmile River and Big River, inclusive, that exceed a minimum size; 3) Chinook salmon inhabiting basins along this stretch of coastline exhibit patchy population or metapopulation dynamics in which the occupancy of any given basin depends on migrants from other basins, and possibly from larger basins to the north and south; and 4) Chinook salmon inhabiting basins between the Tenmile River and Big River, inclusive, exhibit patchy population or metapopulation dynamics in which the occupancy of any given basin depends on migrants from other basins in this region and possibly to the north, while other basins to the south only sporadically harbor Chinook salmon.

Table 23. Geometric means, estimated λ, and long- and short-term trends for abundance time series in the California Coastal Chinook salmon ESU.

	5-year geometric mean			**Trend**	
	Recent	**Minimum**	**Maximum**	**Long term**	**Short term**
Freshwater Creek[a]	22	13	22	0.137 (–0.405, 0.678)	0.137 (–0.405, 0.678)
Mad River					
Canon Creek[b]	73	19	103	0.0102 (–0.106, 0.127)	0.155 (–0.069, 0.379)
Eel River					
Sprowl Creek[c]	43	43	497	–0.096 (–0.157, –0.034)	–0.183 (–0.356, –0.010)
Tomki Creek[c]	61	13	2,233	–0.199 (–0.351, –0.046)	0.294 (0.055, 0.533)

[a] S. Ricker, CDFG, Steelhead Research and Monitoring Program, Arcata, CA. Pers. commun., 30 May 1999.

[b] Preston (1999).

[c] PFMC (2002a).

returning spawners at a weir on Freshwater Creek (tributary to Humboldt Bay). None of these time series is especially suitable for analyzing trends or estimating population growth rates.

Freshwater Creek

Counts of Chinook salmon passing the weir near the mouth of Freshwater Creek, a tributary to Humboldt Bay, provide a proper census of a small ($N \approx 20$) population of natural and hatchery-origin Chinook salmon (Figure 112). Chinook salmon occupying this watershed may be part of a larger “population” that uses tributaries of Humboldt Bay (NCCC-TRT in prep.). The time series comprises only 8 years of observations, too few to draw strong inferences regarding trends. Clearly, the trend is positive, although the role of hatchery production in producing this signal may be significant (Table 23 and Figure 112).

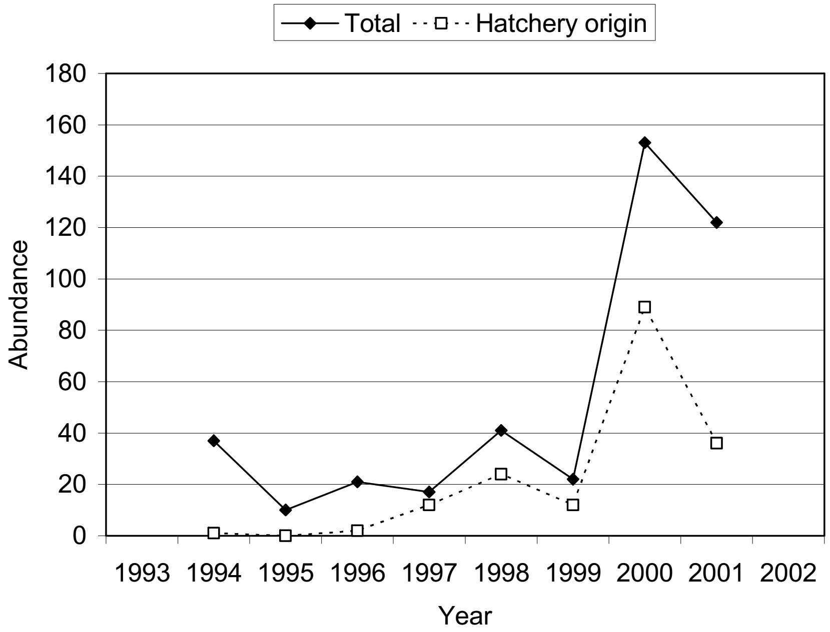


Figure 112. Number of Chinook salmon at the weir on Freshwater Creek, 1994–2001.

Mad River

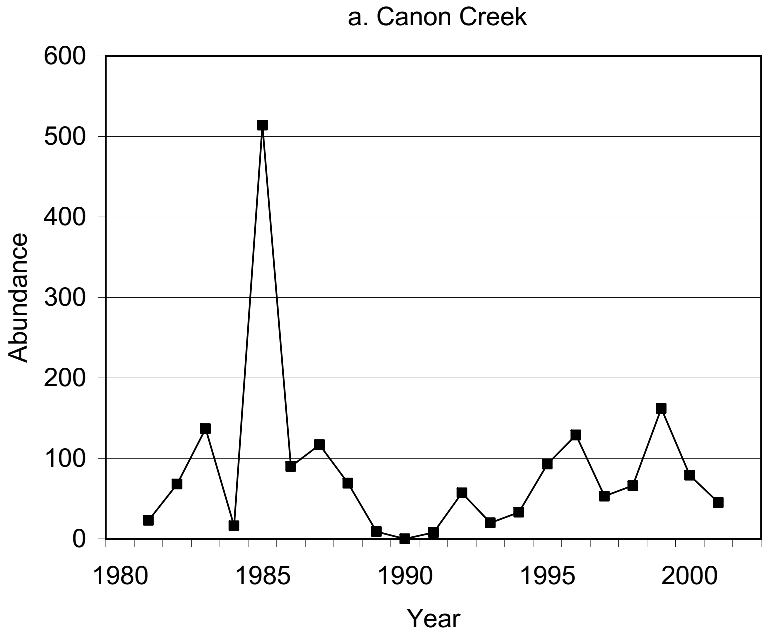
Data for naturally spawning fish are available from spawner surveys on Canon Creek, and to a lesser extent on the North Fork Mad River. Only the counts from Canon Creek extend continuously to the present (Figure 113a). Due to high variability in these counts, short- and long-term trends do not differ significantly from zero, although the tendency is toward a positive trend. Due to a hypothesized, but unquantified, effect of interannual variation in water availability on distribution of spawners in the basin, it is not clear whether these data provide any useful information for the population as a whole; however, more sporadic counts from the mainstem Mad River suggest that the estimates from Canon Creek capture gross signals and support the hypothesis of a recent positive trend in abundance (Figure 113b).

Eel River

The Eel River plausibly harbors anywhere from one to five independent populations (NCCC-TRT in prep.; Table 22). Three current time series provide information for the populations that occupy this basin: 1) counts of adults reaching Van Arsdale Fish Station near the effective headwater terminus of the Eel River (Figure 114a); 2) spawner surveys on Sprowl Creek (tributary to the Eel River) (Figure 114b); and 3) spawner surveys on Tomki Creek (tributary to the Eel River) (Figure 114c). These data are not especially suited to rigorous analysis of population status for a number of reasons, and sophisticated analyses were not pursued.

Two characteristics of the data weaken inferences regarding population status drawn from the time series of counts of adult Chinook salmon reaching Van Arsdale Fish Station (VAFS). First, adult salmon reaching VAFS include both natural- and hatchery-spawned fish, yet the long-term contribution of hatchery production to the spawner population is unknown and may be quite variable due to sporadic operation of the egg take-and-release programs since the mid-1970s. Second, and perhaps more important, it is not clear what VAFS natural spawner counts indicate about the population or populations of Chinook salmon in the Eel River. As a weir count, measurement error is expected to be small for these counts. However, very little spawning habitat exists above VAFS, which sits just below the Cape Horn Dam. This dearth of habitat suggests that counts made at VAFS represent the upper edge of the spawners' distribution in the upper Eel River. Spawner access to VAFS and other headwater habitats in the Eel River basin is likely to depend strongly on the timing and persistence of suitable river flow, which suggests that a substantial component of the process error in these counts is not due to population dynamics. For these reasons, no statistical analysis of these data was pursued.

Additional data for the Eel River population or populations are available from spawner surveys from Tomki and Sprowl creeks, which yield estimates of abundance based on 1) quasi-systematic index site spawner surveys that incorporate mark-recapture analysis of carcasses and 2) additional so-called compatible data from other surveys. Analysis for Sprowl Creek indicates negative long- and short-term trends; similar analysis indicates a long-term decline and short-term increase for Tomki Creek (Table 22). Caution in interpreting these results is warranted, particularly given the quasi-systematic collection of these data, and the likelihood that these data include unquantified variability due to flow-related changes in spawners' use of mainstem and tributary habitats. In particular, inferences regarding population status based on



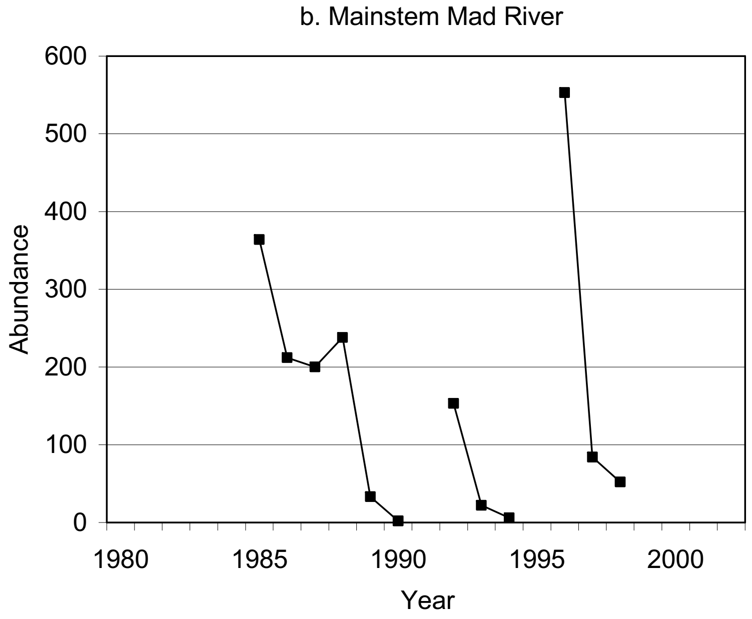


Figure 113. Abundance time series for Chinook salmon in portions of the Mad River basin: a. spawner counts on Canon Creek, 1981–2001; b. spawner counts on portions of the mainstem Mad River, 1985–1998.

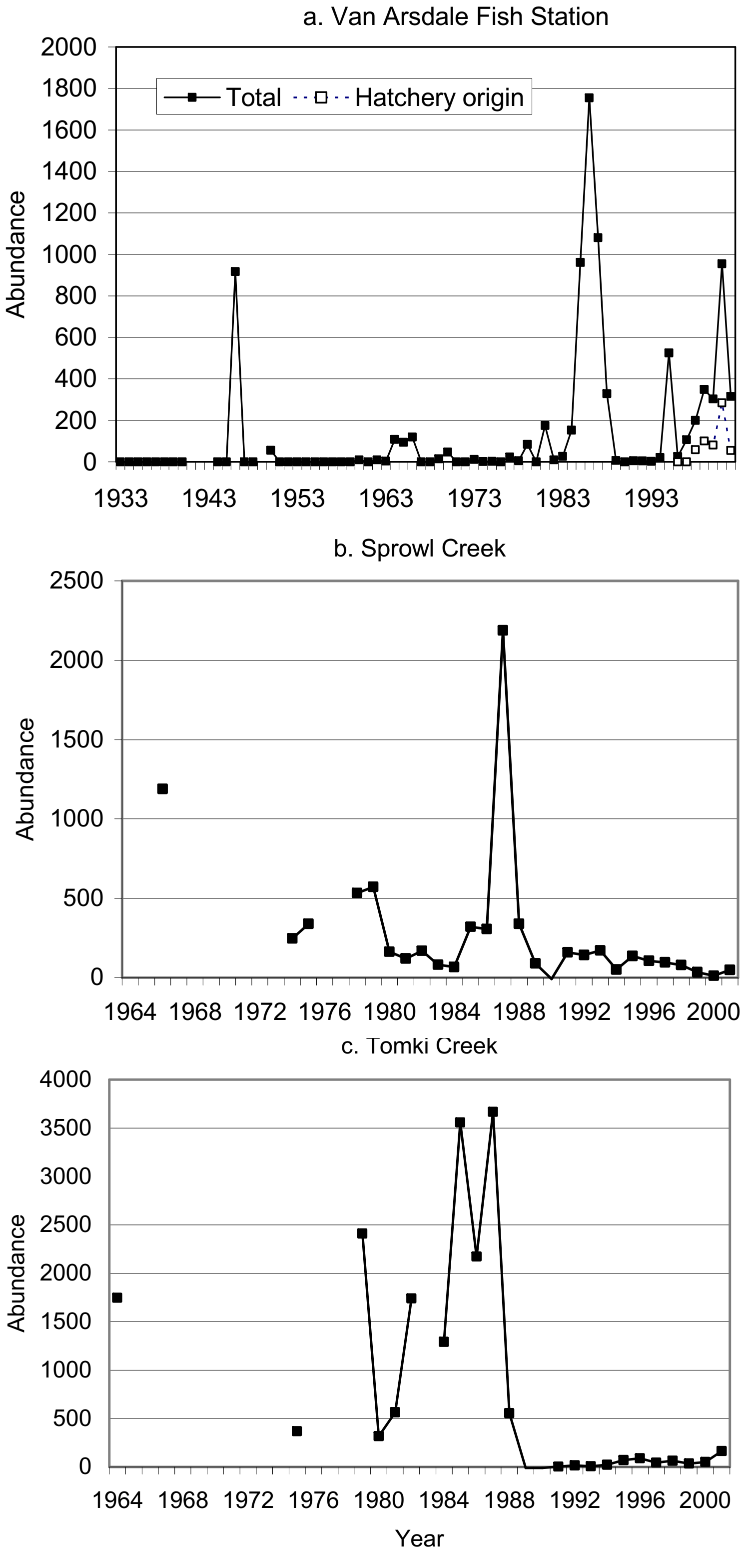


Figure 114. Abundance time series for Chinook in portions of the Eel River basin: a. counts of Chinook at Van Arsdale Fish Station at the upstream terminus of anadromous access on the mainstem Eel River; b. estimates of spawner abundance based on spawner surveys and additional data from Sprowl Creek; c. estimates of spawner abundance based on spawner surveys and additional data from Tomki Creek.

extrapolations from these data to basinwide estimates of abundance are expected to be weak and perhaps not warranted.

Mattole River

The Mattole Salmon Group has conducted spawner and redd surveys on the Mattole River and tributaries since 1994. The surveys provide useful information on the distribution of salmon and spawning activity throughout the basin. Local experts have used these and ancillary data to develop rough "index" estimates of spawner escapement to the Mattole River; however, the intensity and coverage of these surveys have not been consistent, and the resulting data are not suitable for rigorous estimation of abundance (e.g., through area-under-the-curve analysis).

Russian River

No long-term, continuous time series are available for sites in the Russian River basin, but sporadic estimates based on spawner surveys are available for some tributaries. Video-based counts of upstream migrating adult Chinook passing a temporary dam near Mirabel on the Russian River are available for 2000–2002. Counts are incomplete, due to technical difficulties with the video apparatus, occasional periods of poor water clarity, occasional overwhelming numbers of fish, and disparities between counting and migration periods; thus, these data represent a minimum count of adult Chinook. Counts have exceeded 1,300 fish in each of the last 3 years (5,465 in 2002); and a rigorous mark-recapture estimate of outmigrant abundance in 2002 exceeded 200,000.[12] Because Chinook have not been produced at the Don Clausen Hatchery since 1997, these counts represent natural production or straying from other systems. No data were available to assess the genetic relationship of these fish to others in this or other ESUs.

Summary

Historical and current information indicates that abundance in putatively independent populations of Chinook is depressed in many of those basins where they have been monitored. The relevance of recent strong returns to the Russian River to ESU status is not clear because the genetic composition of these fish is unknown. Reduction in geographic distribution, particularly for spring-run Chinook and for basins in the southern portion of the ESU, continues to present substantial risk. Genetic concerns are reviewed below (see subsection, New Hatchery Information, below). As for previous status reviews, uncertainty continues to contribute substantially to assessments of risk facing this ESU.

New Hatchery Information

Hatchery stocks that are considered for inclusion in this ESU are 1) Mad River Hatchery; 2) hatchery activities of the Humboldt Fish Action Council on Freshwater Creek; 3) Yager Creek Hatchery, operated by Pacific Lumber Company; 4) Redwood Creek Hatchery; 5) Hollow Tree Creek Hatchery; 6) Van Arsdale Fish Station; and 7) hatchery activities of the Mattole Salmon Group. Chinook are no longer produced at the Don Clausen Hatchery on Warm Springs Creek

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[12] S. Chase, Sonoma County Water Agency, Santa Rosa, CA. Pers. commun., 18 December 2002.

(Russian River). In general, hatchery programs in this ESU are not oriented toward large-scale production; rather, they are small-scale operations oriented at supplementing depressed populations.

Freshwater Creek

This hatchery is operated by Humboldt Fish Action Council (HFAC) and the California Department of Fish and Game (CDFG) to supplement and restore natural production in Freshwater Creek. All spawners are from Freshwater Creek; juveniles are marked, and hatchery fish are excluded from use as broodstock. Weir counts provide good estimates of the proportion of hatchery- and natural-origin fish returning to Freshwater Creek (30–70% hatchery from 1997 to 2001); the contribution of HFAC production to spawning runs in other streams tributary to Humboldt Bay is unknown.

Mad River

Recent production from this hatchery has been based on small numbers of spawners returning to the hatchery. There are no estimates of naturally spawning Chinook abundance available for the Mad River to determine the contribution of hatchery production to Chinook in the basin as a whole. Broodstock has generally been drawn from Chinook returning to the Mad River; however, releases in the 1970s and 1980s included substantial releases of fish from out of the basin (Freshwater Creek) and out of the ESU (Klamath-Trinity and Puget Sound).

Eel River

Four hatcheries, none of which are major production hatcheries, contribute to production of Chinook salmon in the Eel River basin: hatcheries on Yager Creek (recent effort is approximately 12 females spawned per year), Redwood Creek (approximately 12 females), Hollow Tree Creek, and the Van Arsdale Fish Station (VAFS) (approximately 60 males and females). At the first three hatcheries, broodstock is selected from adults of nonhatchery origin; at VAFS, broodstock includes both natural and hatchery-origin fish. In all cases, however, insufficient data on naturally spawning Chinook are available to estimate the effect of hatchery fish on production or other characteristics of naturally spawning Chinook in the Eel River basin. Since 1996, all fish released from VAFS have been marked. Subsequent returns indicate that approximately 30% of the adult Chinook trapped at VAFS are of hatchery origin. It is not clear what these numbers indicate about hatchery contributions to the population of fish spawning below VAFS.

Mattole River

The Mattole Salmon Group has operated a small hatchbox program since 1980 (current effort approximately 40,000 eggs from approximately 10 females) to supplement and restore Chinook salmon and other salmonids in the Mattole River. All fish are marked, but no rigorous estimate of hatchery contributions to adult escapement is possible. Hatchery-produced outmigrants comprised approximately 17.3% (weighted average) of outmigrants trapped during 1997, 1998, and 2000 (Mattole Salmon Group 2000). Trapping efforts did not fully span the period of natural outmigration, so this figure may overestimate the contribution of hatchbox production to total production in the basin.

Russian River

Production of Chinook salmon at the Don Clausen (Warm Springs Hatchery) ceased in 1997 and had been largely ineffective for a number of years prior to that. Recent returns of Chinook salmon to the Russian River stem from natural production, and possibly from fish straying from other basins, including perhaps Central Valley stocks.

Summary

Artificial propagation of Chinook salmon in this ESU remains at relatively low levels. No putatively independent populations of Chinook salmon in this ESU appear to be entirely dominated by hatchery production, although proportions of hatchery fish can be quite high where natural escapement is small and hatchery production appears to be successful (e.g., Freshwater Creek). It is not clear whether current hatcheries pose a risk or offer a benefit to naturally spawning populations. Extant hatchery programs are operated under guidelines designed to minimize genetic risks associated with artificial propagation and, save for historical inputs to the Mad River Hatchery stock, do not appear to be at substantial risk of incorporating out-of-basin or out-of-ESU fish. Thus, it is likely that artificial propagation and degradation of genetic integrity do not represent a substantial conservation risk to the ESU. Categorizations of hatchery stocks in the California Coastal Chinook salmon ESU (SSHAG 2003) can be found in Appendix A, Table A-1.

Comparison with Previous Data

Few new data, and few new data sets, were available for consideration, and none of the recent data contradicts the conclusions of previous status reviews. Chinook salmon in the California Coastal Chinook salmon ESU continue to exhibit depressed population sizes relative to historical abundances; this is particularly true for spring-run Chinook salmon, which may no longer be extant anywhere within the range of the ESU. Evaluation of the significance of recent potential increases in abundance of Chinook salmon in the Russian River must weigh the substantial uncertainty regarding the genetic relatedness of these fish to others in the northern part of the ESU.

Harvest rates are not explicitly estimated for this ESU; however, it is likely that current restrictions on harvest of Klamath River fall-run Chinook salmon maintain low ocean harvest of Chinook from the California Coastal Chinook salmon ESU (PFMC 2002a, 2002b). Potential changes in age-structure of Chinook salmon populations (e.g., Hankin et al. 1993) and associated risk have not been evaluated for this ESU.

No information exists to suggest new risk factors or substantial effective amelioration of risk factors noted in the previous status reviews, except for recent changes in ocean conditions. Recent favorable ocean conditions have contributed to apparent increases in abundance and distribution for a number of anadromous salmonids, but the expected persistence of this trend is unclear.

11. Sacramento River Winter-Run Chinook Salmon ESU

Summary of Previous BRT Conclusions

The status of Chinook salmon coastwide was formally assessed in 1998 (Myers et al. 1998); however, NMFS had previously recognized Sacramento River winter-run Chinook salmon as a distinct population segment under the ESA (NMFS 1987).

Summary of Major Risk Factors and Status Indicators

Historically, winter-run Chinook salmon depended on access to spring-fed tributaries to the upper Sacramento River that stayed cool during the summer and early fall. Adults enter freshwater in early winter and spawn in the spring and summer. Juveniles rear near the spawning location until at least the fall, when water temperatures in lower reaches are suitable for migration. Winter-run Chinook salmon were abundant and comprised populations in the McCloud, Pit, and Little Sacramento rivers, with perhaps smaller populations in Battle Creek and the Calaveras River. Based on commercial fishery landings in the 1870s, Fisher (1994) estimated that the total run size of winter-run Chinook salmon may have been 200,000 fish.

The most obvious challenge to winter-run Chinook salmon was the construction of Shasta Dam, which blocked access to the entire historical spawning habitat. It was not expected that winter-run Chinook salmon would survive this habitat alteration (Moffett 1949). Cold-water releases from Shasta Dam, however, created conditions suitable for winter-run Chinook salmon for roughly 100 km downstream from the dam. Presumably, there were several independent populations of winter-run Chinook salmon in the Pitt, McCloud, and Little Sacramento rivers and various tributaries to these rivers, such as Hat Creek and the Fall River. These populations merged to form the present single population. If there ever were populations in Battle Creek and the Calaveras River, they have been extirpated.

In addition to having only a single extant population dependent on artificially created conditions, winter-run Chinook salmon face numerous other threats. Chief among these threats is small population size—escapement fell below 200 fish in the 1990s. Population size declined monotonically from highs of near 100,000 fish in the late 1960s, indicating a sustained period of poor survival. There are questions of genetic integrity due to winter-run Chinook salmon having passed through several bottlenecks in the 20th century. Other threats include inadequately screened water diversions, predation at artificial structures and by nonnative species, pollution from Iron Mountain Mine (among other sources), adverse flow conditions, high summer water temperatures, unsustainable harvest rates, passage problems at various structures (e.g., Red Bluff Diversion Dam), and vulnerability to drought.

Previous BRT Conclusions

The Chinook salmon BRT spent little time considering the status of winter-run Chinook salmon, because winter-run Chinook salmon were already listed as endangered at the time of previous BRT meetings.

Listing status: Endangered.

New Data and Updated Analyses

Viability Assessments

Two studies have been done on the population viability of Sacramento River winter-run Chinook salmon. Botsford and Brittnacher (1998), in a paper that is part of the draft recovery plan, developed delisting criteria using a simple age-structured, density-independent model of spawning escapement. They concluded, on the basis of the 1967–1995 data, that winter-run Chinook salmon were certain to fall below the quasi-extinction threshold of three consecutive spawning runs with fewer than 50 females.

Lindley and Mohr (2003) developed a slightly more complex Bayesian model of winter-run Chinook salmon spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures initiated in 1989. This model, due to its allowance for the growth-rate change, its accounting for parameter uncertainty, and use of newer data (through 1998), suggested a lower, but still biologically significant, expected quasi-extinction probability of 28%.

Draft Recovery Plan

The draft recovery plan for Sacramento River winter-run Chinook salmon (NMFS 1997a) provides a comprehensive review of the population's status, life history, habitat requirements, and risk factors. It also provides a recovery goal: an average of 10,000 female spawners per year and a $\lambda \geq 1.0$, calculated over 13 years of data (assuming a certain level of precision in spawning escapement estimates).

New Abundance Data

The Sacramento River winter-run Chinook salmon spawning run has been counted at Red Bluff Diversion Dam (RBDD) fish ladders since 1967. Escapement has been estimated with a carcass survey since 1996. Through the mid-1980s, the RBDD counts were very reliable. At that time, changes to the dam operation were made to alleviate juvenile and adult passage problems. Now, only the tail end of the run (about 15% on average) is forced over the ladders, greatly reducing the accuracy of the RBDD counts. The carcass mark-recapture surveys were initiated to improve escapement estimates. The two measures are in very rough agreement, and there are substantial problems with both estimates, making it difficult to choose one as more reliable than the other. One problem with the carcass-based measure is estimation of the probability of capturing carcasses—it appears that the probability of initial carcass recovery depends strongly on the sex and size of the fish, and possibly on whether it has been previously

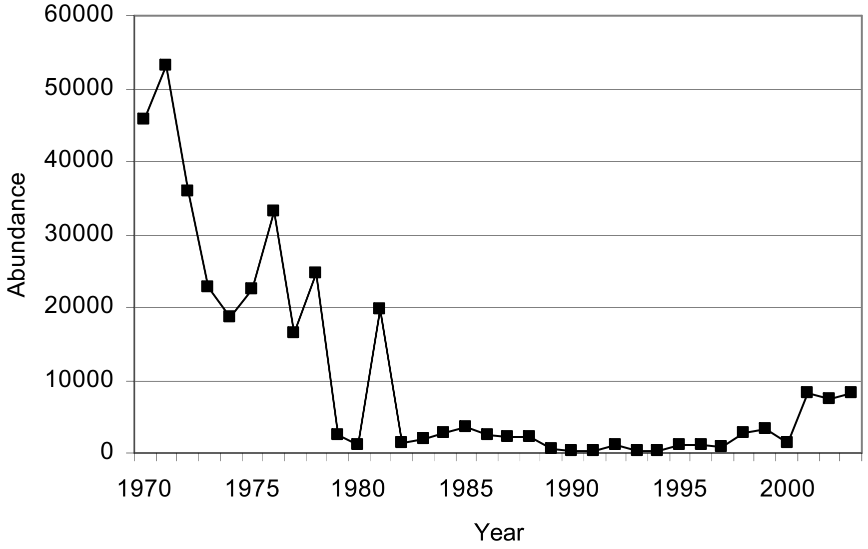

Figure 115. Estimated Sacramento River winter-run Chinook spawner abundance, 1970–2002.

recovered. In the winter-run Chinook salmon carcass surveys, a high ratio of females to males is observed (e.g., Snider et al. 1999), and several studies of salmon carcass recovery have noted that females are recovered with a higher probability than males, presumably because of the different behavior of males and females (e.g., Shardlow et al. 1986 and references therein). In spite of these problems, both abundance measures suggest that the abundance of Sacramento River winter-run Chinook salmon is increasing. Based on the RBDD counts, the winter-run Chinook salmon population has been growing rapidly since the early 1990s (Figure 115), with a short-term trend of 0.26 (Table 24). On the population growth rate–population size space, the Sacramento River winter-run Chinook salmon population has a somewhat low population growth and moderate size compared to other Central Valley salmonid populations (Figure 116).

Table 24. Summary statistics for trend analyses 90% confidence intervals are in parentheses). Results for other populations are shown for comparison.

Population	**5-year mean**	**5-year min.**	**5-year max.**	**λ**	**μ**	**Long-term trend**	**Short-term trend**
Sacramento River winter-run Chinook	2,191	364	65,683	0.97 (0.87, 1.09)	–0.10 (–0.21, 0.01)	–0.14 (–0.19, –0.09)	0.26 (0.04, 0.48)
Butte Creek spring-run Chinook	4,513	67	4,513	1.30 (1.09, 1.60)	0.11 (–0.05, 0.28)	0.11 (0.03, 0.19)	0.36 (0.03, 0.70)
Deer Creek spring-run Chinook	1,076	243	1,076	1.17 (1.04, 1.35)	0.12 (–0.02, 0.25)	0.11 (0.02, 0.21)	0.16 (–0.01, 0.33)
Mill Creek spring-run Chinook	491	203	491	1.19 (1.00, 1.47)	0.09 (–0.07, 0.26)	0.06 (–0.04, 0.16)	0.13 (–0.07, 0.34)
Sacramento River steelhead	1,952	1,425	12,320	0.95 (0.90, 1.02)	–0.07 (–0.13, 0.00)	–0.09 (–0.13, –0.06)	NA

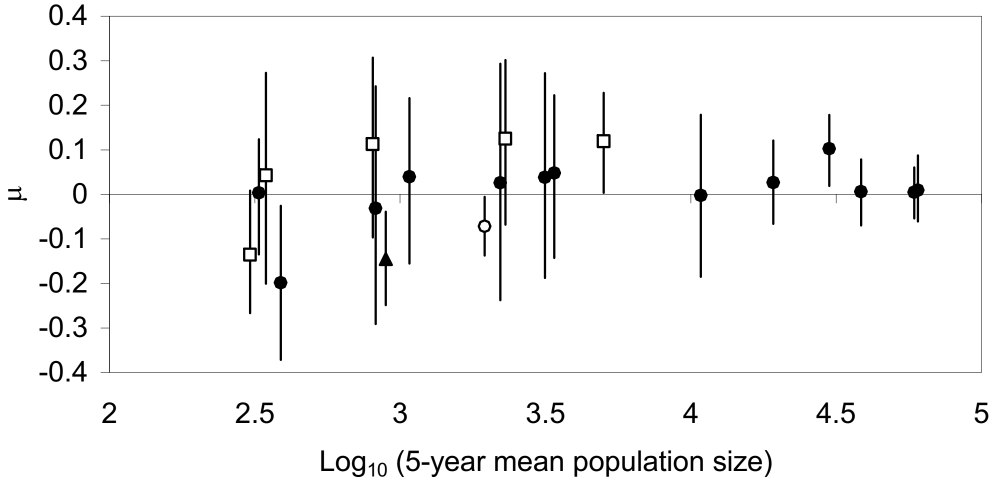

Figure 116. Abundance and growth rate of Central Valley salmonid populations. ○ = steelhead; □ = spring-run Chinook; ▲ = winter-run Chinook; • = other Chinook stocks. Error bars represent central 0.90 probability intervals for μ estimates. Note: as defined in other sections of the status reviews, μ ≈ log(λ).

Sacramento River winter-run Chinook salmon may be responding to a number of factors, including wetter than normal winters, changes in ocean harvest regulations since 1995 that have significantly reduced harvests, changes in RBDD operation, improved temperature management on the upper Sacramento River (including installation of a cold-water release device on Shasta Dam), water quality improvements due to remediation of Iron Mountain Mine discharges, changes in operations of the state and federal water projects, and a variety of other habitat improvements. Although the status of winter-run Chinook salmon is improving, there is only one winter-run Chinook salmon population, and it depends on cold-water releases from Shasta Dam, which could be vulnerable to a prolonged drought. The recent 5-year geometric mean is only 3% of the maximum, post-1967, 5-year geometric mean.

The RBDD counts are suitable for modeling as a random-walk-with-drift (RWWD, also known as the "Dennis model" [Dennis et al. 1991]). In the RWWD model, population growth is described by exponential growth or decline:

$$N_{t+1} = N_t \exp(\mu + \eta_t) \tag{22}$$

where N_t is the population size at time t, μ is the mean population growth rate, and η_t is a normal random variable with mean = 0 and variance = σ^2_p.

The RWWD model, as written in Equation 22, ignores measurement error. Observations (y_t) can be modeled separately,

$$y_t = N_t \exp(\varepsilon_t) \tag{23}$$

where ε_t is a normal random variable with mean = 0 and variance = σ^2_m. Equations 22 and 23 together define a state-space model that, after linearizing by taking logarithms, can be estimated using the Kalman filter (Lindley 2003).

A recent analysis of the RBDD data (Lindley and Mohr 2003) indicated that the population growth since 1989 was higher than in the preceding period. For this reason, two forms of the RWWD model are fitted—one with a fixed growth rate (constant-growth model) and another with a growth rate with a step-change model in 1989, when conservation actions began (step-change model, $\mu_t = \mu$ for $t < 1989$, $\mu_t = \mu + \delta$ for $t \geq 1989$). In both cases, a 4-year running sum was applied to the spawning escapement data to form a total population estimate (Holmes 2001). Results of model fitting are shown in Table 25. The constant-growth model satisfies all model diagnostics, although visual inspection of the residuals shows a strong tendency to underpredict abundance in the most recent 10 years. The residuals of the step-change model fail the Shapiro-Wilks test for normality; the residuals look truncated on the positive side, meaning that good years are not as extreme as bad years. Sacramento River winter-run Chinook salmon growth rate might be better modeled as a mixture between a normal distribution and another distribution reflecting near-catastrophic population declines caused by episodic droughts.

According to Akaike's information criterion (AIC), the step-change model is a much better approximation to the data than the constant population growth rate model, with an AIC difference of 9.61 between the two models (indicating that the data provide almost no support for the constant-growth model). The step-change model suggests the winter-run Chinook salmon population currently has a λ of 1.21, while for the constant population growth-rate model, $\lambda = 0.97$.[13] The extinction risks predicted by the two models are extremely different: winter-run Chinook salmon have almost no risk of extinction if the apparent recent increase in λ holds in the future, but are certain to go extinct if the population grows at its average rate, with a most likely time of extinction of 100 years. Although it would be dangerous to assume that recent population growth will hold indefinitely, it does appear that the status of Sacramento River winter-run Chinook salmon is improving.

Table 25. Parameter estimates for the constant-growth and step-change models applied to Sacramento River winter-run Chinook salmon (90% confidence intervals are in parentheses).

Parameter	Model	
	Constant μ	**Step change μ**
μ	–0.085 (–0.181, 0.016)	–0.214 (–0.322, –0.113)
δ	NA	0.389 (0.210, 0.574)
σ^2_p	0.105 (0.094, 0.122)	0.056 (0.046, 0.091)
σ^2_m	0.0025 (2.45E–6, 0.0126)	0.011 (3.92E–6, 0.022)
P_{100}(ext)*	0.40 (0.00, 0.99)	0.003 (0.0, 0.0)

* Probability of extinction (population size greater than 1 fish) within 100 years.

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[13] In this section, λ is defined as $\exp(\mu + \sigma 2p/2)$, the mean annual population growth rate.

Harvest Impacts

Substantial changes in ocean fisheries off central and northern California have occurred since the last status review (PFMC 2002a, 2002b). The ocean harvest rate of Sacramento River winter-run Chinook salmon is thought to be a function of the Central Valley Chinook salmon ocean harvest index (CVI), which is defined as the ratio of ocean catch south of Point Arena, California, to the sum of this catch and the escapement of Chinook salmon to Central Valley streams and hatcheries. Note that other stocks (e.g., Klamath River Chinook salmon) contribute to the catch south of Point Arena, and that fish from the Central Valley are caught in Oregon fisheries. This harvest index ranged from 0.55 to nearly 0.80 from 1970 to 1995, when harvest regimes were adjusted to protect Sacramento River winter-run Chinook salmon. In 2001, the CVI fell to 0.27. The reduction in harvest is presumably at least partly responsible for the record spawning escapement of fall-run Chinook salmon (≈ 540,000 fish in 2001) and concurrent increases in other Chinook salmon runs in the Central Valley.

Because they mature before the ocean fishing season, Sacramento River winter-run Chinook salmon should have lower harvest rates than fall-run Chinook salmon, if they have similar age at maturity. At the time of the last status review, the only information on the harvest rate of Sacramento River winter-run Chinook salmon came from a study conducted in the 1970s. Hallock and Fisher (1985) reported that the average catch/(catch+escapement) for the 1969–1971 broodyears was 0.40 for the ocean fishery. For the 1968–1975 period, freshwater sport fisheries caught an average of 10% of the Sacramento River winter-run Chinook salmon.

The recent release of significant numbers of adipose fin-clipped, winter-run Chinook salmon provides new, but limited, information on the harvest of Sacramento River winter-run Chinook salmon in coastal recreational and troll fisheries. The PFMC's Sacramento River Winter and Spring Chinook Salmon Workgroup (SRWSCW) conducted a cohort reconstruction of the 1998 broodyear (PFMC 2003a). Winter-run Chinook salmon are mainly vulnerable to ocean fisheries as 3-year-olds. SRWSCW calculated, on the basis of 123 coded-wire-tag recoveries, that the ocean fishery impact rate on 3-year-olds was 0.23, and the in-river sport fishery impact rate was 0.24. These impacts combine to reduce escapement to 100 (1 – 0.23) (1 – 0.24) = 59% of what it would have been in the absence of fisheries, assuming no natural mortality during the fishing season. The high estimated rate of harvest in the river sport fishery, which arises from the recovery of eight coded-wire tags, was a surprise because salmon fishing is closed from January 15 to July 31 to protect Sacramento River winter-run Chinook salmon. The tags were recovered in late December and early January, at the tail end of the fishery for late-fall-run Chinook salmon. The estimate of river sport fishery impact is much less certain than the ocean fishery impact estimate because of the lower number of tag recoveries, less rigorous tag sampling, and larger expansion factors. The California Fish and Game Commission is moving forward with an emergency action to amend sport fishing regulations to ban retention of salmon caught in the river's sport fisheries on January 1 rather than January 15. Had such regulations been in place in 1999–2000, the freshwater harvest rate would have been 20% of that observed.

New Hatchery Information

Livingston Stone NFH was constructed at the base of Shasta Dam in 1997, with the sole purpose of helping to restore natural production of winter-run Chinook salmon. Livingston Stone NFH was designed as a conservation hatchery with features intended to overcome the problems of Coleman NFH (better summer water quality, natal water source). All production is adipose fin clipped. Each individual considered for use as broodstock is genotyped to ensure that it is a Sacramento River winter-run Chinook salmon. No more than 10% of the broodstock is composed of hatchery-origin fish, and no more than 15% of the run is taken for broodstock, with a maximum of 120 fish. Figure 117 shows the number of Sacramento River winter-run Chinook salmon released by Coleman and Livingston Stone NFHs; Figure 118 shows the number of Sacramento River winter-run Chinook salmon spawners taken into the hatchery.

New Comments

The California State Water Contractors, the San Luis and Delta-Mendota Water Authority, and the Westlands Water District recommend that the listing status of Sacramento River winter-run Chinook salmon be changed from endangered to threatened. They base this proposal on the recent upturn of adult abundance, recently initiated conservation actions (restoration of Battle Creek, ocean harvest reductions, screening of water diversions, remediation of Iron Mountain Mine, and improved temperature control), and a putative shift in ocean climate in 1999.

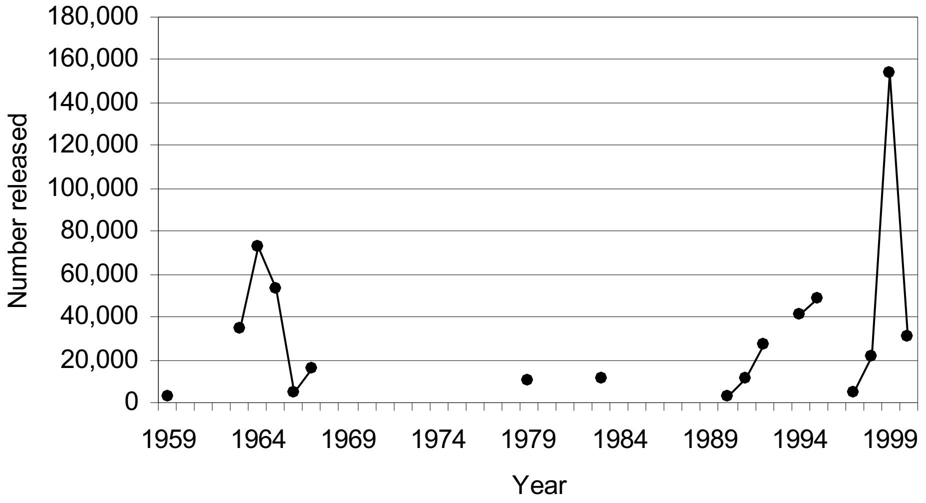

Figure 117. Number of juvenile Sacramento River winter-run Chinook salmon released by Coleman and Livingston Stone National Fish Hatcheries, 1963–2000.

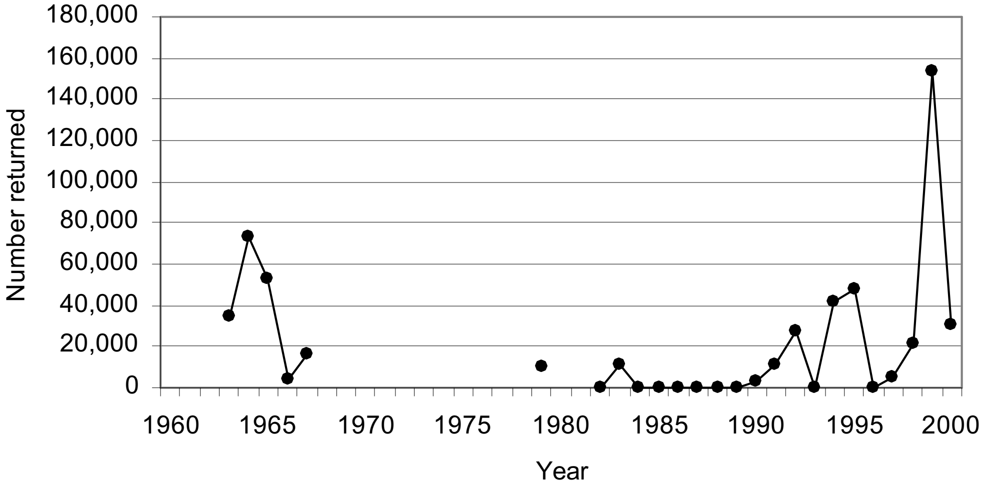

Figure 118. Number of adult Sacramento River winter-run Chinook salmon collected for broodstock by Coleman and Livingston Stone National Fish Hatcheries, 1989–2000.

12. Central Valley Spring-Run Chinook Salmon ESU

Summary of Previous BRT Conclusions

The status of the Central Valley spring-run Chinook salmon ESU was formally assessed during a coastwide status review (Myers et al. 1998). In June 1999, a BRT convened to update the status of this ESU by summarizing information and comments received since the 1997 status review and presenting BRT conclusions concerning four deferred Central Valley Chinook salmon ESUs (NMFS 1999a).

Summary of Major Risk Factors and Status Indicators

Threats to Central Valley spring-run Chinook salmon fall into three broad categories: loss of most historical spawning habitat, degradation of remaining habitat, and genetic threats from the Feather River Hatchery spring-run Chinook salmon program. Like most spring-run Chinook salmon, Central Valley spring-run Chinook salmon require cool freshwater while they mature over the summer. In the Central Valley, summer water temperatures are suitable for Chinook salmon only above 150–500 m elevations, and most such habitat in the Central Valley is now upstream of impassable dams (Figure 119). Only three wild populations of spring-run Chinook salmon with consistent spawning runs (on Mill, Deer, and Butte creeks, tributaries to the lower Sacramento River draining out of the southern Cascade Mountains) are extant. These populations reached quite low abundance levels during the late 1980s (5-year mean population sizes of 67–243 spawners), compared to a historical peak abundance of perhaps 700,000 spawners for the ESU (estimate of Fisher [1994], based on early gillnet fishery catches). The upper Sacramento River supports a small spring-run population, but population status is poorly documented, and the degree of hybridization with fall-run Chinook salmon is unknown. Of the numerous populations once inhabiting Sierra Nevada streams, only the Feather River and Yuba River populations remain. The Feather River population depends on Feather River Hatchery production and may be hybridized with fall-run Chinook salmon. Little is known about the status of the spring-run Chinook salmon population on the Yuba River, other than that it appears to be small.

In addition to outright loss of habitat, Central Valley spring-run Chinook salmon must contend with widespread habitat degradation and modification of rearing and migration habitats in the natal stream, the Sacramento River, and the Sacramento delta. The natal tributaries do not have large impassable dams, like many Central Valley streams, but they do have many small

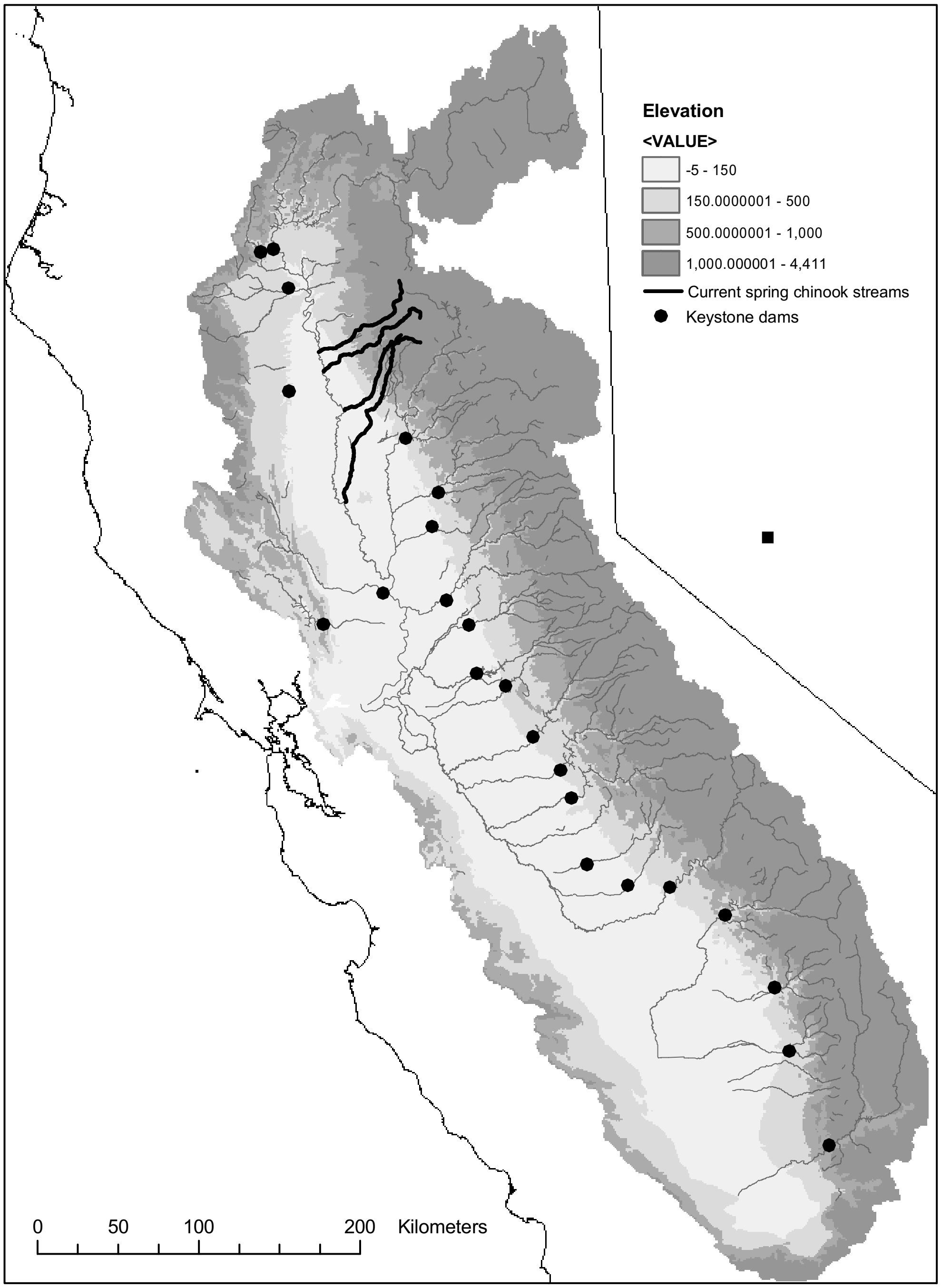

Figure 119. Map of Central Valley, California, showing the locations of spring-run Chinook salmon populations with consistent runs, plus Big Chico Creek, which in recent years has had a small run. These populations are found in the only watersheds with substantial accessible habitat above 500 m elevation. Keystone dams are the lowest impassable dams on a river or stream.

hydropower dams and water diversions that, in some years, have greatly reduced or eliminated in-stream flows during spring-run migration periods. Problems in the migration corridor include unscreened or inadequately screened water diversions, predation by nonnative species, and excessively high water temperatures.

The Feather and Yuba rivers contain populations that are thought to be significantly influenced by the Feather River Hatchery spring-run Chinook salmon stock. The Feather River Hatchery spring-run Chinook salmon program releases its production far downstream of the hatchery,[14] causing high rates of straying (CDFG 2001a). There is concern that fall-run and spring-run Chinook salmon have hybridized in the hatchery. The BRT viewed the Feather River Hatchery stocks as a major threat to the genetic integrity of the remaining wild, spring-run Chinook salmon populations.

Previous BRT Conclusions

In the original Chinook salmon status review, a majority of the BRT concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction (Myers et al. 1998). Listing of this ESU was deferred, and in the status review update, the BRT majority shifted to the view that this ESU was not in danger of extinction, but was likely to become endangered in the foreseeable future (NMFS 1999a). A major reason for this shift was data indicating that a large run of spring-run Chinook salmon on Butte Creek in 1998 was naturally produced, rather than strays from Feather River Hatchery.

Naturally spawning spring-run Chinook salmon in the Feather River were included in the listing, but the Feather River Hatchery stock of spring-run Chinook salmon was excluded.

Listing status: Threatened.

New Data and Updated Analyses

Status Assessments

In 1998, the CDFG reviewed the status of spring-run Chinook salmon in the Sacramento River drainage in response to a petition to list these fish under the California Endangered Species Act (CESA) (CDFG 1998). CDFG concluded that spring-run Chinook salmon formed an interbreeding population segment distinct from other Chinook salmon runs in the Central Valley. CDFG estimated that peak run sizes might have exceeded 600,000 fish in the 1880s, after substantial habitat degradation had already occurred. They blamed the decline of spring-run Chinook salmon on the early commercial gillnet fishery, water development that blocked access to headwater areas, and habitat degradation. Current risks to the remaining populations include continued habitat degradation related to water development and use, and the operation of Feather River Hatchery. CDFG recommended that Sacramento River spring-run Chinook salmon be listed as threatened under the CESA.

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[14] In 2003, California Department of Fish and Game planned to release half its spring-run Chinook salmon production into the river, half into San Pablo Bay.

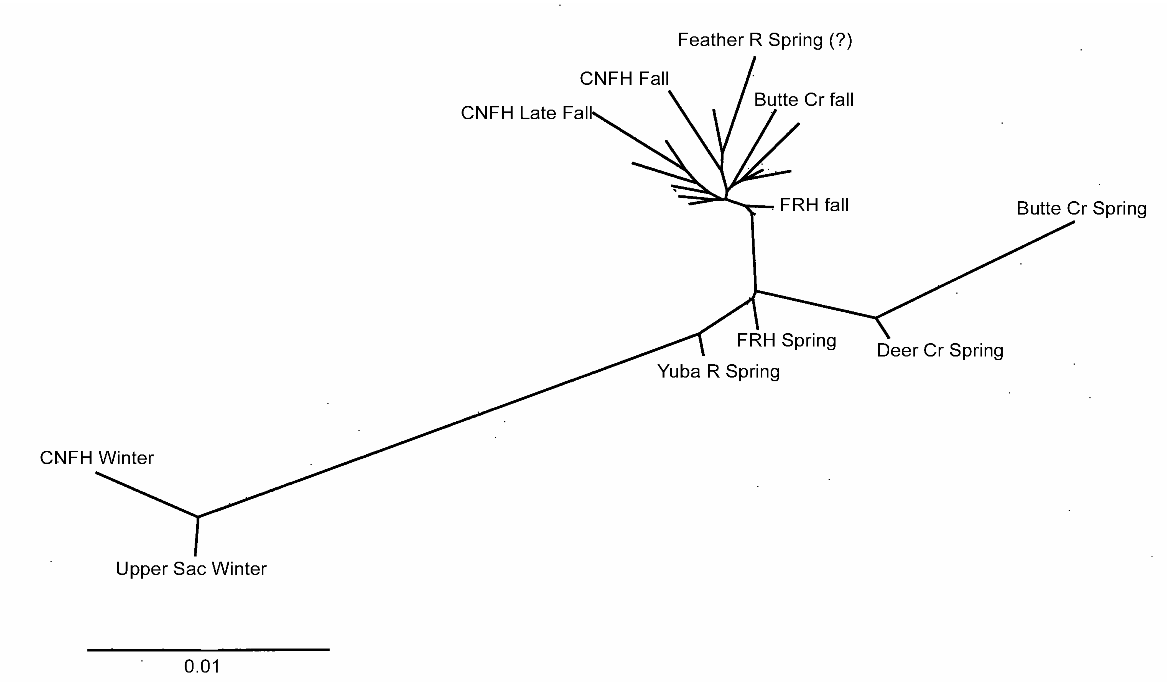

Figure 120. Neighbor joining tree (Cavalli-Sforza and Edwards' [1967] chord distances) for Central Valley Chinook salmon populations, based on 24 polymorphic allozyme loci (Teel unpublished data). Populations labeled with only a number are various fall-run Chinook salmon populations. The "?" after Feather River spring indicates that California Department of Fish and Game biologists are not certain that the fish collected for that sample are truly spring-run Chinook salmon.

Population Structure

There are preliminary results for two studies of spring-run Chinook salmon population structure. The data sets provide two important insights. First, Central Valley spring-run Chinook salmon do not appear to be monophyletic, yet wild Central Valley spring-run Chinook salmon populations from different basins are more closely related to each other than to fall-run Chinook salmon from the same basin. Second, neither Feather River natural-origin nor Feather River Hatchery–origin spring-run Chinook salmon are closely related to any of the three wild populations, although they are closely related to each other and to Central Valley fall-run Chinook salmon.

David Teel of the NWFSC used allozymes to show that Butte and Deer creeks spring-run Chinook salmon are not closely related to sympatric fall-run Chinook salmon populations or the Feather River Hatchery spring-run Chinook salmon stock (Figure 120). Feather River Hatchery spring-run Chinook salmon, putative Feather River natural spring-run Chinook salmon, and Yuba River spring-run Chinook salmon fell into a large cluster composed mostly of natural- and hatchery-origin fall-run Chinook salmon.

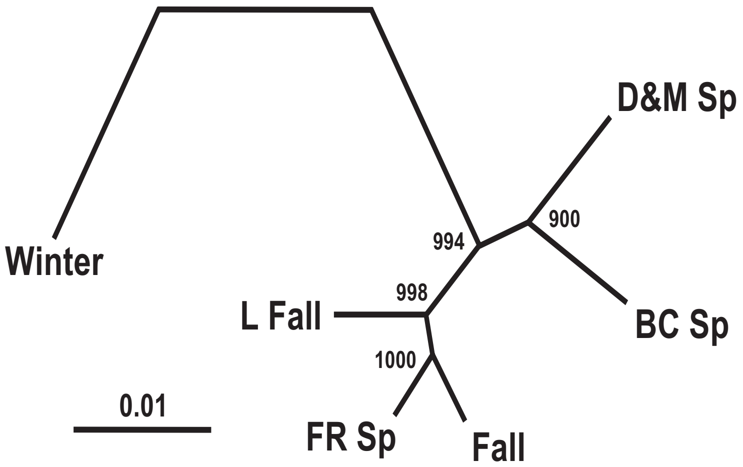

Figure 121. Neighbor joining tree (Cavalli-Sforza and Edwards' [1967] chord distances) for Central Valley Chinook salmon populations, based on 12 microsatellite loci. D&M = Deer and Mill Creek; BC = Butte Creek; FR = Feather River; Sp = spring-run Chinook salmon; L Fall = late-fall-run Chinook salmon; Winter = winter-run Chinook salmon. The tree was constructed using Cavalli-Sforza and Edwards' measure of genetic distance and the unweighted pair-group method arithmetic averaging. Source: Hedgecock (2002).

Dennis Hedgecock, using 12 microsatellite markers, showed two distinct populations of Chinook salmon in the Feather River (Hedgecock 2002). One population is formed by early running (spring-run) Chinook salmon, the other by late running fish (fall-run). Once run timing was accounted for, hatchery and naturally spawning fish appeared to form a homogeneous population. The Feather River spring-run population is most closely related to Feather River fall-run ($F_{st} = 0.010$) and Central Valley fall-run Chinook salmon ($F_{st} = 0.008$) and is distinct from spring-run Chinook salmon in Deer, Mill ($F_{st} = 0.016$), and Butte ($F_{st} = 0.034$) creeks. Figure 121 shows the neighbor joining tree with Cavalli-Sforza and Edwards' (1967) chord distances and unweighted pair-group method arithmetic averaging.

At least two hypotheses could explain the Feather River observations:

1. An ancestral Mill/Deer/Butte-type spring-run Chinook salmon was forced to hybridize with the fall-run Chinook salmon, producing an intermediate form.
2. The ancestral Feather River spring-run Chinook salmon had a common ancestor with the Feather River fall-run Chinook salmon, following the pattern seen in Klamath River Chinook salmon but different from the pattern seen in Deer, Butte, and Mill creeks. The Feather River and Feather River Hatchery populations have merged.

Hedgecock argues against the first hypothesis. Feather River fish cluster well within Central Valley fall-run Chinook salmon rather than between Mill/Deer/Butte spring-run Chinook salmon and Central Valley fall-run Chinook salmon, as would be expected under hypothesis 1. Furthermore, there is no evidence from linkage disequilibria that Feather River spring- and fall-run populations are hybridizing, that is, these populations are reproductively isolated. It is perhaps not surprising that Feather River spring-run Chinook salmon might have a different ancestry than spring-run Chinook salmon in Mill, Deer, and Butte creeks, because the Feather River is in a different ecoregion.

Historical Habitat Loss

Yoshiyama et al. (2001) detailed the historical distribution of Central Valley spring-run Chinook salmon; they estimated that 72% of salmon spawning and rearing habitat has been lost in the Central Valley. This figure is for fall- as well as spring-run Chinook salmon, so the amount of spring-run Chinook salmon habitat lost is presumably higher because spring-run Chinook salmon spawn and rear in higher elevations, areas more likely to be behind impassable dams. They deem the CDFG's 95% loss estimate (Reynolds et al. 1993) as "perhaps somewhat high but probably roughly accurate."

Regardless of the cause of the genetic patterns, these new data do not support the current configuration of the Central Valley spring-run Chinook salmon ESU. Feather River spring-run Chinook salmon do not appear to share a common ancestry or evolutionary trajectory with other spring-run Chinook salmon populations in the Central Valley. They share the designation of spring-run Chinook salmon, and indeed, the Feather River and Feather River Hatchery have a Chinook salmon spawning run that starts much earlier than other Sacramento Basin rivers. There is no longer a distinct bimodal distribution to run timing, and substantial fractions of fish released as Feather River Hatchery spring-run Chinook salmon have returned during the fall-run Chinook salmon period (and vice versa) (CDFG 1998). If Feather River and Feather River Hatchery spring-run Chinook salmon are retained in the Central Valley spring-run Chinook salmon ESU, then the ESU configuration of the Central Valley late-fall-run Chinook salmon ESU (among several others) should be reconsidered for the sake of consistency, because late-fall-run Chinook salmon are more distinct genetically, and arguably as distinct in terms of life history, than Feather River Hatchery spring-run Chinook salmon.

Life History

The CDFG recently began intensive studies of Butte Creek spring-run Chinook salmon (Ward et al. 2002). One of the more interesting observations is that while the great majority of spring-run Chinook salmon leave Butte Creek as young-of-the-year, yearling outmigrants make up roughly 25% of the ocean catch of Butte Creek spring-run Chinook salmon.

Harvest Information

Substantial changes in ocean fisheries off central and northern California have occurred since the last status review (PFMC 2002a, 2002b). Ocean harvest rate of Central Valley spring-run Chinook salmon is thought to be a function of the CVI, which is defined as the ratio of ocean catch south of Point Arena, California, to the sum of this catch and the escapement of Chinook salmon to Central Valley streams and hatcheries. Note that other stocks (e.g., Klamath River Chinook salmon) contribute to the catch south of Point Arena. This harvest index ranged from 0.55 to nearly 0.80 from 1970 to 1995, when harvest regimes were adjusted to protect winter-run Chinook salmon. In 2001, the CVI fell to 0.27. The reduction in harvest is presumably at least partly responsible for the record spawning escapement of fall-run Chinook salmon (≈ 540,000 fish in 2001) and recent increases in spring-run populations.

Coded-wire tagging of juvenile spring-run Chinook salmon in Butte Creek provides some limited information on the ocean distribution of this population; but there have not yet been enough tag recoveries for a full cohort reconstruction. Butte Creek spring-run Chinook salmon have a more northerly distribution than winter-run Chinook salmon (PFMC 2003a), with recoveries off Oregon and in the Klamath Management Zone and Fort Bragg areas. The majority of recoveries have been south of Point Arena.

Abundance Data

The time series of abundance for Mill, Deer, Butte, and Big Chico creeks spring-run Chinook salmon have been updated through 2001. These time series show that the increases in population that started in the early 1990s have continued (Figure 122). During this period, there have been significant habitat improvements (including the removal of several small dams and increases in summer flows) in these watersheds, as well as reduced ocean fisheries and a favorable terrestrial and marine climate.

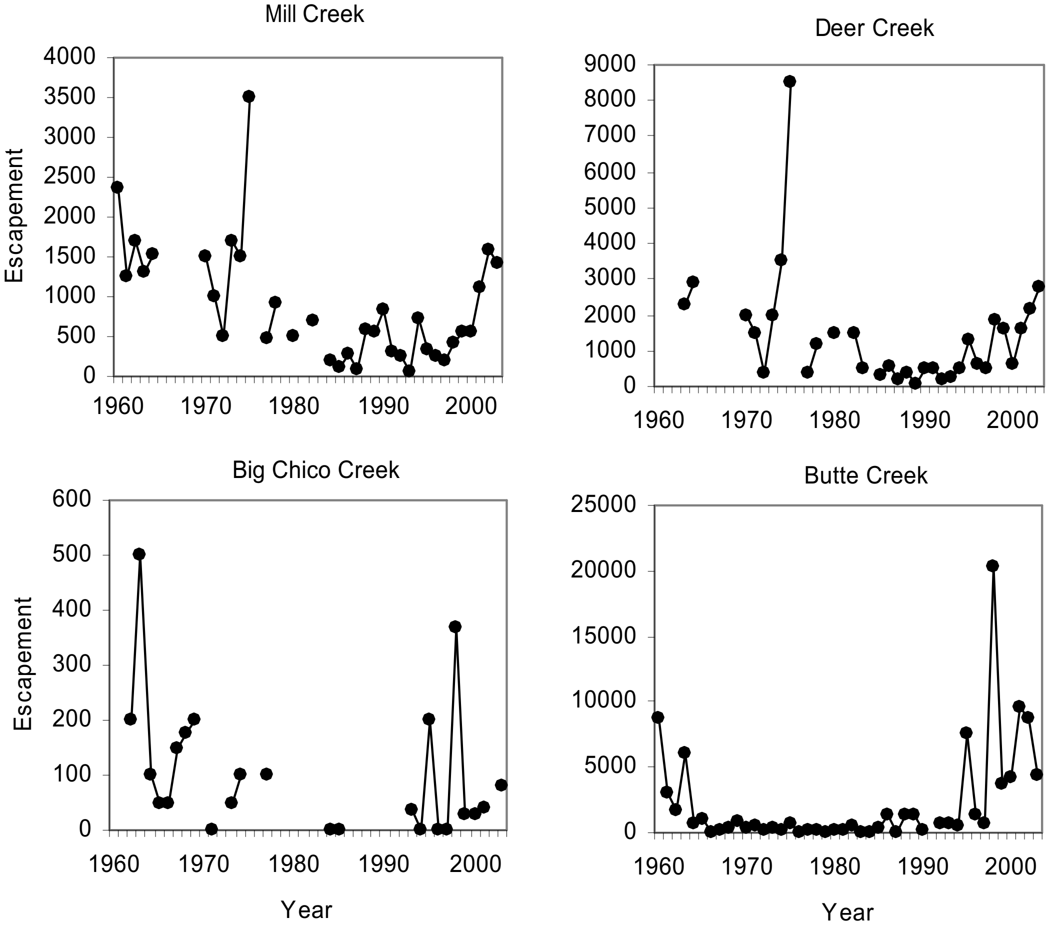

Figure 122. Time series of population abundance for Central Valley spring-run Chinook salmon.

Table 26. Summary statistics for trend analyses for Central Valley spring-run Chinook salmon ESU populations. Numbers in parentheses are 90% confidence intervals.

Population	5-year mean	5-year min	5-year max	λ	μ	Long-term trend	Short-term trend
Sacramento River winter-run Chinook salmon	2,191	364	65,683	0.97 (0.87, 1.09)	–0.10 (–0.21, 0.01)	–0.14 (–0.19, –0.09)	0.26 (0.04, 0.48)
Butte Creek spring-run Chinook salmon	4,513	67	4,513	1.30 (1.09, 1.60)	0.11 (–0.05, 0.28)	0.11 (0.03, 0.19)	0.36 (0.03, 0.70)
Deer Creek spring-run Chinook salmon	1,076	243	1,076	1.17 (1.04, 1.35)	0.12 (–0.02, 0.25)	0.11 (0.02, 0.21)	0.16 (–0.01, 0.33)
Mill Creek spring-run Chinook salmon	491	203	491	1.19 (1.00, 1.47)	0.09 (–0.07, 0.26)	0.06 (–0.04, 0.16)	0.13 (–0.07, 0.34)

The time series for Butte, Deer, and Mill creeks are barely amenable to simple analysis with the random-walk-with-drift model (Holmes 2001, Lindley 2003). The data series are short, and inconsistent methods were used until 1992, when a consistent snorkel survey was initiated on Butte and Deer creeks. The full records for these three systems are analyzed with the knowledge that there may be significant errors in pre-1992 observations. Table 26 summarizes the analyses of these time series.

It appears that the three spring-run Chinook salmon populations in the Central Valley are growing. The current 5-year geometric means for all three populations are also the maximum 5-year means. All three spring-run Chinook salmon populations have long- and short-term $\lambda > 1$ (λ is defined as $\exp[\mu + \sigma^2_p / 2]$—the mean annual population growth rate), with lower bounds of 90% confidence intervals generally >1. Long- and short-term trends are also positive, although some confidence interval lower bounds are negative. Central Valley spring-run Chinook salmon have some of the highest population growth rates in the Central Valley, but other than Butte Creek and the hatchery-influenced Feather River, population sizes are relatively small compared to fall-run Chinook salmon populations (Figure 123).

New Hatchery Information

Feather River Hatchery currently aims to release 5 million spring-run Chinook salmon smolts per year, although actual releases have been mostly lower than this goal (Figure 124). Returns to the hatchery appear to be directly proportional to the releases (Figure 125).

New Comments

The State Water Contractors (SWC 2002) submitted several documents, one of them relevant to the status review for Central Valley spring-run Chinook salmon. The document, “Reconsideration of the Listing Status of Spring-Run Chinook Salmon within the Feather River

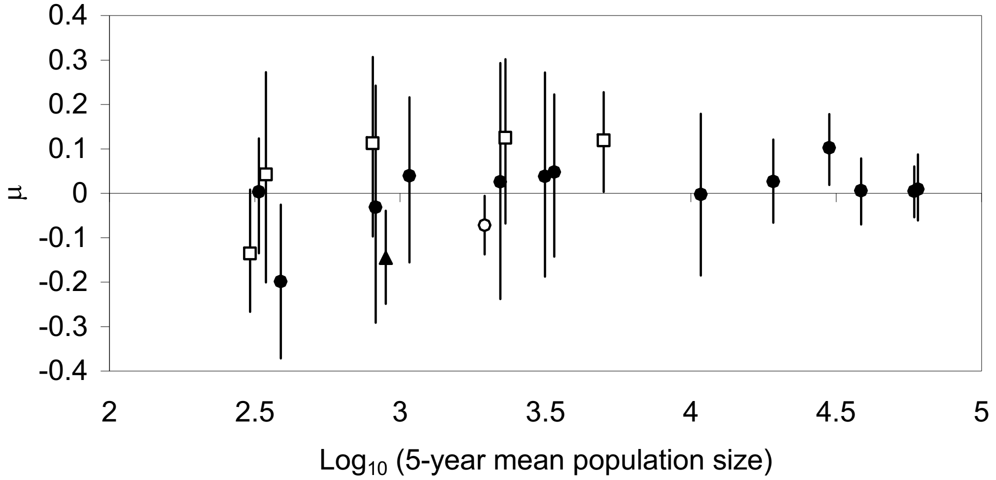

Figure 123. Abundance and growth rate of Central Valley salmonid populations. ○ = steelhead; ☐ = spring-run Chinook; ▲ = winter-run Chinook; • = other Chinook stocks. Error bars represent central 0.90 probability intervals for μ estimates. Note: as defined in other sections of the status reviews, $\mu \approx \log(\lambda)$.

Portion of the Central Valley ESU," argues that Feather River spring-run Chinook salmon should not be included in the Central Valley spring-run Chinook salmon ESU and do not otherwise warrant protection under the ESA. SWC also suggested that NMFS conduct a series of evaluations of the following topics:

- impact of hatchery operations on the population dynamics and the genetic integrity of natural stocks,
- hatcheries as conservation,
- effects of mixed-stock fisheries,
- assessment of the relative roles of different mortality factors,
- experimental assessment of the effects of river operations,
- efficacy of various habitat improvements,
- stock identification for salvage and ocean fishery management, and
- constant fractional marking.

The California Farm Bureau Federation (CFBF 2002) submitted comments with several attachments calling for the removal of most salmonid ESUs from the endangered species list. The attachments included 1) an analysis by Miller (2002) showing that significant and expensive changes to water operations in the delta provide fairly modest benefits to Chinook salmon populations; 2) "Reconsideration of the Listing Status of Spring-Run Chinook Salmon within the Feather River Portion of the Central Valley ESU," discussed in the preceding paragraph; 3) a memo (Palmisano 2003) arguing that because changes in marine climate have been shown to influence salmon stocks, other putative causes for declines of salmonid populations must be

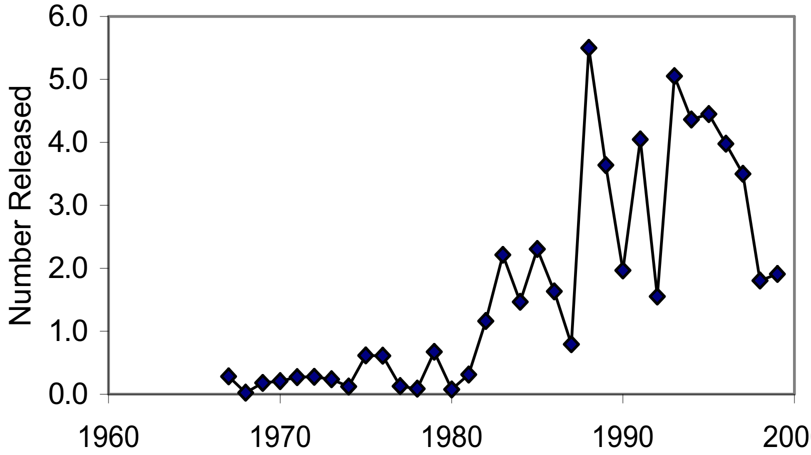

Figure 124. Number of spring-run Chinook salmon released by Feather River Hatchery, 1967–1999.

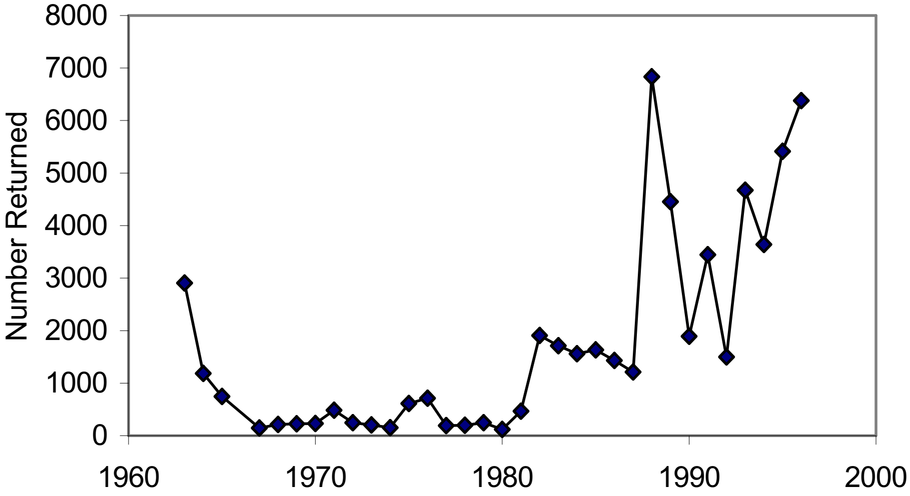

Figure 125. Number of spring-run Chinook salmon returning to Feather River Hatchery, 1963–1999.

overrated. In a CFBF review of the Alsea decision, the CFBF argues that hatchery fish must be included in risk analyses.

Comparison with Previous Data

The upward trends in abundance of the Mill, Deer, and Butte creek populations noted in the most recent previous status review (NMFS 1999a) have apparently continued, probably due in part to the combined effects of habitat restoration, reduced fishing effort in the ocean, and favorable climatic conditions. New population genetics information confirms previous suspicions that Feather River Hatchery and Feather River spring-run Chinook salmon are not closely related to the Mill, Deer, and Butte creek spring-run Chinook salmon populations.

13. Chinook Salmon BRT Conclusions

Snake River Fall-Run Chinook Salmon ESU

A majority (60%) of the BRT votes for the Snake River fall-run 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 (Table 27). 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, when the BRT concluded that Snake River fall-run Chinook salmon "face a substantial risk of extinction if present conditions continue" (Waples et al. 1991b). The BRT found moderately high risks in all VSP elements, with mean risk matrix scores ranging from 3.0 for growth rate/productivity to 3.6 for spatial structure (Table 28).

On the positive side, the number of natural-origin spawners in 2001 was well in excess of 1,000 for the first time since counts at Lower Granite Dam began in 1975. Management actions have reduced (but not eliminated) the fraction of fish passing Lower Granite Dam that are strays from out-of-ESU hatchery programs. Returns in the last 2 years also reflect an increasing contribution from supplementation programs based on the native Lyons Ferry Hatchery broodstock. With the exception of the increase in 2001, the ESU has fluctuated between approximately 500 and 1,000 adults, suggesting a somewhat higher degree of stability in growth rate and trends than is seen in many other salmon populations.

Table 27. Tally of the FEMAT vote distribution regarding the status of nine Chinook salmon ESUs reviewed by the Chinook salmon BRT. Each of 15 BRT members allocated 10 points among the three status categories.

ESU	At risk of extinction	Likely to become endangered	Not likely to become endangered
Snake River fall run	38	91	21
Snake River spring/summer run	30	102	18
Upper Columbia River spring run	79	67	4
Puget Sound	12	111	27
Lower Columbia River	25	107	18
Upper Willamette River	32	105	13
California Coastal[a]	36	100	13
Sacramento River winter run[b]	78	49	3
Central Valley spring run[b]	35	90	5

[a] One BRT member assigned 9 points.

[b] Votes tallied for 13 BRT members.

Table 28. Summary of risk scores (1 = low to 5 = high) for four VSP categories (see subsection, Factors Considered in Status Assessments, for a description of the risk categories) for the nine Chinook salmon ESUs reviewed. Data presented are means (range).

ESU	Abundance	Growth rate/ productivity	Spatial structure and connectivity	Diversity
Snake River fall run	3.4 (2–5)	3.0 (2–5)	3.6 (2–5)	3.5 (2–5)
Snake River spring/summer run	3.6 (2–5)	3.5 (3–5)	2.2 (1–3)	2.3 (1–3)
Upper Columbia River spring run	4.4 (3–5)	4.5 (3–5)	2.9 (2–4)	3.5 (2–5)
Puget Sound	3.3 (2–4)	3.6 (3–4)	2.9 (2–4)	3.2 (2–4)
Lower Columbia River	3.2 (2–4)	3.7 (3–5)	3.5 (3–4)	3.9 (3–5)
Upper Willamette River	3.7 (2–5)	3.1 (2–5)	3.6 (3–4)	3.2 (2–4)
California Coastal[a]	3.9 (3–5)	3.3 (3–4)	3.2 (2–4)	3.1 (2–4)
Sacramento River winter run[b]	3.7 (3–5)	3.5 (2–5)	4.8 (4–5)	4.2 (3–5)
Central Valley spring run[b]	3.5 (3–4)	2.8 (2–4)	3.8 (3–5)	3.8 (3–5)

[a] One BRT member assigned 9 points.

[b] Votes tallied for 13 BRT members.

In spite of the recent increases, however, the recent geometric mean number of naturally produced spawners is still less than 1,000, a very low number for an entire ESU. Because of the large fraction of naturally spawning hatchery fish, it is difficult to assess the productivity of the natural population. The relatively high risk matrix scores for spatial structure and diversity (3.5–3.6) reflect the BRT's concerns that a large fraction of historical habitat for this ESU is inaccessible, diversity associated with those populations has been lost, the single remaining population is vulnerable to variable environmental conditions or catastrophes, and continuing immigration from outside the ESU at levels that are higher than occurred historically. Some BRT members were concerned that the efforts to remove stray, out-of-ESU hatchery fish only occur at Lower Granite Dam, well upstream of the geographic boundary of this ESU. Specific concerns are that natural spawners in lower river areas will be heavily affected by strays from Columbia River hatchery programs, and that this approach effectively removes the natural buffer zone between the Snake River ESU and Columbia River ocean-type Chinook salmon. The effects of these factors on ESU viability are not known, because the extent of natural spawning in areas below Lower Granite Dam is not well understood, except in the lower Tucannon River.

Snake River Spring/Summer-Run Chinook Salmon ESU

About two-thirds (68%) of the BRT votes for the Snake River spring/summer-run 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 (Table 27). As indicated by mean risk matrix scores, the BRT had much higher concerns about abundance (3.6) and growth rate/productivity (3.5) than for spatial structure (2.2) and diversity (2.3) (Table 28).

Although there are concerns about loss of an unquantified number of spawning aggregations that historically may have provided connectivity between headwater populations, natural spawning in this ESU still occurs in a wide range of locations and habitat types.

Like many other ESUs, this one saw a large increase in escapement in many (but not all) populations in 2001. The BRT considered this an encouraging sign, particularly given the record low returns seen in many of these populations in the mid-1990s. However, recent abundance in this ESU is still short of the levels that the proposed recovery plan for Snake River salmon indicated should be met over at least an 8-year period (NMFS 1995a). The BRT considered it a positive sign that the nonnative Rapid River broodstock has been phased out of the Grande Ronde system, but the relatively high level of both production/mitigation and supplementation hatcheries in this ESU leads to ongoing risks to natural populations and makes it difficult to assess trends in natural productivity and growth rate.

Upper Columbia River Spring-Run Chinook Salmon ESU

The BRT's assessment of the overall risks faced by the Upper Columbia River spring-run Chinook salmon ESU were divided, with a slight majority (53%) of the votes cast in the "danger of extinction" category and a substantial minority (45%) in the "likely to be endangered" category (Table 27). The mean risk matrix scores reflect strong ongoing concerns regarding abundance (4.4) and growth rate/productivity (4.5) in this ESU and somewhat less (but still significant) concerns for spatial structure (2.9) and diversity (3.5) (Table 28).

Many populations in this ESU have rebounded somewhat from the critically low levels that immediately preceded the last status review evaluation, which was reflected in the substantial minority of BRT votes not cast in the "danger of extinction" category. Although the BRT considered this an encouraging sign, the last year or two of higher returns come on the heels of a decade or more of steep declines to all-time record low escapements. In addition, this ESU continues to have a very large influence from hatchery production, both from production/mitigation and supplementation programs. The extreme management measures taken in an effort to maintain populations in this ESU during some years in the late 1990s (collecting all adults from major basins at downstream dams) are a strong indication of the ongoing risks to this ESU, although the associated hatchery programs may ultimately play a role in helping to restore self-sustaining natural populations.

Puget Sound Chinook Salmon ESU

A majority (74%) of the BRT votes for the Puget Sound 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 (Table 27). The BRT found moderately high risks in all VSP elements, with mean risk matrix scores ranging from 2.9 for spatial structure to 3.6 for growth rate/productivity (Table 28).

Most population indices for this ESU have not changed substantially since the last BRT assessment. The Puget Sound TRT has identified approximately 31 historical populations, of which nine are believed to be extinct; most of the populations that have been lost were early run. Other concerns noted by the BRT are the concentration of the majority of natural production in just two basins, high levels of hatchery production in many areas of the ESU, and widespread loss of estuary and lower floodplain habitat diversity (and, likely, associated life history types). Although in the last 2 to 3 years populations in this ESU have not experienced the sharp increases seen in many other ESUs, more populations increased than decreased over the 4 years since the last BRT assessment. After adjusting for changes in harvest rates, however, trends in productivity are less favorable. Most populations are relatively small, and recent natural production within the ESU is only a fraction of estimated historical run size. On the positive side, harvest rates for all populations have been reduced from their peaks in the 1980s, and some hatchery reforms have been implemented (e.g., elimination of many net pen programs that were leading to widespread straying, and transition of other programs to more local broodstocks). The BRT felt that these management changes should help facilitate recovery if other limiting factors (especially habitat degradation) are also addressed. The BRT felt that the large recovery effort organized around the Puget Sound Shared Strategy was a positive step because it could help to link and coordinate efforts in many separate, local watersheds.

Lower Columbia River Chinook Salmon ESU

A majority (71%) 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 (Table 27). Moderately high concerns for all VSP elements are indicated by mean risk matrix scores ranging from 3.2 for abundance to 3.9 for diversity (Table 28).

The BRT still considered all of the risk factors identified in previous reviews. The 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 remains an important BRT concern. Although some natural production currently occurs in 20 or so populations, only one exceeds 1,000 spawners. High hatchery production continues to pose genetic and ecological risks to natural populations and to mask their performance. Most populations in this ESU have not seen as pronounced increases in recent years as occurred in many other geographic areas.

Upper Willamette River Chinook Salmon ESU

A majority (70%) of the BRT votes for the Upper Willamette 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 (Table 27). The BRT found moderately high risks in all VSP elements (mean risk matrix scores ranged from 3.1 for growth rate/productivity to 3.6 for spatial structure) (Table 28).

Although the number of adult spring-run Chinook salmon crossing Willamette Falls is in the same range (about 20,000–70,000) it has been in for the last 50 years, a large fraction of these are hatchery produced. The score for spatial structure reflects BRT concern that perhaps a third of the historical habitat used by fish in this ESU is currently inaccessible behind dams, and the BRT remained concerned that natural production in this ESU is restricted to a very few areas. Increases in natural production in the last 3 to 4 years in the largest remaining population (the McKenzie) were considered encouraging by the BRT. With the relatively large incidence of hatchery fish, it is difficult to determine trends in natural production.

California Coastal Chinook Salmon ESU

A majority (67%) of the BRT votes for the California Coastal Chinook salmon ESU fell in the "likely to become endangered" category, with votes falling in the "danger of extinction" category outnumbering those in "not warranted" category by nearly two to one (Table 27). The BRT found moderately high risks in all VSP elements, with mean risk matrix scores ranging from 3.1 for diversity to 3.9 for abundance (Table 28).

The BRT was concerned about continued evidence of low population sizes relative to historical abundance and mixed trends in the few time series of abundance indices available for analysis, and by the low abundances and potential extirpations of populations in the southern part of the ESU. The BRT's concerns regarding genetic integrity of this ESU were moderate or low relative to similar issues for other ESUs because 1) hatchery production in this ESU is on a minor scale, and 2) current hatchery programs are largely focused on supplementing and restoring local populations. However, the BRT did have concerns with respect to diversity that were based largely on the loss of spring-run Chinook salmon in the Eel River basin and elsewhere in the ESU, and to a lesser degree on the potential loss of diversity concurrent with low abundance or extirpation of populations in the southern portion of the ESU. Overall, the BRT was very concerned about the paucity of information and resultant uncertainty associated with estimates of abundance, natural productivity, and distribution of Chinook salmon in this ESU.

Sacramento River Winter-Run Chinook Salmon ESU

A majority (60%) of the BRT votes for the Sacramento River winter-run Chinook salmon ESU fell into the "in danger of extinction" category, with a minority (38%) voting for the "likely to become endangered" and only 2% voting for "not warranted." (Table 27). The main VSP concerns were in the spatial structure and diversity categories (4.8 and 4.2, respectively), although there was significant concern about the abundance and productivity categories (3.7 and 3.5, respectively) (Table 28).

The BRT's main concerns relate to the lack of diversity within this ESU. The BRT was very troubled that this ESU is represented by a single population that has been displaced from its historical spawning habitat into an artificial habitat created and maintained by a dam. The BRT presumed that several independent populations of winter-run Chinook salmon were merged into a single population, with the potential for a significant loss of life history and genetic diversity. Furthermore, the population has passed through at least two recent bottlenecks—one when Shasta Dam was filled and another in the late 1980s and early 1990s—that probably further reduced genetic diversity. The population has been removed from the environment where it evolved, dimming its long-term prospects for survival. The BRT was modestly heartened by the increase in abundance since the lows of the late 1980s and early 1990s.

Central Valley Spring-Run Chinook Salmon ESU

A large majority (69%) of the BRT votes for the Central Valley spring-run Chinook salmon ESU fell into the "likely to become endangered" category, with a minority (27%) of votes going to "in danger of extinction" and (4%) "not warranted" (Table 27). Concerns about abundance, spatial structure, and diversity (3.5–3.8) were roughly equal, with less concern about productivity (2.8) (Table 28).

A major BRT concern was loss of diversity caused by the extirpation of spring-run Chinook salmon populations from most of the Central Valley, including all San Joaquin River tributaries. The only populations left in the Sierra Nevada ecoregion are supported by the Feather River Hatchery. Another major BRT concern was the small number and location of extant spring-run Chinook salmon populations—only three streams, originating in the southern Cascade Mountains, support self-sustaining runs of spring-run Chinook salmon, which are close together, increasing their vulnerability to catastrophe. Two of the three extant populations are fairly small, and all were recently quite small. The BRT was also concerned about the Feather River Hatchery spring-run Chinook salmon population, which is not in the ESU but does produce fish that potentially could interact with other spring-run Chinook salmon populations, especially given the off-site release of the production.

STEELHEAD

14. Background and History of Steelhead Listings

Background

Steelhead is the name commonly applied to the anadromous form of the biological species *Oncorhynchus mykiss*. The present distribution of steelhead extends from the Kamchatka Peninsula in Asia, east to Alaska, and south to southern California (NMFS 1999a), although the historical range of *O. mykiss* extended at least to the Mexico border (Busby et al. 1996). *O. mykiss* exhibit perhaps the most complex suite of life history traits of any species of Pacific salmonid. They can be anadromous or freshwater resident (and under some circumstances, apparently yield offspring of the opposite form). Those that are anadromous can spend up to 7 years in freshwater prior to smoltification, then spend up to 3 years in salt water prior to first spawning. The half-pounder life history type in southern Oregon and northern California spends only 2 to 4 months in salt water after smoltification, then returns to freshwater and outmigrates to sea again the following spring without spawning. This species can also spawn more than once (iteroparous), whereas all other species of *Oncorhynchus* except *O. clarki* spawn once then die (semelparous). The anadromous form is under the jurisdiction of NMFS, while the resident freshwater forms, usually called rainbow or redband trout, are under the jurisdiction of USFWS.

Although no subspecies are currently recognized within any species of Pacific salmon, Behnke (1992) proposed that two subspecies of *O. mykiss* with anadromous life history occur in North America: *O. mykiss irideus* (the coastal subspecies), which includes coastal populations from Alaska to California (including the Sacramento River), and *O. mykiss gairdneri* (the inland subspecies), which includes populations from the interior Columbia, Snake, and Fraser rivers. In the Columbia River, the boundary between the two subspecies occurs at approximately the Cascade Crest. A third subspecies of anadromous *O. mykiss* (*O. mykiss mykiss*) occurs in Kamchatka, and several other subspecies of *O. mykiss* are recognized that have only resident forms (Behnke 1992).

Within the range of West Coast steelhead, spawning migrations occur throughout the year, with seasonal peaks of activity. In a given river basin there may be one or more peaks in migration activity; because these runs are usually named for the season in which the peak occurs, some rivers may have runs known as winter-, spring-, summer-, or fall-run steelhead. For example, large rivers, such as the Columbia, Rogue, and Klamath rivers, have migrating adult steelhead at all times of the year. Local variations in the names identify the seasonal runs of steelhead; in northern California, some biologists have retained the terms spring- and fall-run steelhead to describe what others would call summer-run steelhead.

Steelhead can be divided into two basic reproductive ecotypes, based on the state of sexual maturity at the time of river entry and duration of spawning migration (Burgner et al. 1992). The stream-maturing type (summer-run steelhead in the Pacific Northwest and northern California) enters freshwater in a sexually immature condition between May and October and requires several months to mature and spawn. The ocean-maturing type (winter-run steelhead in the Pacific Northwest and northern California) enters freshwater between November and April, with well-developed gonads, and spawns shortly thereafter. In basins with both summer and winter steelhead runs, the summer run appears to occur where habitat is not fully used by the winter run or where a seasonal hydrologic barrier, such as a waterfall, separates them. Summer-run steelhead usually spawn farther upstream than winter-run steelhead (Withler 1966, Roelofs 1983, Behnke 1992). Coastal streams are dominated by winter-run steelhead, whereas inland steelhead of the Columbia River basin are almost exclusively summer-run steelhead. Winter-run steelhead may have been excluded from inland areas of the Columbia River basin by Celilo Falls or by the considerable migration distance from the ocean. The Sacramento–San Joaquin River basin may have historically had multiple runs of steelhead, which probably included both ocean- and stream-maturing stocks (CDFG 1995, McEwan and Jackson 1996). These steelhead are referred to as winter-run steelhead by the California Department of Fish and Game (CDFG); however, some biologists call them fall-run steelhead (Cramer et al. 1995).

Inland steelhead of the Columbia River basin, especially the Snake River subbasin, are commonly referred to as either A-run or B-run. These designations are based on a bimodal migration of adult steelhead at Bonneville Dam (235 km from the mouth of the Columbia River) and differences in age (1- versus 2-ocean) and adult size observed among Snake River steelhead. It is unclear, however, whether life history and body-size differences observed upstream are correlated back to the groups forming the bimodal migration observed at Bonneville Dam. Furthermore, the relationship between patterns observed at the dams and distribution of adults in spawning areas throughout the Snake River basin is not well understood. A-run steelhead are believed to occur throughout the steelhead-bearing streams of the Snake River basin and the inland Columbia River; B-run steelhead are thought to be produced only in the Clearwater, Middle Fork Salmon, and South Fork Salmon rivers (IDFG 1994).

The half-pounder is an immature steelhead that returns to freshwater after only 2 to 4 months in the ocean, generally overwinters in freshwater, then outmigrates again the following spring. Half-pounders are generally less than 400 mm and are reported only from the Rogue, Klamath, Mad, and Eel rivers of southern Oregon and northern California (Snyder 1925, Kesner and Barnhart 1972, Everest 1973, Barnhart 1986); however, it has been suggested that as mature steelhead, these fish may only spawn in the Rogue and Klamath river basins (Cramer et al. 1995). Various explanations for this unusual life history have been proposed, but there is still no consensus as to what, if any, advantage it affords to the steelhead of these rivers.

In May 1992, the Oregon Natural Resources Council (ONRC) and 10 copetitioners petitioned NMFS to list Oregon's Illinois River winter-run steelhead (ONRC et al. 1992). NMFS concluded that Illinois River winter-run steelhead by themselves did not constitute an ESA "species" (Busby et al. 1993, NMFS 1993b). In February 1994, NMFS received a petition seeking protection under the ESA for 178 populations of steelhead (anadromous *O. mykiss*) in Washington, Idaho, Oregon, and California. At the time, NMFS was conducting a status review of coastal steelhead populations (*O. mykiss irideus*) in Washington, Oregon, and California. In response to the broader petition, NMFS expanded the ongoing status review to include inland steelhead (*O. mykiss gairdneri*) occurring east of the Cascade Mountains in Washington, Idaho, and Oregon.

In 1995, the steelhead BRT met to review the biology and ecology of West Coast steelhead. After considering available information on steelhead genetics, phylogeny, and life history; freshwater ichthyogeography; and environmental features that may affect steelhead, the BRT identified 15 ESUs—12 coastal forms and 3 inland forms. After considering available information on population abundance and other risk factors, the BRT concluded that 5 steelhead ESUs (Central California Coast, South-Central California Coast, Southern California, California Central Valley, and Upper Columbia River) were presently in danger of extinction, 5 steelhead ESUs (Lower Columbia River, Oregon Coast, Klamath Mountains Province, Northern California, and Snake River Basin) were likely to become endangered in the foreseeable future, 4 steelhead ESUs (Puget Sound, Olympic Peninsula, Southwest Washington, and Upper Willamette River) were not presently in significant danger of becoming extinct or endangered, although individual stocks within these ESUs may be at risk, and 1 steelhead ESU (Middle Columbia River) was not presently in danger of extinction but the BRT was unable to reach a conclusion as to its risk of becoming endangered in the foreseeable future.

Of the 15 steelhead ESUs identified by NMFS, 5 are not listed under the ESA: Southwest Washington, Olympic Peninsula, and Puget Sound (NMFS 1996a), Oregon Coast (NMFS 1998c), and Klamath Mountain Province (NMFS 2001c); 8 are listed as threatened: Snake River Basin, Central California Coast and South-Central California Coast (NMFS 1997b), Lower Columbia River, California Central Valley (NMFS 1998c), Upper Willamette River, Middle Columbia River (NMFS 1999b), and Northern California (NMFS 2000), and 2 are listed as endangered: Upper Columbia River and Southern California (NMFS 1997b).

The West Coast Steelhead BRT[15] met in January, March, and April 2003 to discuss new data received and to determine whether the new information warranted any modification of the original BRT's conclusions. This report summarizes new information and the preliminary BRT conclusions on the following ESUs: Snake River Basin, Upper Columbia River, Middle Columbia River, Lower Columbia River, Upper Willamette River, Northern California, Central California Coast, South-Central California Coast, Southern California, and California Central Valley.

Resident Fish

As mentioned earlier, *O. mykiss* exhibits varying degrees of anadromy. Nonanadromous forms are usually called rainbow trout; however, nonanadromous inland *O. mykiss* are often

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[15] The BRT for the updated status review for West Coast steelhead included from the NMFS Northwest Fisheries Science Center: Thomas Cooney, Dr. Robert Iwamoto, Gene Matthews, Dr. Paul McElhany, Dr. James Myers, Dr. Mary Ruckelshaus, Dr. Thomas Wainwright, Dr. Robin Waples, and Dr. John Williams; from NMFS Southwest Fisheries Science Center: Dr. Peter Adams, Dr. Eric Bjorkstedt, Dr. David Boughton, Dr. John Carlos Garza, Dr. Steve Lindley, and Dr. Brian Spence; from the U.S. Fish and Wildlife Service, Abernathy, WA: Dr. Donald Campton; and from the USGS Biological Resources Division, Seattle: Dr. Reginald Reisenbichler.

called Columbia River redband trout. A form that occurs in the upper Sacramento River is called Sacramento redband trout. Although the anadromous and nonanadromous forms have long been taxonomically classified within the same species, in any given area the exact relationship between the forms is not well understood. In coastal populations, it is unusual for the two forms to co-occur; they are usually separated by a natural or man-made migration barrier. Co-occurrence of the two forms in inland populations appears to be more frequent. Where they co-occur, "it is possible that offspring of resident fish may migrate to the sea, and offspring of steelhead may remain in streams as resident fish" (Burgner et al. 1992, p. 6; Shapovalov and Taft 1954). Mullan et al. (1992) found evidence that in very cold streams, juvenile steelhead had difficulty attaining mean threshold size for smoltification and concluded that most fish in the Methow River in Washington that did not emigrate downstream early in life were thermally fated to a resident life history regardless of whether they were the progeny of anadromous or resident parents. Additionally, Shapovalov and Taft (1954) reported evidence of *O. mykiss* maturing in freshwater and spawning prior to their first ocean migration; this life history variation has also been found in cutthroat trout (*O. clarki*) and some male Chinook salmon (*O. tshawytscha*).

As part of this status review update, a concerted effort was made to collect biological information for resident populations of *O. mykiss*. Information from listed ESUs in Washington, Oregon, and Idaho is contained in a draft report by Kostow (2003) and summarized in Appendix B, Table B-1; relevant information for specific ESUs is presented in subsequent sections. Information about resident *O. mykiss* populations in California is in Appendix B, Table B-2.

The BRT had to consider in more general terms how to conduct an overall risk assessment for an ESU that includes both resident and anadromous populations, particularly when the resident individuals may outnumber the anadromous ones but their biological relationship is unclear or unknown. Some guidance is found in Waples (1991), which outlines the scientific basis for the NMFS ESU policy. That paper suggests that an ESU that contains both forms could be listed based on a threat to only one of the life history traits "if the trait were genetically based and loss of the trait would compromise the 'distinctiveness' of the population" (p. 16). That is, if anadromy were considered important in defining the distinctiveness of the ESU, loss of that trait would be a serious ESA concern. In discussing this issue, the NMFS ESU policy (NMFS 1991a) affirmed the importance of considering the genetic basis of life history traits such as anadromy and recognized the relevance of a question posed by one commenter: "What is the likelihood of the nonanadromous form giving rise to the anadromous form after the latter has gone locally extinct?"

The BRT discussed another important consideration—the role anadromous populations play in providing connectivity and linkages among different spawning populations within an ESU. An ESU in which all anadromous populations are lost and the remaining resident populations are fragmented and isolated would have a very different future evolutionary trajectory than one in which all populations remain linked genetically and ecologically by anadromous forms. Furthermore, in many (if not all) *O. mykiss* ESUs, the geographic area used by anadromous (but not resident) fish may represent a "significant portion of the range" of the ESA species, especially if considering the area the marine migration encompasses.

In spite of concerted efforts to collect and synthesize available information on resident forms of *O. mykiss*, existing data are very sparse, particularly regarding interactions between resident and anadromous forms (Kostow 2003). The BRT was frustrated by the complex questions involving the relationship between resident and anadromous forms, given this paucity of key information. To focus the issue, the BRT considered a hypothetical scenario that has varying degrees of relevance to individual steelhead ESUs. In this scenario, the once-abundant and widespread anadromous life history is extinct, or nearly so, but relatively healthy native populations of resident fish remain in many geographic areas. The question the BRT considered was: Under what circumstances would you conclude that such an ESU was not in danger of extinction or likely to become endangered? The BRT identified the required conditions as follows:

- The resident forms are capable of maintaining connectivity among populations to the extent that the ESU's historical evolutionary processes are not seriously disrupted.
- The anadromous life history is not permanently lost from the ESU but can be regenerated from the resident forms.

Regarding the first criterion, although some resident salmonid forms are known to migrate considerable distances in freshwater, extensive river migrations have not been demonstrated to be an important behavior for resident *O. mykiss*, except in rather specialized circumstances (e.g., forms that migrate from a stream to a large lake or reservoir as a surrogate for the ocean). Therefore, the BRT felt that loss of the anadromous form would, in most cases, substantially change the character and future evolutionary potential of steelhead ESUs. Regarding the second criterion, it is well established that resident forms of *O. mykiss* can occasionally produce anadromous migrants, and vice versa (Mullan et al. 1992, Zimmerman and Reeves 2000, Kostow 2003), just as has been shown for other salmonid species such as *O. nerka* (Foerster 1947, Fulton and Pearson 1981, Kaeriyama et al. 1992), coastal cutthroat trout (*O. clarki clarki)* (Griswold 1996, Johnson et al. 1999), brown trout (*Salmo trutta*) (Jonsson 1985), and Arctic char (*Salvelinus alpinus*) (Nordeng 1983). However, available information indicates that these occurrences are relatively rare, and there is even less empirical evidence that, once lost, a self-sustaining anadromous run can be regenerated from a resident salmonid population. Although regeneration must have occurred during the evolutionary history of *O. mykiss,* the BRT found no reason to believe that such an event would occur with any frequency or within a specified time period. This would be particularly true if the conditions that promote and support the anadromous life history continue to deteriorate. In this case, the expectation would be that natural selection would gradually eliminate the migratory or anadromous trait from the population, as individuals inheriting a tendency for anadromy migrate out of the population but do not survive to return as adults and pass on their genes to subsequent generations.

Given the above considerations, the BRT focused primarily on information for anadromous populations in the risk assessments for steelhead ESUs. This was particularly true with respect to case 3 resident fish populations, the vast majority of which are of uncertain ESU status. However, as discussed in Section 25, BRT Conclusions, the presence of relatively numerous, native resident fish was considered to be a mitigating risk factor for some ESUs.

15. Snake River Basin Steelhead ESU

The Snake River Basin steelhead ESU is distributed throughout the Snake River drainage system, including tributaries in southwest Washington, eastern Oregon, and north/central Idaho (NMFS 1996a). Snake River steelhead migrate a substantial distance from the ocean (up to 1,500 km) and use high-elevation tributaries (typically 1,000–2,000 m above sea level) for spawning and juvenile rearing. Snake River steelhead occupy habitat that is considerably warmer and drier (on an annual basis) than other steelhead ESUs. Snake River basin steelhead are generally classified as summer run, based on their adult run-timing patterns. Summer-run steelhead enter the Columbia River from late June to October. After holding over the winter, summer-run steelhead spawn the following spring (March to May). Managers classify upriver summer steelhead runs into two groups based primarily on ocean age and adult size on return to the Columbia River: A-run steelhead are predominantly age-1 ocean fish, while B-run steelhead are larger, predominated by age-2 ocean fish.

With the exception of the Tucannon River and some small tributaries to the mainstem Snake River, the tributary habitat used by Snake River Basin steelhead ESU is above Lower Granite Dam. Major groupings of populations and subpopulations can be found in 1) the Grande Ronde River system; 2) the Imnaha River drainage; 3) the Clearwater River drainages; 4) the South Fork Salmon River; 5) the smaller mainstem tributaries before the confluence of the mainstem Snake River; 6) the Middle Fork Salmon River, 7) the Lemhi and Pahsimeroi rivers, and 8) upper Salmon River tributaries.

Resident *O. mykiss* are believed to be present in many of the drainages used by Snake River steelhead. Very little is known about interactions between co-occurring resident and anadromous forms within this ESU. The following review of abundance and trend information focuses on information directly related to the anadromous form.

Historical Returns

Although direct historical estimates of production from the Snake River basin are not available, the basin is believed to have supported more than half the total steelhead production from the Columbia River basin (Mallet 1974). There are some historical estimates of returns to portions of the drainage. Lewiston Dam, on the lower Clearwater River, began operation in 1927. Counts of steelhead passing through the adult fish ladder at the dam reached 40,000–60,000 in the early 1960s (Cichosz et al. 2001). Based on relative drainage areas, the Salmon River basin likely supported substantial production as well. In the early 1960s, returns to the Grande Ronde and Imnaha rivers may have exceeded 15,000 and 4,000 steelhead per year, respectively (ODFW 1991). Extrapolations from tag-recapture data indicate that the natural steelhead return to the Tucannon River may have exceeded 3,000 adults in the mid-1950s (Thompson et al. 1958).

Summary of Previous BRT Conclusions

The primary concern regarding Snake River steelhead identified in the 1998 status review was a sharp decline in natural stock returns beginning in the mid-1980s. Of 13 trend indicators at that time, 9 were in decline and 4 were increasing. In addition, Idaho Department of Fish and Game (IDFG) parr survey data indicated declines for both A-run and B-run steelhead in wild and natural stock areas. The high proportion of hatchery fish in the run was also identified as a concern, particularly because of the lack of information on the actual contribution of hatchery fish to natural spawning. The review recognized that some wild spawning areas have relatively little hatchery spawning influence (Selway, lower Clearwater, Middle and South Fork Salmon, and lower Salmon rivers). In other areas, such as the upper Salmon River, there is likely little or no natural production of locally native steelhead. The review identified threats to genetic integrity from past and present hatchery practices as a concern. A concern for the North Fork Clearwater stock was also identified: the stock is currently maintained through the Dworshak Hatchery program but cut off from access to its native tributary by Dworshak Dam. The 1998 review also highlighted concerns for widespread habitat degradation and flow impairment throughout the Snake River basin and for substantial modification of the seaward migration corridor by hydroelectric power development on the Snake and mainstem Columbia rivers.

The previous BRT status review noted that the aggregate trend in abundance as measured by ladder counts at the uppermost Snake River dam (Lower Granite Dam, since 1972) has been upward since the mid-1970s, while the aggregate return of naturally produced steelhead was downward for the same period (Table 29). The decline in natural production was especially pronounced in the later years in the series.

Listing status: Threatened.

New Data and Updated Analyses

Abundance and Trends

Estimates of annual returns to specific production areas are not available for most of the Snake River Basin steelhead ESU. Estimates are available for two tributaries below Lower Granite Dam (Tucannon and Asotin creeks). Annual ladder counts at the dam, and associated sampling information, allow for an estimate of aggregate returns to the Snake River basin.

In addition, area-specific estimates are available for the Imnaha River and two major sections of the Grande Ronde River system. Updated estimates of return levels are summarized in Table 29. Returns to Lower Granite Dam remained at relatively low levels through the 1990s; the 2001 run size at Lower Granite Dam was substantially higher relative to the 1990s (see Figures 126 and 127). The recent geometric mean abundance was down for the Tucannon River relative to the last BRT status review. Returns to the Imnaha and Grande Ronde river survey areas were generally higher relative to the early 1990s (see Figures 128–130).

Table 29. Summary of abundance and trend estimates for the Snake River Basin steelhead ESU. Interim delisting target levels are explained in the text.

Populations	5-year mean % natural origin	Recent 5-year geometric mean			Short-term trend (%/year)		Interim target	Current vs. target
		Total	Natural					
		Mean (range)	Current	Previous	Current	Previous		
Tucannon[a]	26 [44][e]	407 (257–628)	106	140	–3.7	–18.3	1,300	8%
Lower Granite Run[b]	14	106,175 (70,721–259,145)	14,864	9,500	+6.1	+6.9	52,100	29%
Snake A run[b]	15	87,842 (50,974–25,950)	12,667	–	+8.5	–	–	–
Snake B run[b]	11	17,305 (9,736–33,195)	1,890	–	–0.6	–	–	–
Asotin Creek[c]	Unknown	87 exp. redds (0–543)	–	200	+4.0	–19.7	500	–
Upper Grande Ronde[d]	77	1.54 rpm[f] (0.3–4.7)	–	–	–2.9	–	–	–
Joseph Creek	100[g]	1,542 (1,077–2,385)	1,542	–	+5.0	–	1,400	110%
Imnaha[d]	80	3.7 rpm[f] (2.0–6.8)	–	–	–3.7	–	–	–
Camp Creek	100[g]	155 (55–307)	155	80	+2.0	+1.7	–	–

[a] 5-year geometric mean calculated using years 1999–2001.

[b] 5-year geometric mean calculated using years 1997–2001.

[c] 5-year geometric mean calculated using years 1998–2001.

[d] 5-year geometric mean calculated using years 1996–2000.

[e] Estimate from previous status review.

[f] rpm = redds per mile.

[g] Assumed 100%; no hatchery releases into basin.

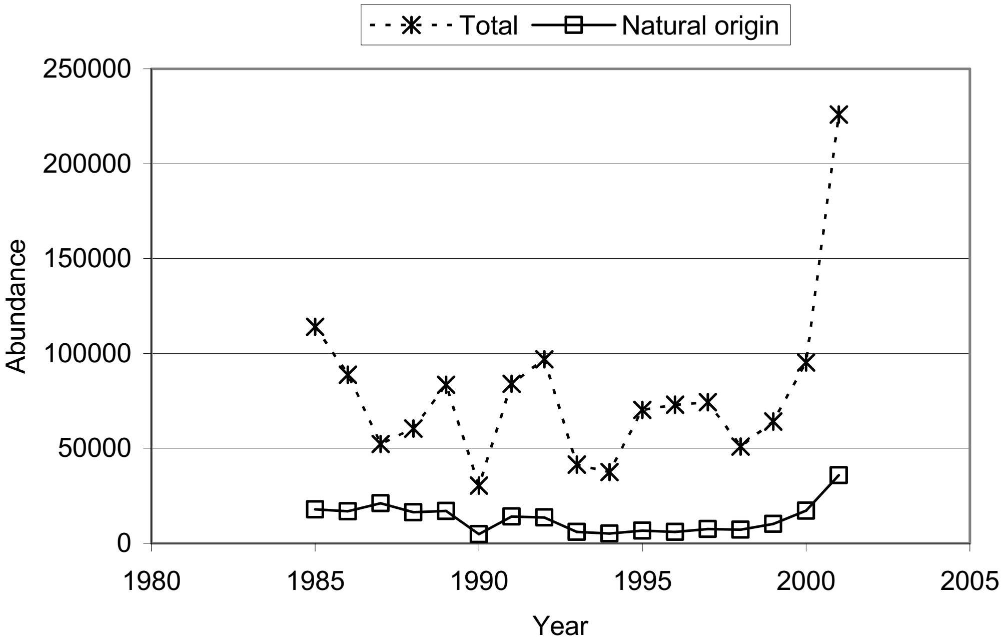

Figure 126. Lower Granite Dam counts of Snake River A-run steelhead, 1985–2001. Source: Yuen (2002).

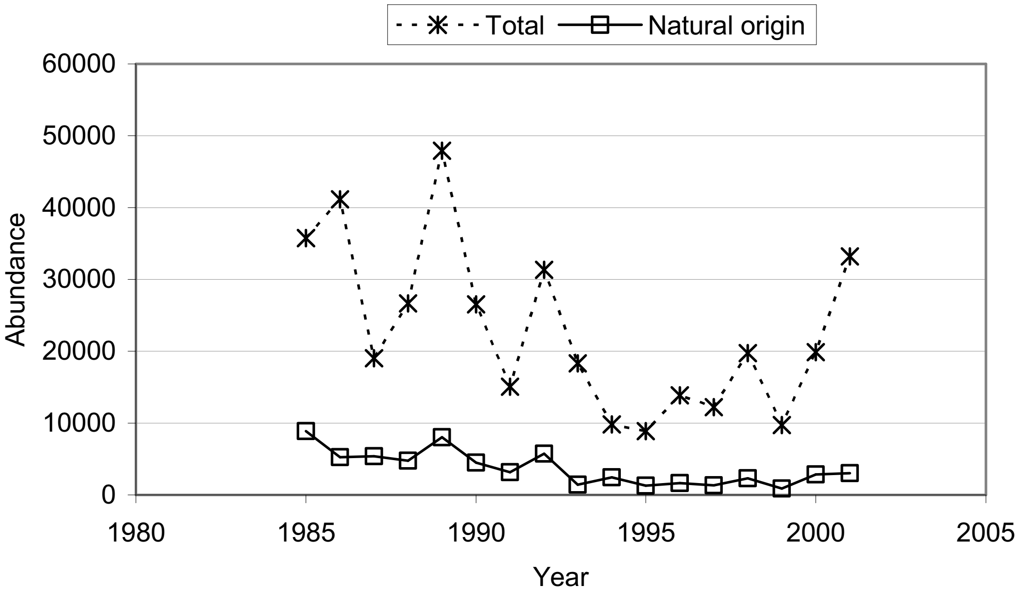

Figure 127. Lower Granite Dam counts of Snake River B-run steelhead, 1985–2001. Source: Yuen (2002).

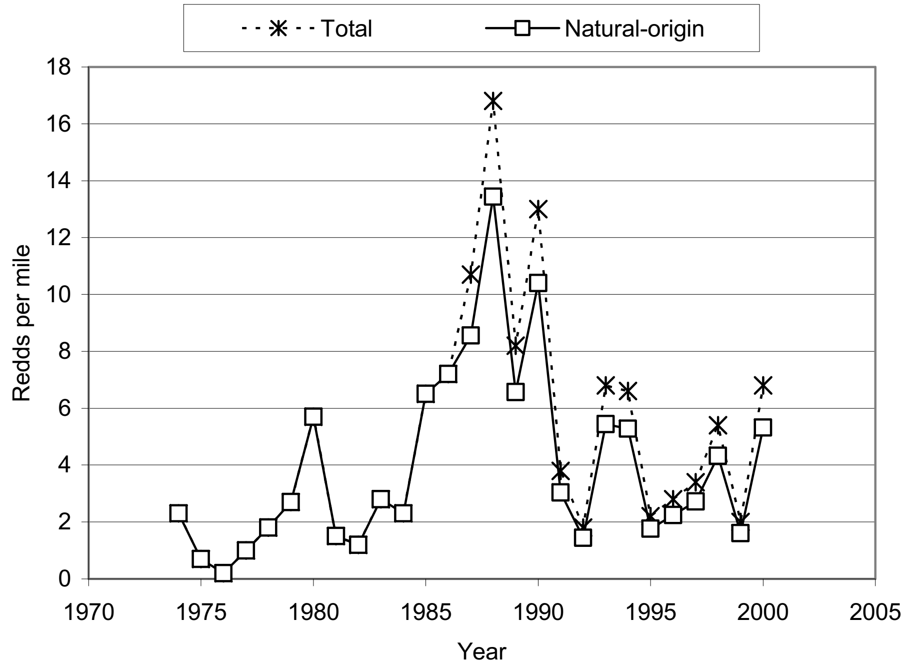

Figure 128. Spawner abundance counts (redds per mile) for Imnaha River steelhead, 1974–2000.

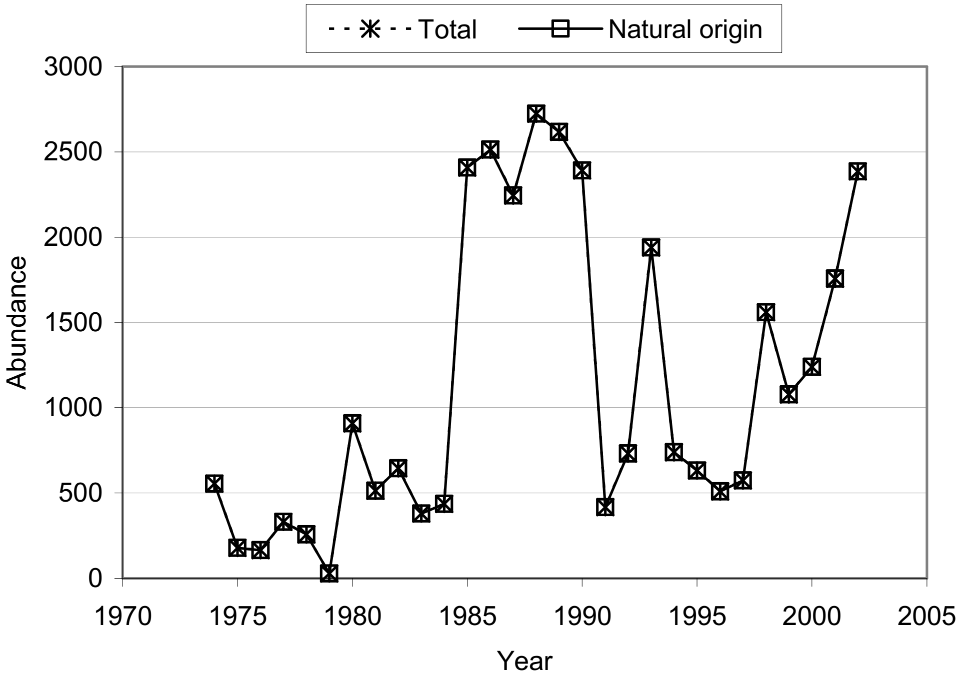

Figure 129. Spawner escapement for Joseph Creek steelhead: Grande Ronde, 1974–2002. Source: Expanded from redd counts from Oregon Department of Fish and Wildlife (see Appendix A, Table A-2).

Overall, long-term trends remained negative for four of the nine available series (including aggregate measures and specific production area estimates; Figure 132). Short-term trends improved relative to the period analyzed for the previous status review. The median short-term trend was +2.0% for the 1990–2001 period. Five out of the nine data sets showed a positive trend (Figure 133).

IDFG has provided updated analyses of parr density survey results through 1999. IDFG concluded that generational parr density trends, which are analogous to spawner-to-spawner survivorship, indicate that Idaho spring/summer-run Chinook and steelhead, with and without hatchery influence, failed to meet replacement for most generations competed since 1985 (Kiefer 2002). These data do not reflect the influence of increased returns in 2001 and 2002.

Population growth rate (λ) estimates for Snake River steelhead production areas (Table 30, Figures 131, 132) demonstrate a similar pattern when compared to the simple trend analysis described above. The median long-term λ estimate across the nine series was 0.998, assuming that natural returns are produced only from natural-origin spawners, and 0.733 if both hatchery and wild potential spawners are assumed to have contributed to production at the same rate. Short-term λ estimates are higher: 1.013 assuming a hatchery effectiveness of 0, and 0.753 assuming hatchery and wild fish contribute to natural production in proportion to their numbers. These values are consistent with another recent analysis of population growth rates (McClure et al. 2003), which estimated λ at the ESU level as 0.96 if hatchery fish do not reproduce, and 0.73 if they reproduce at a rate equal to that of wild fish. This analysis spanned the time period from 1980 to 2000, making it clear that the most recent returns have had an influence on λ

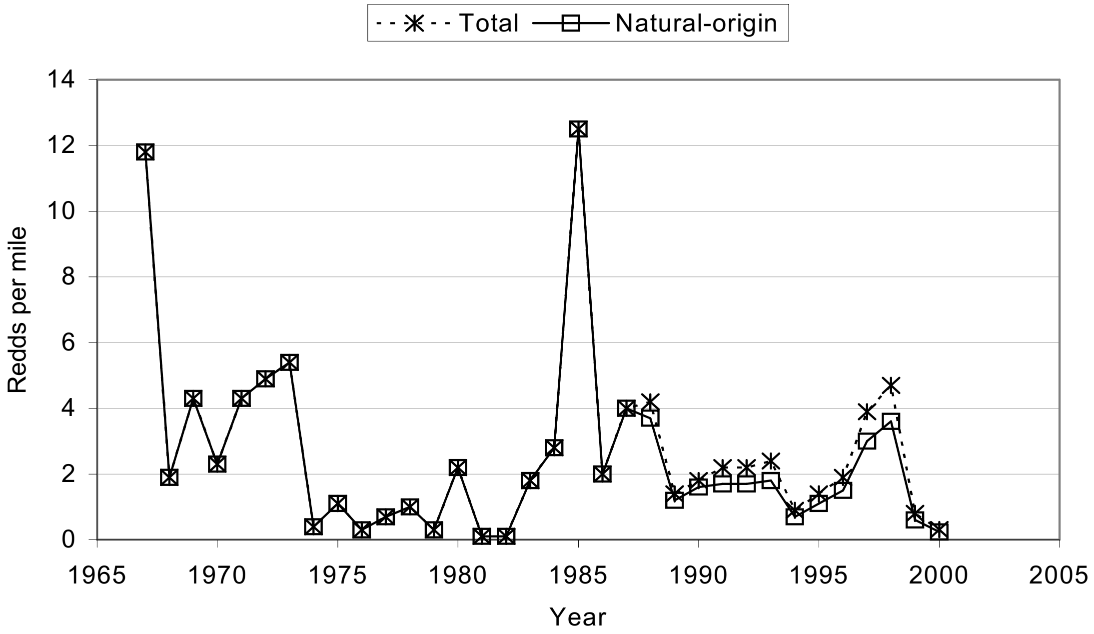

Figure 130. Spawner escapement for the upper mainstem Grande Ronde River, 1967–2000. Source: Spawning ground survey data from ODFW (see Appendix A, Table A-2).

estimates, particularly in the short term. (Note that population growth rate calculations in the Biological Opinion on the Federal Columbia River Power System [NMFS 2000] used assumptions of hatchery fish effectiveness bracketed by those in McClure et al. [2003].)

The standardized abundance trend and population growth rate estimates provided in this report do not explicitly differentiate potential density-dependent effects from density-independent survival effects. Abundance levels for many production areas considered in the analyses varied over a wide range. In several cases, it is likely that abundance, at least in some years, could be high enough to affect survival through density-dependent mechanisms. To provide perspective on the potential for density-dependent influences, recent geometric mean spawner abundance estimates are contrasted with interim delisting levels provided by NOAA Fisheries' regional office (http://www.nwr.noaa.gov/occd/InterimTargets.html). Interim delisting levels for Snake River spring/summer-run Chinook production units were derived from recommendations of the Bevan Recovery Team (Bevan et al. 1994). Interim delisting levels for upper Columbia River spring-run Chinook and steelhead were from Ford et al. (2001). The method described in Ford et al. (2001) was used to develop interim delisting levels for mid-Columbia and Snake river steelhead production areas. The approach uses estimates of habitat area and, where available, estimates of spawning escapements during historical periods of high, sustained returns.

Resident *O. mykiss* Considerations

The available information on resident *O. mykiss* populations within the ESU is summarized in Table 31 and Appendix B, Table B-1, including a broad overview of the distribution of case 1, 2, and 3 resident populations within the ESU. See the subsection,

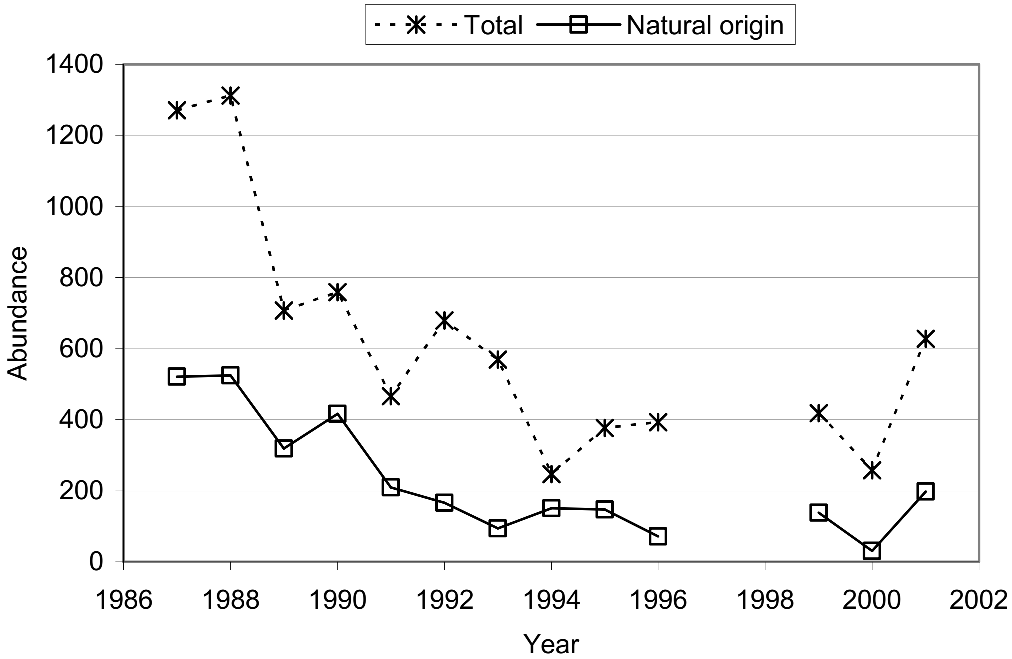

Figure 131. Estimated spawner escapement for Tucannon River steelhead, 1987–2001. Source: Washington Department of Fish and Wildlife (see Appendix A, Table A-2).

Table 30. Snake River Basin steelhead ESU population growth-rate analysis. Summary of available trend data sets, results of calculating annual population growth rate (λ), geometric mean, and probability λ less than 1.0.

			Percent Wild							
Population	**Series length**	**Method[a]**	**1987–1996**	**1997–2001**	**1997–2001 geometric mean**	**HF[b]**	**Long-term λ[c]**	**Probability λ < 1**	**Short-term λ[d]**	**Probability λ < 1**
Lower Granite Dam—aggregate	1990–2001	dc	0.18	0.14	14,768	0	0.994	0.551	1.051	0.297
						1	0.703	1.000	0.687	0.999
Lower Granite Dam—A run	1985–2001	dc	0.18	0.15	12,666	0	0.998	0.512	1.078	0.215
						1	0.674	1.000	0.692	0.999
Lower Granite Dam—B run	1985–2001	dc	0.18	0.11	1,890	0	0.927	0.915	0.941	0.782
						1	0.655	1.000	0.646	1.000
Tucannon River	1987–2001	dc	0.39	0.26	95	0	0.886	0.998	0.924	0.895
						1	0.733	0.998	0.712	0.988
Grande Ronde River—upper	1967–2000	rpm	0.83	0.77	NA	0	0.967	0.668	1.013	0.436
						1	0.951	0.736	0.958	0.705
Grande Ronde River—Joseph Creek	1974–2002	tlc	1.00	1.00	1,542	na	1.069	0.130	1.018	0.418
Imnaha River	1974–2000	rpm	0.80	0.80	na	0	1.042	0.242	0.929	0.873
						1	1.026	0.534	0.899	0.927
Imnaha River—Camp Creek	1974–2002	tlc	1.00	1.00	154	na	1.077	0.099	1.007	0.460
Imnaha River—Little Sheep Creek	1985–2002	tlc	0.30	0.14	42	0	1.045	0.323	1.082	0.267
						1	0.718	0.998	0.794	0.984

[a] Methods: dc = dam counts; rc = redd counts; rpm = redds per mile index; tlc = estimated total live fish on spawning grounds.

[b] Population growth rates calculated for two hatchery effectiveness (HF) assumptions; HF = 0.0 hatchery fish available to spawn do not contribute to natural production, HF = 1.0 hatchery returns available to spawn contribute to broodyear natural production at the same rate as natural-origin spawners.

[c] Long term = the length of the available data series.

[d] Short term = 1990–2001 or most recent year.

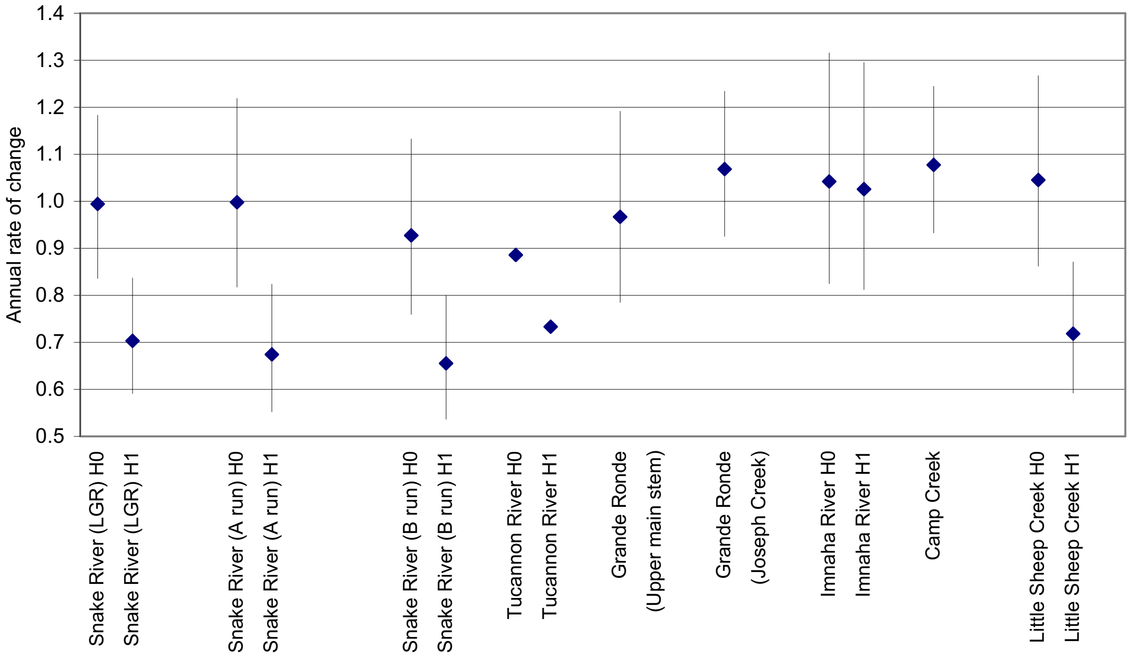

Figure 132. Long-term median population growth-rate estimates and 95% confidence limits for the Snake River Basin steelhead ESU. Paired estimates are based on calculations where hatchery-origin spawners have reproductive success equal to 0 (H0) or equivalent to natural-origin spawners (H1) (some hatchery confidence limits estimated by extrapolation).

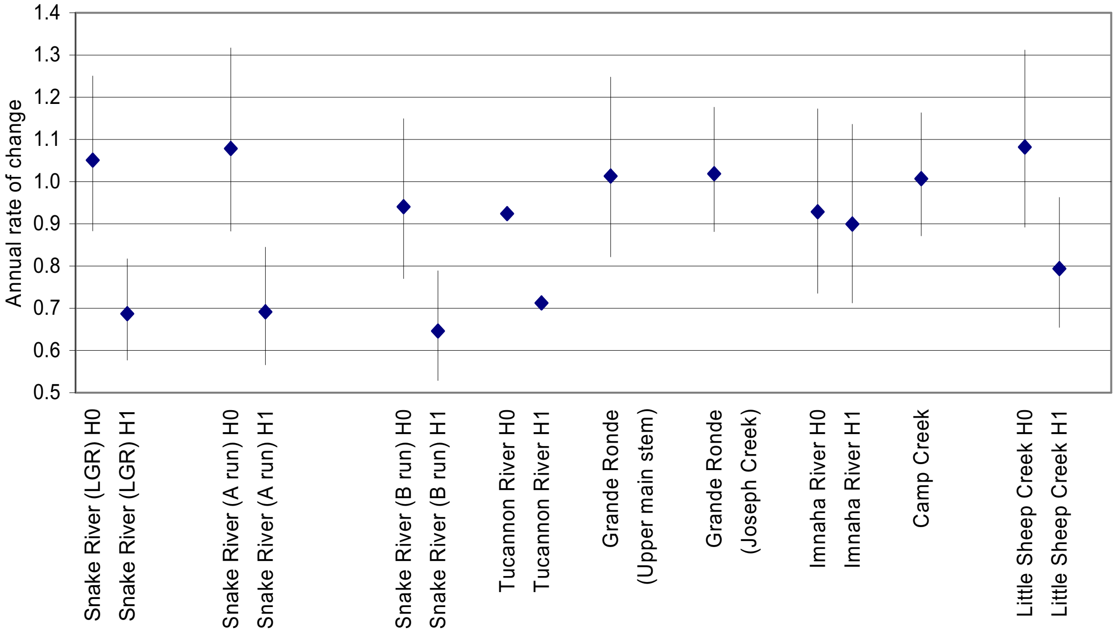

Figure 133. Short-term median population growth-rate estimates and 95% confidence limits for the Snake River Basin steelhead ESU. Paired estimates are based on calculations where hatchery-origin spawners have reproductive success equal to 0 (H0) or equivalent to natural-origin spawners (H1).

Table 31. Distribution of Snake River Basin steelhead ESU trout populations by category.

Category 1 populations[a] (sympatric)	**Category 2 populations (major natural barriers[b])**	**Category 3 populations (major artificial barriers[b])**
Potentially all areas that are or were used by steelhead. Tucannon River Asotin River Grande Ronde River Imnaha River Salmon found in about 43% of streams Clearwater River Selway River Other potential areas	Palouse River Malad River Several Hells Canyon tributaries Upper Malheur basin "recent" disconnect from lower Malheur Lake basin	Trout distributions currently more restricted than historically. North Fork Clearwater (Dworshak Dam) Mainstem Snake (Hells Canyon Dam) Powder Burnt Malheur Owyhee Weiser Payette Boise Burneau Salmon Falls Creek Several small tributaries

[a] The generalized listing of basins and subbasins does not imply that these constitute single trout populations or that trout distribution is continuous throughout the areas listed. Detailed trout distribution is usually unknown and actual demographically independent trout populations have not been described. All current trout distributions are decreased from historical distributions. In particular many mainstem and lower basin tributaries are no longer used but probably were historically. Many current trout populations are only in upper basins and are highly fragmented.

[b] Only major barriers are noted; numerous small barriers, both natural and artificial, also exist. Many other natural barriers are present but have *O. clarki*, rather than *O. mykiss*, above them. *O. mykiss* distribution in areas of sympatry with steelhead may be restricted in some areas if native *O. clarki* are also in the basin.

Resident Fish, in Section 14 for an explanation of the three cases and their relevance to ESU determinations; it discusses how resident fish are considered in risk analyses. Kostow (2003) reviewed information on the abundance and distribution of resident trout for this ESU. IDFG presence-absence survey results indicate that *O. mykiss* were found in 48% of the 84 streams sampled throughout the Salmon River basin. Westslope cutthroat trout were found in 43% of the locations sampled. When the species co-occurred in a tributary system, the cutthroat trout tended to be found in smaller headwater tributaries, while the *O. mykiss* were in larger tributaries lower in the system. Steelhead occupied lower mainstem and associated tributaries. IDFG suggested that some resident rainbow in the Salmon and Clearwater drainages may be the result of hatchery rainbow introductions.

The relative abundance of resident *O. mykiss* in the Imnaha and Grande Ronde river basins has not been clearly defined. *O. mykiss* production has been documented in both basins. Kostow (2003) reports that although no formal surveys of resident trout abundance have been conducted in the Imnaha River basin, the results of genetics sampling in the basin support the presence of a resident form. Resident *O. mykiss* abundance in the Tucannon River is believed to be relatively low based on observations during steelhead redd count surveys (Kostow 2003).

Resident *O. mykiss* populations are present above the Hells Canyon Dam complex, but their relationship to existing steelhead populations below the dams has not been determined (Kostow 2003). There have been relatively few specific studies of potential relationships between sympatric resident and anadromous *O. mykiss* in the Snake River basin.

Genetic analysis of case 3 resident *O. mykiss* above Dworshak Dam shows that the sampled population is genetically more similar to Dworshak steelhead than are other Snake River *O. mykiss* populations (Waples 1998, Kostow 2003). This finding suggests that the sampled population may be derived primarily from residualized steelhead or native resident fish from the North Fork Clearwater River. However, the genetic data cannot rule out some introgression from nonnative rainbow trout.

Kostow (2003) reported that field biologists noted spatial and temporal overlaps in spawning between resident and anadromous *O. mykiss* in the Grande Ronde, Imnaha, Tucannon, and upper Snake river basins. ODFW is conducting experimental cross-breeding studies using resident and anadromous *O. mykiss* from the Grande Ronde basin. Preliminary results indicate that all potential crosses produce outmigrating smolts. Steelhead × steelhead crosses had the highest smolt production rate, and resident trout × resident trout crosses had the lowest. Adult female steelhead × resident male trout crosses, the combination most likely to occur in nature, had the second highest smolt production rate. Adult returns from the study were forthcoming at the time of writing.

Genetic analyses (e.g., Leary 2001) of case 3 resident populations in tributaries above the Hells Canyon Dam concluded that some populations are native redband trout, but others are hybridized with hatchery rainbow trout. A number of genetic studies of Snake River *O. mykiss* that are under way should provide more specific information about resident populations in the future.

New Hatchery Information

Artificial Production History

Almost all artificial production of steelhead in the Snake River Basin ESU has been associated with two major mitigation initiatives—the Lower Snake River Compensation Program (LSRCP) and the mitigation program for Dworshak Dam on the North Fork Clearwater River. LSRCP is administered by the USFWS and was established as compensation for losses incurred as a result of the construction and operation of the four lower Snake River hydroelectric dams. Production under this initiative generally began in the mid-1980s. The Dworshak mitigation program provides for artificial production as compensation for the loss of access to the North Fork Clearwater, a major historical production area. Dworshak Hatchery, completed in 1969, is the focus for that production.

Hatchery releases of steelhead within the Snake River basin are summarized by time period and production area in Table 32. The following subsections summarize historical and current artificial production steelhead programs by major geographic area within the ESU.

Table 32. Hatchery releases of steelhead in the Snake River basin steelhead ESU, organized by major steelhead production areas and broodstock of the release.

		Average releases per year*		
Basin	**Stock**	**1985–1989**	**1990–1994**	**1995–2001**
Mainstem Snake River	Dworshak B	2,400	1,760	–
	Lyons Ferry	141,383	72,306	73,616
	Oxbow A	912,769	651,723	440,999
	Salmon River A	68,800	–	93,325
	Wallowa	205,133	138,915	–
	Wells	112,559	–	–
	Mixed	20,352	–	–
	Imnaha River	–	6,722	–
	Snake River A	–	–	95,018
	Pahsimeroi A	–	8,695	–
	Mainstem total	1,463,396	880,121	702,958
Tucannon River	Lyons Ferry	32,300	14,116	151,723
	Tucannon River	157,469	62,860	8,574
	Wallowa	16,197	–	–
	Wells	40,229	–	–
	Pahsimeroi A	–	23,852	–
	Mixed	–	26,008	–
	Tucannon total	246,195	126,836	160,297
Asotin River	Lyons Ferry	16,895	6,092	16,328
	Oxbow A	–	27,200	–
	Pahsimeroi A	–	27,569	–
	Wallowa	5,800	–	–
	Wells	8,930	–	–
	Asotin Total	31,625	60,861	16,328
Mainstem Clearwater River	Dworshak B	1,618,440	1,893,944	1,755,111
	Clearwater B	–	–	113,581
North Fork Clearwater River	Dworshak B	–	–	391,210
South Fork Clearwater River	Clearwater B	–	–	85,398
	Dworshak B	612,152	869,839	739,543
	Selway River	–	14,313	19,483
	Clearwater total	2,230,592	2,778,096	3,104,326
Mainstem Grande Ronde River	Wallowa	782,060	616,379	975,089
Wallowa River	Wallowa	529,852	985,339	524,416
	Grande Ronde total	1,311,912	1,601,718	1,499,505
Lower and mainstem Salmon River	Salmon River A	325,000	432,867	161,537
	Salmon River B	9,900	–	24,940
	Dworshak B	–	112,291	109,015
	Oxbow A	–	100,972	63,879
	Pahsimeroi A	–	235,306	68,695

Table 32 continued. Hatchery releases of steelhead in the Snake River basin steelhead ESU, organized by major steelhead production areas and broodstock of the release.

		Average releases per year*		
Basin	**Stock**	**1985–1989**	**1990–1994**	**1995–2001**
Little Salmon River	Hagerman A	61,621	–	–
	Oxbow A	120,261	200,380	341,639
	Salmon River A	399,135	232,716	271,400
	Dworshak B	–	367,068	222,438
	Pahsimeroi A	–	65,632	39,933
	Salmon River B	–	–	48,471
Panther Creek	Pahsimeroi A	49,264	–	–
	Salmon River A	141,100	–	–
North Fork Salmon River	Salmon River A	92,300	71,600	30,070
	Oxbow A	–	26,995	–
	Pahsimeroi A	–	38,100	43,500
Lemhi River	Dworshak B	125,000	86,857	–
	Pahsimeroi A	–	–	132,741
	Salmon River A	–	–	129,287
Pahsimeroi River	Pahsimeroi A	845,968	693,118	718,435
	Salmon River A	–	–	114,506
East Fork Salmon River	East Fork Salmon B	475,023	197,670	34,283
	Dworshak B	87,315	773,329	240,523
	Hagerman B	54,042	–	–
	Salmon River B	–	–	71,494
Upper Salmon River	Hagerman A	157,237	–	–
	Pahsimeroi A	–	447,944	368,748
	Salmon River A	889,353	669,844	590,289
	Dworshak B	–	–	130,186
	Salmon River B	–	–	18,387
	Sawtooth A	–	–	32,348
	Salmon total	3,832,518	4,752,697	4,006,745
Imnaha River	Imnaha River	188,275	325,833	169,758
	Little Sheep Creek	–	–	131,776
	Imnaha Total	188,275	325,833	301,534
ESU total	All stocks	10,097,233	10,526,167	10,033,360

* Averages calculated by time period to facilitate comparison of release levels since the last status review (Busby et al. 1996) with previous levels.

The broodstock for Tucannon releases was primarily the Lyons Ferry Hatchery stock, which was originally derived from Wells Hatchery and Wallowa Hatchery stocks. ODFW originally derived the Wallowa Hatchery stock by trapping returning adults in the lower Snake River. Pahsimeroi Hatchery stock was used in the program in one year when full production was lost at Lyons Ferry Hatchery due to disease outbreaks, primarily infectious hematopoietic necrosis virus (IHNV) (Gephart and Nordheim 2001).

Return rates to the Tucannon River from the hatchery program have been relatively low. Beginning in 1998, the release location for hatchery steelhead was moved downriver in response to studies indicating improved survivals from lower river releases and to minimize the opportunity for interbreeding between hatchery and natural returns (which included listed spring-run Chinook) to the basin. Beginning with the 1999/2000-cycle year, the Tucannon River hatchery steelhead program began evaluating the feasibility of using local broodstock for the program. A full switchover to an endemic broodstock may occur in the future, depending on the success of the pilot program. Problems associated with trapping and rearing of the new broodstock, as well as genetic questions, still need to be addressed.[16]

Hatchery Summaries

Grande Ronde and Imnaha rivers

There are LSRCP steelhead hatchery mitigation releases in the Grande Ronde and Imnaha river systems. The LSRCP compensation objective for Grande Ronde steelhead returns is 9,200. Trapping facilities for adult broodstock are located at Big Canyon Creek acclimation site. The original program used outside broodstock (including Skamania Hatchery stock) from 1979 to 1982 before switching to the Wallowa broodstock. Smolts are acclimated and released at two sites—one within the Wallowa drainage, the other at Big Canyon Creek. Oregon manages the Minam River, Joseph Creek, and Wenaha River drainages for natural production. Other sections of the Grande Ronde River have been outplanted to supplement natural production (Nowak 2001).

LSRCP program releases into the Imnaha River come from a satellite facility on Little Sheep Creek after primary rearing at Wallowa Hatchery. Additional releases are targeted in Horse Creek and the upper Imnaha River basin (Bryson 2001).

Clearwater River basin

Steelhead hatchery releases into the Clearwater River basin are managed under two programs—LSRCP and Dworshak Dam mitigation. The Lower Snake Compensation Plan program in the Clearwater River drainage uses the Clearwater hatchery as a central rearing facility and has an overall production objective of 14,000 adult steelhead returns to the Snake River. Program release sites include acclimation ponds on the Powell River (Lochsa River drainage), the Red River, and Crooked River sites in the South Fork Clearwater River. The Dworshak mitigation program has an adult return objective of 20,000 adult steelhead as compensation for losses due to Dworshak Dam, an anadromous block that cuts off the North Fork Clearwater River. Genetics studies have indicated that the hatchery stock used in the Dworshak program may be representative of the original North Fork run (Cichosz et al. 2001).

Salmon River basin

Steelhead hatchery releases into the Salmon River drainage are under the auspices of two major steelhead hatchery programs—LSRCP and IDFG programs funded by Idaho Power Company. In addition, there are state and tribal experimental supplementation programs in

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[16] B. Leland, Washington Department of Fish and Wildlife, Olympia, WA. Pers. commun., 31 March 2003.

the drainage. The LSRCP program goal for the Salmon River basin is to produce an annual return of 25,000 adult steelhead above Lower Granite Dam. Juvenile steelhead produced at Magic Valley Hatchery and Hagerman National Fish Hatchery are released into the Salmon River drainage. The Idaho Power Company–funded program for steelhead has an objective of releasing 400,000 pounds of steelhead smolts (Servheen 2001).

The Middle Fork Salmon River drainages have had minimal or no hatchery releases. The upper Salmon River drainages—the Pahsimeroi, Lemhi, Little Salmon, and Lower Salmon river areas—have received releases in recent years.

Categorizations of Snake River basin hatchery stocks (SSHAG 2003) are summarized in Appendix B, Table B-3.

16. Upper Columbia River Steelhead ESU

The life history patterns of upper Columbia River steelhead are complex. Adults return to the Columbia River in the late summer and early fall; most migrate relatively quickly up the main stem to their natal tributaries. A portion of the returning run overwinters in the mainstem reservoirs, passing over the upper mid-Columbia dams in April and May of the following year. Spawning occurs in the late spring of the calendar year following entry into the river. Juvenile steelhead spend 1 to 7 years rearing in freshwater before migrating to the ocean. Smolt outmigrations are predominantly age-2 and age-3 juveniles. Most adult steelhead return after 1 or 2 years at sea, starting the cycle again.

Estimates of the annual returns of upper Columbia River steelhead populations are based on dam counts. Cycle counts are used to accommodate the prevalent return pattern in upriver summer-run steelhead (runs enter the Columbia River in late summer and fall, some fish overwinter in mainstem reservoirs—migrating past the upper dams prior to spawning the following spring). Counts over Wells Dam are assumed to be returns originating from natural production and hatchery outplants into the Methow and Okanogan river systems. The total returns to Wells Dam are calculated by adding annual broodstock removals at Wells to the dam counts. The annual estimated return levels above Wells Dam are broken down into hatchery and wild components by applying the ratios observed in the Wells sampling program for run years since 1982.

Harvest rates on upper river steelhead have been cut back substantially from historical levels. Legislation in the early 1970s eliminated direct commercial harvest of steelhead in non-Indian fisheries. Incidental impacts in fisheries directed at other species continued in the lower river, but at substantially reduced levels. In the 1970s and early 1980s, recreational fishery impacts in the upper Columbia River escalated to very high levels in response to increasing returns augmented by substantial increases in hatchery production. In 1985, steelhead recreational fisheries in this region (and in other Washington tributaries) were changed to mandate release of wild fish. Treaty harvest of summer-run steelhead (including returns to the upper Columbia River) occurs mainly in mainstem fisheries directed at upriver bright fall-run Chinook salmon.

Hatchery returns predominate the estimated escapement in the Wenatchee, Methow, and Okanogan river drainages. The effectiveness of hatchery spawners relative to their natural counterparts is a major uncertainty for both populations. Hatchery effectiveness can be influenced by at least three sets of factors: relative distribution of spawning adults, relative timing of spawning adults, and relative effectiveness of progeny. No direct information is available for the upper Columbia River stocks. Outplanting strategies have varied over the period the return/spawner data were collected (1976–1994 broodyears). Although the return timing into the Columbia River is similar for both wild and hatchery steelhead returning to the upper Columbia, the spawning timing in the hatchery is accelerated. The long-term effects of such acceleration on the spawning timing of returning hatchery-produced adults in nature is not known. We have no direct information on relative fitness of upper Columbia River steelhead progeny with at least one parent of hatchery origin.

Summary of Previous BRT Conclusions

The 1998 steelhead status review identified a number of concerns for the Upper Columbia River steelhead ESU: "While the total abundance of populations within this ESU has been relatively stable or increasing, it appears to be occurring only because of major hatchery supplementation programs. Estimates of the proportion of hatchery fish in spawning escapement are 65% (Wenatchee River) and 81% (Methow and Okanogan rivers). The major concern for this ESU is the clear failure of natural stocks to replace themselves. The BRT members are also strongly concerned about the problems of "genetic homogenization due to hatchery supplementation...apparent high harvest rates on steelhead smolts in rainbow trout fisheries and the degradation of freshwater habitats within the region, especially the effects of grazing, irrigation diversions and hydroelectric dams." The BRT also identified two major areas of uncertainty: relationship between anadromous and resident forms, and the genetic heritage of naturally spawning fish within this ESU.

Listing status: Endangered.

New Data and Updated Analyses

Population Definitions and Criteria

We developed an initial set of population definitions for the Upper Columbia River steelhead ESU, along with basic criteria for evaluating the status of each population, using the VSP guidelines described in McElhany et al. (2000). The definitions and criteria are described in Ford et al. (2001) and have been used in the development and review of Mid-Columbia PUD plans and the FCRPS Biological Opinion. The interim population definitions and criteria have been submitted as recommendations to the Interior Columbia Basin Technical Recovery Team. Briefly, the joint technical team recommended that the Wenatchee, Entiat, and Methow rivers be considered as separate populations within the Upper Columbia River steelhead ESU. The Okanogan River may have supported a fourth population; the committee deferred a decision on the Okanogan to the Technical Recovery Team. Ford et al. (2001) developed and describes abundance, productivity, and spatial structure criteria for each population in the ESU.

Current Abundance

Returns of both hatchery- and naturally produced steelhead to the upper Columbia River have increased in recent years. Priest Rapids Dam is below Upper Columbia River steelhead ESU production areas. The average 1997–2001 return counted through the Priest Rapids fish ladder was approximately 12,900 steelhead. The average for the previous 5 years (1992–1996) was 7,800 fish.

Total returns to the upper Columbia River continue to be predominantly hatchery-origin fish. The natural-origin percentage of the run over Priest Rapids increased to over 25% in the 1980s, and then dropped to less than 10% by the mid-1990s. The median percent of natural origin for 1997–2001 was 17%. Abundance estimates of returning, naturally produced upper Columbia River steelhead are based on extrapolations from mainstem dam counts and associated sampling information (e.g., hatchery/wild fraction, age composition). The natural component of the annual steelhead run over Priest Rapids increased from an average of 1,040 (1992–1996) to 2,200 (1997–2001).

The estimate of the combined natural steelhead return to the Wenatchee and Entiat rivers increased to a geometric mean of approximately 900 for the 1996–2001 period. The percentage of returning upper Columbia River steelhead dropped from 35% to 29% for the recent 5-year period. In terms of natural production, recent production levels remain well below the interim recovery levels developed for these populations (Table 33, Figure 134).

The Methow River steelhead population is the primary natural production area above Wells Dam. The 1997–2001 geometric mean of natural returns over Wells Dam was 358, lower than the geometric mean return prior to the 1998 status review (Table 33, Figure 135). The most recent return reported in the data series, 1,380 naturally produced steelhead in 2001, was the highest single annual return in the 25-year data series. Hatchery returns continue to dominate the run over Wells Dam. The average percent of wild origin dropped to 9% for 1996–2001, compared to 19% for the period prior to the previous status review.

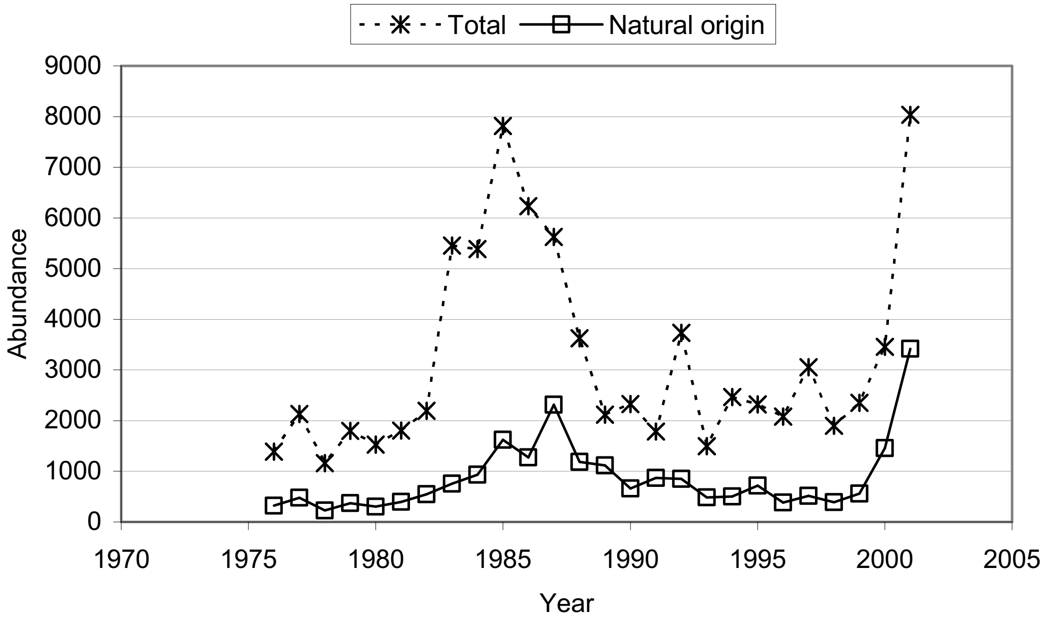

Figure 134. Estimated annual spawner escapements of Wenatchee and Entiat river steelhead, 1976–2001. Sources: Cooney (2001); 1999–2001 data from WDFW (see Appendix A, Table A-2).

Table 33. Summary of current abundance and trend information relative to previous BRT status review for Upper Columbia River steelhead.

Population	5-year mean % natural origin	Recent 5-year geometric mean Total Mean (range)	Recent 5-year geometric mean Natural Current	Recent 5-year geometric mean Natural Previous	Short-term trend (%/year) Current	Short-term trend (%/year) Previous	Interim target[a]	Current vs. target
Wenatchee/ Entiat	29 (35[b])	3,279 (1,899–8,036)	894	800	+6.5	+2.6	3,000	30%
Methow/ Okanogan	9 (19[b])	3,714 (1,879–12,801)	358	450	+13.8	–12.0	2,500	14%

[a] Interim targets are from Ford et al. (2001).

[b] Estimates are from Busby et al. (1996).

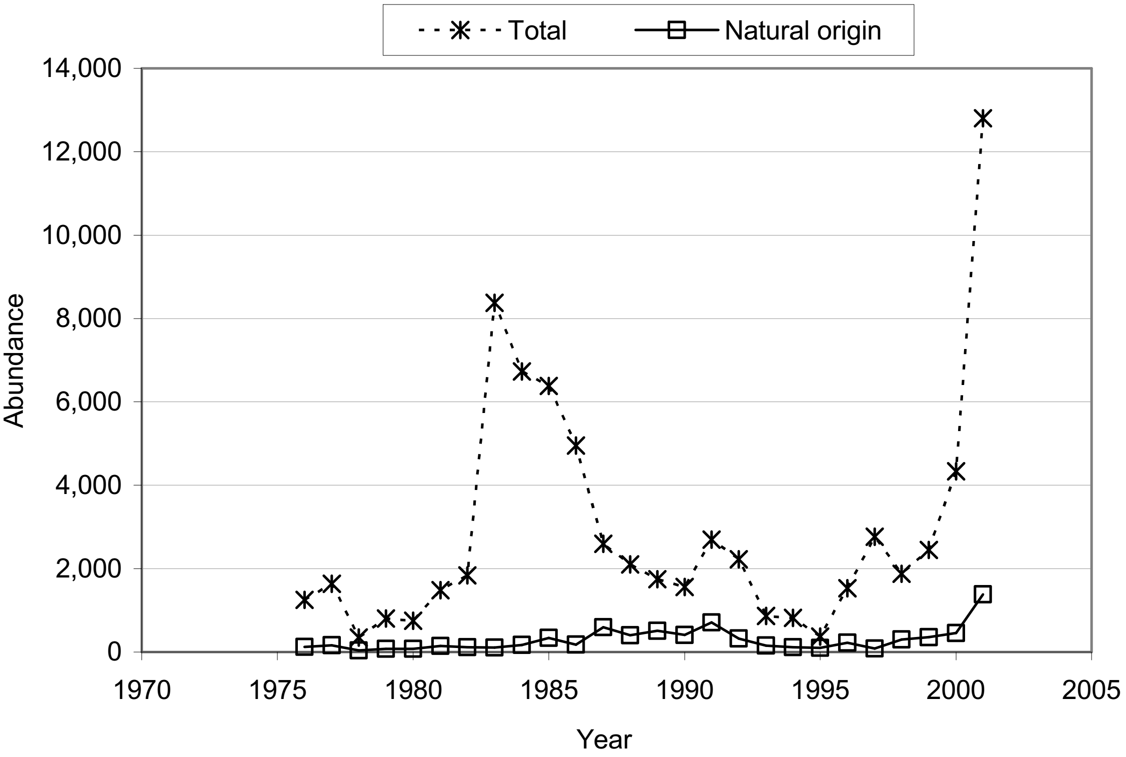

Figure 135. Estimated annual spawner escapements for Methow River steelhead, 1976–2001. Sources: Cooney (2001); 1999–2001 data from Washington Department of Fish and Wildlife (see Appendix A, Table A-2).

The analyses described above relied on the 1976–2001 abundance data set. The starting date for that series is set by the advent of counting at Wells Dam, which allowed for separate estimates of run strength to the Methow/Okanogan rivers and the Wenatchee/Entiat rivers. Prior to 1976, scientists had no direct ability to separate out counts returning to different subbasins above Rock Island Dam. The median run (at that time almost all of natural origin) from 1933 to 1954 was approximately 2,300.

Current Productivity

Natural returns have increased in recent years for both stock groupings (Table 34). Population growth rates (expressed as λ, calculated using the running sum method) are substantially influenced by assumptions regarding the relative effectiveness of hatchery spawners. The same key factor must be considered in analyzing return-per-spawner data sets. The relative contribution of returning steelhead of hatchery origin to natural spawning is not clearly understood. There may be timing and spatial differences in the distribution of hatchery- and wild-origin spawners that affect production of juveniles. Eggs and subsequent juveniles from natural spawning involving hatchery-origin fish may survive at a different rate relative to spawning of natural-origin adults.

Both short-term (1990–2001) and long-term (1976–2001) estimates of λ are positive under the assumption that hatchery fish have not contributed to natural production in recent years. Assuming that hatchery fish contributed to natural production at the same level as wild fish, λ estimates are substantially lower—under this scenario natural production is consistently and substantially below the total number (hatchery plus natural origin) of spawners in any given year. This result is consistent with those of McClure et al. (2003) and results in the 2000 FCRPS Biological Opinion (NMFS 2000), in which λ was estimated from the ESU-level time series for the time period 1980–2000. Although the total spawners have an apparent population growth rate of 1.00 (with relatively high variability), this growth rate is lowered to 0.69 if hatchery fish contributed to subsequent generations at the same rate as wild fish. Clearly, determining the actual contribution of hatchery fish is an important element in determining the true status of this ESU.

Assumptions regarding the relative effectiveness of hatchery-origin spawners also influence return-per-spawner patterns for the two steelhead production areas (Figures 136 and 137). Under the assumption that hatchery and wild spawners are both contributing to the subsequent generation of natural returns, return-per-spawner levels have been consistently below 1.0 since 1976. Under this scenario, natural production would be expected to decline rapidly in the absence of hatchery spawners. Under the assumption that hatchery fish returning to the upper Columbia River do not contribute to natural production, return-per-spawner levels were above 1 until the late 1980s. Return-per-spawner estimates subsequently dropped below replacement (1.0) and remained low until the most recent broodyear with measured returns—1996. The actual contribution of hatchery returns to natural spawning remains a key uncertainty for upper Columbia River steelhead. This information need is in addition to any considerations for long-term genetic impacts of high hatchery contributions to natural spawning

Resident *O. mykiss* Considerations

This section summarizes available information on resident *O. mykiss* populations within the ESU. Table 35 and Appendix B, Table B-1 provide an overview of the distribution of case 1, 2, and 3 resident populations within the ESU. See the subsection, Resident Fish, in Section B.1 Background and History of Listings, for an explanation of the three cases and their relevance to ESU determinations. The subsection, Resident Fish, in Section B.1, Steelhead, discusses how resident fish are considered in risk analyses.

Table 34. Upper Columbia River steelhead population growth-rate analysis. Summary of available trend data sets, results of calculating annual population growth rates (λ), geometric mean, probability λ less than 1.0.

			Percent Wild		1997–2001 geometric		Long	Probability	Short	Probability
Population	**Series length**	**Method**[a]	**1987–1996**	**1997–2001**	**mean**	**HF**[b]	**term**[c] **λ**	**λ < 1**	**term**[d] **λ**	**λ < 1**
Wenatchee/Entiat	1976–2001	dc	0.33	0.29	894	0	1.067	0.112	1.093	0.219
						1	0.733	1.000	0.753	0.987
Above Wells Dam	1976–2001	dc	0.17	0.085	358	0	1.086	0.088	1.277	0.357
						1	0.579	1.000	0.565	1.000
Methow River	1976–2001	dc	0.21	0.11	358	0	1.086	0.088	1.277	0.357
						1	0.589	1.000	0.621	1.000

[a] Methods: dc = dam counts.

[b] Population growth rates calculated for two hatchery effectiveness (HF) assumptions: HF = 0.0 hatchery fish available to spawn do not contribute to natural production; HF = 1.0 hatchery returns available to spawn contribute to broodyear natural production at the same rate as natural-origin spawners.

[c] Long term = the length of the available data series.

[d] Short term = 1990–2001 or most recent year.

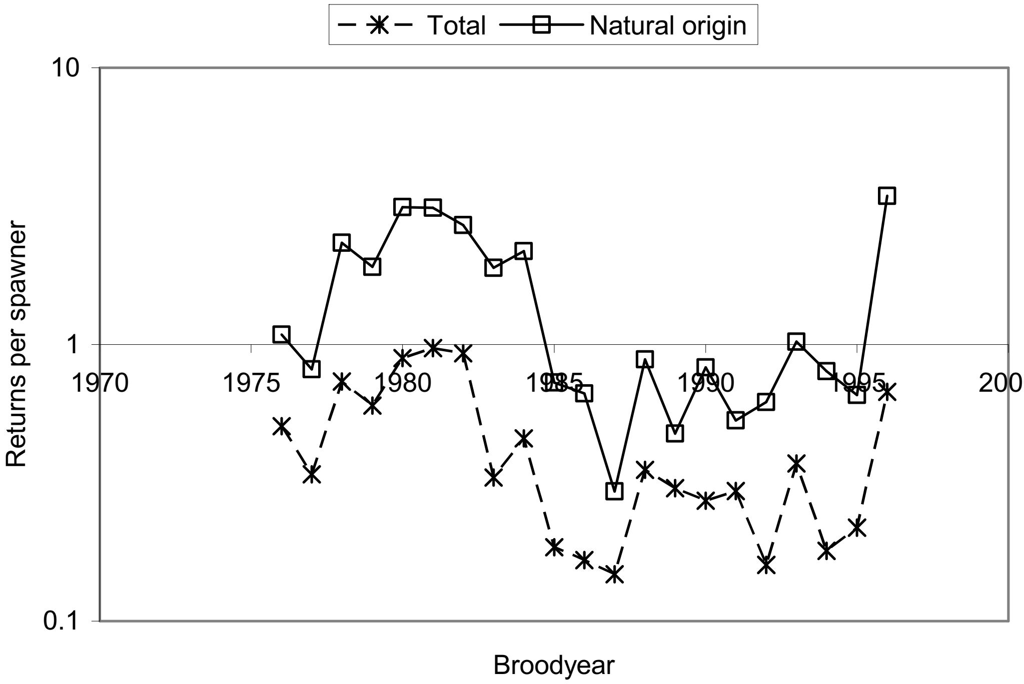

Figure 136. Returns per spawner versus broodyear spawning escapement of Wenatchee/Entiat river steelhead, 1976–2001.

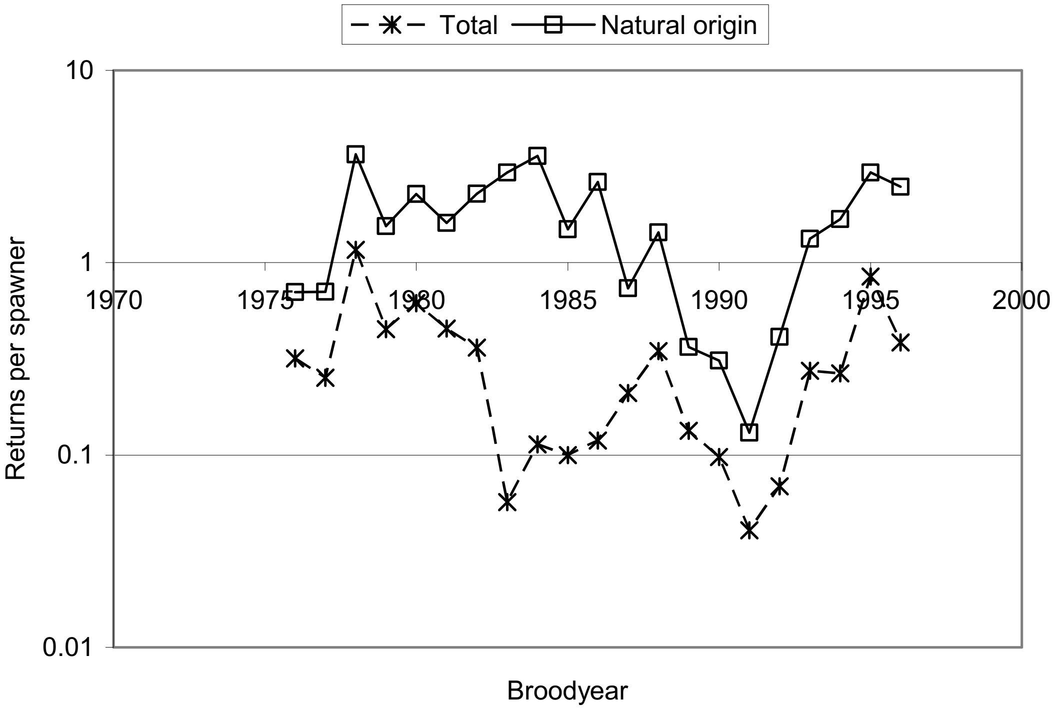

Figure 137. Returns per spawner versus broodyear spawning escapement for Methow River steelhead, 1976–2001.

Resident *O. mykiss* are relatively abundant in upper Columbia tributaries currently accessible to steelhead as well as in upriver tributaries blocked off to anadromous access by Chief Joseph and Grand Coulee dams (Kostow 2003). USFWS biologists surveyed the abundance of trout and steelhead juveniles in the Wenatchee, Entiat, and Methow river drainages in the mid-1980s (Mullan et al. 1992). Adult trout (defined as trout >20 cm) were found in surveys in all basins. Juvenile *O. mykiss* were reported from 94% of the surveys conducted in areas believed to be used by steelhead and resident trout (Kostow 2003). The results also supported the hypothesis that resident *O. mykiss* are more abundant in tributary or mainstem areas above the general areas used by steelhead for rearing.

The original status review did not formally evaluate the current ESU status of resident populations above Chief Joseph Dam, nor did it formally consider whether *O. mykiss* in upper Columbia River tributaries historically were in the same ESU as populations in the Wenatchee, Entiat, Methow, and Okanogan rivers. Kostow (2003) reports that biologists who are familiar with the areas above Chief Joseph Dam believe that *O. mykiss* are present in significant numbers. Several of the tributaries above Chief Joseph Dam have been blocked off by dams, and introductions of exotic gamefish and trout species have been widespread. We are not aware of specific information relevant to the ESU status of case 3 resident populations above dams in the Okanogan or Spokane rivers, or above Chief Joseph and Grand Coulee dams on the mainstem Columbia River. *O. mykiss,* believed to be native populations, are present in a number of tributaries draining into Lake Roosevelt (Kostow 2003). Mullan

Table 35. Distribution[a] of *O. mykiss* by category relative to the Upper Columbia River steelhead ESU.

Category 1 populations (sympatric)[b]	**Category 2 populations (major natural barriers)[c]**	**Category 3 populations (major artificial barriers)[c]**
Potentially all areas that are or were used by steelhead	Upper Entiat Upper Kootenay	Trout distributions currently more restricted than historically
Wenatchee Lower Entiat Methow Okanogan	Okanogan: Enloe Falls[d]	Okanogan Basin: Conconully Dam Enloe Dam[d]
	Methow: Chewuch[d] Lost	Chief Joseph Dam
		Lower Spokane to Post Falls Sanpoil Several small tributaries Lower Pend Oreille to Z Canyon Columbia headwaters in Canada

[a] The generalized listing of basins and subbasins does not imply that these constitute single populations or that distribution is continuous throughout the areas listed. Detailed distribution is usually unknown and actual demographically independent populations are not described. All current distributions are decreased from historical distributions. In particular, many mainstem and lower basin tributaries are no longer used, but probably were historically. Many current populations are only in upper basins and are highly fragmented.

[b] *O. mykiss* distribution in areas of sympatry with steelhead may be restricted in some areas if native *O. clarki* are also in the basin.

[c] Only major barriers are noted; numerous small barriers, both natural and artificial, also exist. Many other natural barriers are present but have *O. clarki* trout, rather than *O. mykiss*, above them.

[d] Expected presence of *O. mykiss* trout, but not confirmed by reliable sources.

et al. (1992) hypothesized that the native trout populations above Chief Joseph Dam effectively preserved native steelhead lineages present before the construction of the mainstem impassable dams. Knudsen et al. (2002) concluded that native resident (case 2) populations persist in some Kootenai River tributaries, in spite of extensive stocking by nonnative rainbow trout.

New Hatchery Information

Hatchery production averaged approximately 300,000 smolts/year in the 1960s, 425,000 in the 1970s, 790,000 in the 1980s, and more than 800,000 in the 1990s (including releases exceeding 1.0 million). Current mitigation and supplementation targets are to use locally obtained returning adults for programs. The objective for the Wenatchee is to release 400,000 smolts per year using broodstock collected from run-of-the-river fish in the Wenatchee (main collection point is Dryden Dam). Broodstock collected at Wells Dam are used for outplanting in the Methow (380,000 target release) and the Okanogan (100,000 target release). The Entiat Basin has been designated as a natural production "reference" drainage—no hatchery outplanting. Presently, no monitoring programs are in place to directly estimate natural production of steelhead in the Entiat. Categorizations of upper Columbia River steelhead hatchery stocks (SSHAG 2003) can be found in Appendix B, Table B-3.

Table 36. Hatchery releases of steelhead in the Upper Columbia River ESU, organized by major steelhead production areas and broodstock.

Basin	**Stock**	**Average[*] releases per year**		
		1985–1989	**1990–1994**	**1995–2001**
Mainstem Columbia River	Ringold	220,421	144,303	–
	Wells	27,757	26,204	202,269
	Skamania	–	35,130	70,523
	Wenatchee River	–	–	500
	Mainstem total	177,270	146,883	273,292
Entiat River	Wells	43,863	43,247	18,098
	Wenatchee River	–	–	12,465
	Entiat total	43,863	43,247	30,564
Methow River	Wells	439,926	428,894	418,227
Okanogan River	Wells	133,198	123,972	119,996
Wenatchee River	Leavenworth	62,376	95,631	23,960
	Ringold	113,225	–	–
	Wells	121,272	351,735	176,643
	Wenatchee River	81,072	–	106,554
	Wenatchee total	377,945	447,366	307,158
ESU total	All stocks	1,243,110	1,249,116	1,149,239

[*] Averages are calculated by time period to facilitate comparison of release levels since the last status review (Busby et al. 1996).

17. Middle Columbia River Steelhead ESU

The Middle Columbia River steelhead ESU includes steelhead populations in Oregon and Washington drainages upstream of the Hood and Wind river systems, up to and including the Yakima River. The Snake River is not included in this ESU. Major drainages in this ESU are the Deschutes, John Day, Umatilla, Walla Walla, Yakima, and Klickitat river systems. Almost all steelhead populations within this ESU are summer-run fish; the exceptions are winter-run components returning to the Klickitat River and Fifteenmile Creek watersheds. A balance between 1- and 2-year-old smolt outmigrants characterize most of the populations within this ESU. Adults return after 1 or 2 years at sea.

Hatchery facilities are located in a number of drainages within the geographic area of this ESU, although there are also subbasins with little or no direct hatchery influence. The John Day River system, for example, has not been outplanted with hatchery steelhead. Similarly, hatchery production of steelhead in the Yakima River system was relatively limited historically and was phased out in the early 1990s. However, the Umatilla and Deschutes river systems each have ongoing hatchery production programs based on locally derived broodstocks. Moreover, straying from out-of-basin production programs into the Deschutes River has been identified as a chronic occurrence. The Walla Walla River (three locations in Washington sections) historically received production releases of Lyons Ferry Hatchery stock summer-run steelhead from the LSRCP. Mill Creek releases were halted after 1998 due to concerns associated with the then pending listing of mid-Columbia River steelhead under the ESA. A new endemic broodstock is under development for the Touchet River release site (beginning with the 1999/2000 return year). Production levels at the Touchet and Walla Walla river release sites have been reduced in recent years (WDFW).[17]

Blockages have prevented access to sizable steelhead production areas in the Deschutes and White Salmon rivers. In the Deschutes River, Pelton Dam blocks access to upstream habitat steelhead historically used. Conduit Dam, constructed in 1913, blocked access to all but 2 to 3 miles of habitat suitable for steelhead production in the Big White Salmon River (Rawding 2001b). Substantial populations of resident trout exist in both areas.

Summary of Previous BRT Conclusions

The previous reviews (NMFS 1998c, 1999b) identified several concerns, including relatively low spawning levels in streams for which information was available, a preponderance of negative trends (10 out of 14), and the widespread presence of hatchery fish throughout the ESU. The 1999 status review update (NMFS 1999b) specifically identified

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[17] WDFW comments submitted to NOAA on comanager draft of preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead, 29 March 2003.

"the serious declines in abundance in the John Day River Basin" as a point of concern, given that the John Day system had supported large populations of naturally spawning steelhead in the recent past. The previous review also expressed concerns about the low abundance of returns to the Yakima River system relative to historical levels "with the majority of production coming from a single stream (Satus Creek)." The review also identified the sharp decline in returns to the Deschutes River system as a concern. The status review update also identified increases of stray steelhead into the Deschutes River as a "major source of concern," as initial results from radio-tagging studies indicated that a substantial proportion of steelhead entering the Deschutes River migrated out of the system prior to spawning. Finally, the status review update identified a set of habitat problems affecting basins within this ESU. High summer and low winter temperatures are characteristic of production or migration reaches associated with populations within this ESU, and water withdrawals had seriously reduced flow levels in several mid-Columbia River drainages, including sections of the Yakima, Walla Walla, Umatilla, and Deschutes rivers. Riparian vegetation and instream structure had been degraded in many areas. The team suggested that for stream segments inventoried within this ESU, riparian restoration was needed for between 37% and 84% of the river bank in various basins (NMFS 1999b).

Listing status: Threatened.

New Data and Updated Analyses

Abundance

With some exceptions, the recent 5-year average (geometric mean) abundance for natural steelhead within this ESU was higher than levels reported in the last status review (NMFS 1999b). Information on recent returns, compared to return levels reported in previous status reviews, is summarized in Table 37 and depicted in Figures 138–147. Returns to the Yakima River, the Deschutes River, and sections of the John Day River system were substantially higher compared to 1992–1997. Yakima River returns are still substantially below interim target levels and estimated historical return levels, with the majority of spawning occurring in one tributary, Satus Creek (Berg 2001). The recent 5-year geometric mean return of the natural-origin component of the Deschutes River run exceeded interim target levels. Recent 5-year geometric mean annual returns to the John Day Basin are generally below the corresponding mean returns reported in the previous status reviews. However, each major production area in the John Day system has shown upward trends since the 1999 return year.

Recent year (1999–2001) redds-per-mile estimates of winter-run steelhead escapement in Fifteenmile Creek were also up substantially relative to annual levels in the early 1990s. Returns to the Touchet River are lower than the previous 5-year average. Trend or count information for the Klickitat River winter-run steelhead run are not available, but current return levels are believed to be below interim target level.

Productivity

Short-term trends in major production areas were positive for 7 of the 12 areas (Table 37). The median annual rate of change in abundance since 1990 was 2.5%; individual trend estimates ranged from –7.9% to 11%. The same basic pattern was reflected in λ estimates for the production areas. The median short-term (1990–2001) annual population growth rate estimate was 1.045, assuming that hatchery fish on the spawning grounds did not contribute to natural production, with 8 of the 12 indicator trends having a positive growth rate. Assuming that potential hatchery spawners contributed at the same rate as natural-origin spawners resulted in lower estimates of population growth rates. The median short-term λ under the assumption of equal hatchery- and natural-origin spawner effectiveness was .967, with 6 of the 12 indicator trends exhibiting positive growth rates.

Long-term trend estimates were also calculated using the entire length of the data series available for each production area (Table 37). The median estimate of long-term trend over the 12 indicator data sets was –2.1% per year (–6.9 to 2.9), with 11 of the 12 being negative. Long-term annual population growth rates (λ) were also negative (Table 37). The median long-term λ was .98, assuming that hatchery spawners do not contribute to production, and .97 assuming that both hatchery- and natural-origin spawners contribute equally. These longer trends are consistent with another recent analysis (McClure et al. 2003) of 28 index areas in the Middle Columbia River steelhead ESU from 1980 to 2000. In this analysis, the average population growth rate across all streams was 0.96, with only 2 of the 28 index areas showing a positive trend. (Note that the analyses in McClure et al. [2003] bracket those in the 2000 FCRPS Biological Opinion, which used slightly different assumptions about hatchery fish spawning effectiveness.)

All of the production area trends available for this ESU indicate relatively low escapement levels in the 1990s. For some of the data sets, earlier annual escapements were relatively high compared to the stream miles available for spawning and rearing. In those cases, it is reasonable to assume that subsequent production may have been influenced by density-dependent effects. In addition, there is evidence of large fluctuations in marine survival for Columbia River and Oregon coast steelhead stocks (Chilcote 2001, Cooney 2001). Spawner return time-series data sets available for mid-Columbia production areas cover a relatively short span of years. As a result, population growth rate projections and stock/recruit function fits using these data sets should be interpreted with caution.

Resident *O. mykiss* Considerations

This section summarizes available information on resident *O. mykiss* populations within the Middle Columbia River steelhead ESU. Table 39 and Appendix B, Table B-1 provide a broad overview of the distribution of case 1, 2, and 3 resident populations within the ESU. See the subsection, Resident Fish, in Section 14, Background and History of Listings, for an explanation of the three cases and their relevance to ESU determinations, and a discussion of how resident fish are considered in risk analyses.

Table 37. Summary of recent 5-year average (geometric mean) population abundance and trend estimates in comparison to estimates included in the previous BRT status review (NMFS 1999b).

		Recent 5-year geometric mean			Short-term trend (%/year)			
		Total	Natural					
Population	5-year mean % natural origin	Mean (range)	Current	Previous	Current	Previous	Interim target	Current vs. target
Klickitat River	Unknown	155 redds(97–261)	–	–	+14.6	–9.2	3,600sum +win	Below target
Yakima River[a]	97[95][c]	1,801(1,058–4,061)	1,747	800	+10.0	+14.0	8,900	20%
Fifteenmile Creek[a]	100[100?][c]	2.87 rpm(1.3–6.0)	–	–	+7.8	–5.4	900	–
Deschutes River	38[50][c]	13,455(10,026–21,457)	5,113	3,000	+11.2	+2.6	5,400	95%
John Day upper main stem	96[100][c]	2,122(926–4,168)	2,037	–	–1.7	–15.2	2,000	102%
John Day lower main stem	nr[d]	1.40 rpm (0.0–5.4)	–	–	–2.5	–15.9	3,200	–
John Day upper North Fork	nr[d]	2.57 rpm(1.6–5.0)	–	–	+9.6	–11.8	2,700	–
John Day lower North Fork	nr[d]	3.52 rpm (1.5–8.8)	–	–	+11.0	–1.2	–	–
John Day Middle Fork	nr[d]	3.70 rpm (1.7–6.2)	–	–	–2.7	–13.7	2,700	–
John Day South Fork	nr[d]	2.52 rpm (0.9–8.2)	–	–	–0.8	–7.4	600	–
Umatilla River	60[76][c]	2,486(1,480–5,157)	1,492	1,096	+8.6	+0.7	2,300	65%
Touchet River[b]	84[93][c]	345 (273–527)	289	300	–0.5	–2.7	900	32%

[a] 5-year geometric mean calculated using years 1997–2001.

[b] 5-year geometric mean calculated using only years 1998–2001.

[c] Estimates from previous status reviews are in brackets.

[d] nr = no releases.

Table 38. Middle Columbia River steelhead ESU population growth-rate analysis. Summary of available trend data sets, results of calculating annual population growth rates (λ), geometric mean, and probability that $\lambda < 1.0$.

Populations	**Series length**	**Methods**[a]	**Proportion wild**		**Hatchery effectiveness assumption**[b]	**Recent (5 yr) Mean**	**Long term λ**[c]	**Prob. long term (λ<1)**	**Short term λ**[d]	**Prob. short term (λ<1)**
			1987–1996	**Last 5 years**						
Yakima River aggregate	1981–2000	dc		0.942	HF = 0.0	901	1.009	0.456	1.002	0.490
Klickitat River	1990–1992 1996–2001	dc	na	na						
Deschutes River	1978–2002	dc	0.4	0.38	HF = 0.0	5566	1.022	0.350	1.076	0.276
					HF = 1.0		0.840	0.999	0.816	0.964
Warm Springs (above weir)	1980–1999		1	1			0.942	0.852	0.904	0.792
John Day River										
Upper main stem	1974–2002	Exp. rc	0.986	0.963	HF = 0.0	2256	0.975	0.699	0.963	0.672
					HF = 1.0		0.966	0.817	0.935	0.789
Lower main stem	1965–2001	Exp. rc		1			0.981	0.850	1.010	0.463
Upper North Fork	1977–2002	Exp. rc		1			1.011	0.412	1.077	0.132
Lower North Fork	1976–2002	Exp. rc		1			1.013	0.430	1.174	0.026
Middle Fork	1974–2002	Exp. rc		1			0.966	0.743	0.954	0.655
South Fork	1974–2002	Exp. rc		1			0.967	0.739	1.011	0.459
Umatilla River	1966–2002	dc	0.758	0.674	HF = 0.0	1658	1.007	0.399	1.070	0.135
					HF = 1.0		0.969	0.854	0.947	0.820
Walla Walla										
Touchet River	1987–2001	dc	0.911	0.842	HF = 0.0	290	0.961	0.769	0.984	0.676
					HF = 1.0		0.939	0.740	0.959	0.666
Main fork	1993–2000	dc	Data series too short to calculate trends							
Fifteenmile Creek (winter run)	1966–2001	rpm	na	na		3.48	0.981	0.635	1.129	0.064

[a] Methods: dc = dam counts; rc = redd counts; rpm = redds per mile index.

[b] Population growth rates calculated for two hatchery effectiveness (HF) assumptions: HF = 0.0 hatchery fish available to spawn, do not contribute to natural production, HF = 1.0 hatchery returns available to spawn, contribute to broodyear natural production at the same rate as natural-origin spawners.

[c] Long term = the length of the available data series.

[d] Short term = 1990–2001, or most recent years.

Resident *O. mykiss* are sympatric with current and historical anadromous steelhead distribution throughout the Middle Columbia River steelhead ESU (Kostow 2003). Pelton/Round Butte Dam in the Deschutes River system and Condit Dam in the White Salmon River are the major anadromous blockages in tributaries in this ESU. Irrigation diversions in other tributaries, including the Umatilla and Yakima rivers, result in partial blockages or reduce the survival of migrating steelhead. Decades of agricultural impacts have heavily affected lower reaches of most major tributaries in this ESU. The Deschutes River is an exception; its lower tributaries are relatively intact, with strong flows of cold water. The resident *O. mykiss* population in the lower Deschutes River is highly productive, supporting some of the largest and most fecund trout in the entire Columbia River basin (Kostow 2003).

Tributaries and mainstem reaches in the upper portions of the Umatilla, Walla Walla, and Klickitat rivers are all relatively intact and support both steelhead and resident *O. mykiss* populations, although there are no specific estimates of abundance for the resident form (Kostow 2003).

Resident *O. mykiss* production varies widely among the tributaries of the relatively large Yakima River system. For 18 years, Roza Dam effectively cut off access for returning anadromous migrants to the upper Yakima River drainage. That area is believed to have been the most productive historical habitat for steelhead. Resident *O. mykiss* currently dominate production above Roza Dam. Two lower Yakima tributaries, Satus and Toppenish creeks, support most of the current steelhead production from the basin. The absence of age-2 and older smolts in these tributaries indicates little or no resident production. Steelhead and resident trout are present in the Naches River subbasin.

The John Day River system may have historically supported large populations of resident trout; their redds have been observed during steelhead redd surveys in this system (Kostow 2003). Some proportion of the age-0/age-1 fish counted during juvenile transects may be resident trout, although these redds are not systematically counted.

Water withdrawals and other agricultural activities have heavily impacted the mainstem Umatilla River. However, headwater reaches are generally intact and have the capacity to support fairly large anadromous and resident *O. mykiss* juvenile production. Abundance estimates of juvenile *O. mykiss* from the upper Umatilla main stem and its tributaries show a high percentage of age-0 and age-1 juveniles, while those age 2 and older make up a relatively small proportion of the juveniles sampled. Kostow (2003) concluded that resident adults may still outnumber returning steelhead in the basin.

Studies of relative spawning distributions and timing for steelhead and sympatric resident *O. mykiss* populations have been conducted on the upper Yakima River (Pearsons et al. (1998) and Deschutes River (Zimmerman and Reeves 2000). Pearsons et al. (1998) concluded that there were substantial overlaps in spawning timing and distribution in the upper Yakima River, with steelhead spawning distributions generally nested within those of resident *O. mykiss*. The Deschutes River study indicated less overlap because of differences in microhabitat the two forms use. In a previous study, Zimmerman and Reeves (1996) documented trout and steelhead pairing late in the steelhead spawning period. Kostow (2003) reported observations of possible steelhead resident pairings during spawning on the John Day, Klickitat, Walla Walla, and Umatilla rivers.

Zimmerman and Reeves (2000) used otolith microchemistry to compare samples of returning adult steelhead to samples taken from resident trout. They concluded that the anadromous steelhead sampled had anadromous mothers, and that the resident trout sampled had resident mothers. The study was unable to determine the corresponding contributions of anadromous and resident males to anadromous and resident progeny.

In the Klickitat River basin, a sample of presumed resident fish from above Castille Falls appears to be of native origin (rather than introduced rainbow trout), based on genetic analyses conducted by WDFW (Phelps et al. 2000). However, this is a case 2 population (above a natural barrier) and is also differentiated from anadromous populations within the ESU. Currens (1997) found genetic evidence for substantial isolation between resident fish in Eightmile Creek (a tributary of Fifteenmile Creek) and anadromous fish within the ESU. This is believed to be a case 1 population—historical contact with anadromous fish and no apparent barrier to migration at present. The genetic profile for the resident fish is consistent with it being a native redband population rather than introduced rainbow trout.

Currens (1997) genetically compared case 3 resident *O. mykiss* above artificial barriers in McKay and Butter creeks (both tributaries of the Umatilla River) with samples from Umatilla River steelhead. Currens found considerable variation among all samples, but the samples from McKay Creek were particularly distinctive. Currens speculated that the McKay Creek population may have been introgressed with nonnative hatchery rainbow trout, which have been stocked in the area.

In the Deschutes River basin, Currens et al. (1990) found genetic differences between *O. mykiss* populations from upper and lower Nena and East Fork Foley creeks that were of the same magnitude as differences among different steelhead populations within the basin. The upper and lower reaches of these creeks are separated by natural waterfalls, which may or may not serve as barriers to anadromous fish (hence, it is uncertain whether these are case 1 or case 3 populations). White River Falls is an ancient barrier, and case 2 resident fish above the falls are genetically quite distinctive (Currens et al. 1990).

In the John Day River, Currens et al. (1987) found that genetic differences between *O. mykiss* from the North and South Forks were larger than differences between presumed steelhead and (case 1) rainbow trout in the South Fork. Genetic analysis of Yakima River *O. mykiss* (Pearsons et al. 1998) found no significant differences between sympatric resident (case 1) and anadromous fish, a finding that is consistent with observations of interbreeding between the two forms.

New Hatchery Information

Relatively high numbers of hatchery-origin steelhead returning from releases outside of the Deschutes River system continue to enter the Deschutes system. We do not know the actual number of out-of-basin-origin hatchery fish that spawn naturally in the Deschutes. Preliminary results from recent radio tracking studies cited in Cramer et al. (2002) backs up the hypothesis that a significant proportion of hatchery strays entering the Deschutes River are “dip-ins,” fish that migrate out of the system prior to spawning. The estimated escapements to the spawning grounds used in the status review updates already include an adjustment to reflect outmigrating stray hatchery fish. The estimates of spawning escapement into the Deschutes River system depicted in Figure 139 assume that 50% of the estimated number of outside hatchery fish passing over Sherars Falls dropped back down and did not contribute to spawning in the Deschutes River system (Chilcote 2002). Cramer et al. (2002) identified two other sets of information regarding the potential contribution of hatchery stocks to natural spawning in the Deschutes River. ODFW spawner surveys in Buckhollow, Bakeoven, and Trout creeks indicate a relatively high

Table 39. Distribution of steelhead populations by category relative to the Middle Columbia River steelhead ESU.

Category 1 populations (sympatric)[a]	**Category 2 populations (major natural barriers)**[b]	**Category 3 populations (major artificial barriers)**[b]
Historically all areas where steelhead are or were present. Trout distributions currently more restricted.	All natural barriers upstream of Klickitat and Deschutes basins.	Trout distributions currently more restricted than historically.
Fifteenmile Creek Eightmile Creek Deschutes River KlickitatRiver Umatilla River Upper Umatilla River John Day River Upper tributaries Walla Walla River Upper tributaries Yakima River Upper Yakima River Naches River Some other small tributaries	Deschutes River White River Upper Deschutes (Big Falls) River Upper North Fork Crooked River John Day River Upper South Fork John Day River	Little White Salmon River (Conduit Dam) Deschutes River (Pelton/Round Butte Dams) Metolius River Squaw Creek Crooked River Umatilla River (irrigation dams) Willow Creek Butter Creek McKay Creek

[a] *O. mykiss* distribution in areas of sympatry with steelhead may be restricted in some areas if native *O. clarki* are also in the basin. The generalized listing of basins and subbasins does not imply that these constitute single trout populations or that trout distribution is continuous throughout the areas listed. Detailed trout distribution is usually unknown and actual demographically independent trout populations have not been described. All current trout distributions are decreased from historical distributions. In particular, many mainstem and lower basin tributaries are no longer used but probably were historically. Many current trout populations are only in upper basins and are highly fragmented.

[b] Only major barriers are noted; numerous small barriers, both natural and artificial, also exist. Many other natural barriers are present but have *O. clarki*, rather than *O. mykiss*, above them.

Table 40. Steelhead hatchery releases in the middle Columbia River region by major steelhead production areas and broodstock.

Basin	Race	Stock	Average[*] releases per year		
			1985–1989	1990–1994	1995–2001
Mainstem Columbia River	Summer	Unknown	4,523	–	–
	Summer	Dworshak B	–	5,440	412
		Mainstem total	4,523	5,440	412
White Salmon River	Summer	Skamania	9,798	18,238	8,641
	Winter	Skamania	12,414	32,615	17,497
	Winter	Elochoman River	–	–	6,428
	Winter	Kalama River	–	–	3,669
	Winter	Beaver Creek	–	–	5,741
		White Salmon total	22,212	50, 854	41,976
Little White Salmon River	Summer	Skamania	0	0	15,395
Klickitat River	Summer	Skamania	87,821	96,704	113,616
Deschutes River	Summer	Deschutes River	209,443	163,505	168,680
Rock Creek	Winter	Skamania	1,428	5,176	4,083
	Winter	Elochoman River	–	–	1,560
		Rock Creek total	1,428	5,176	5,644
Umatilla River	Summer	Umatilla River	66,730	130,958	142,259
Walla Walla River	Summer	Lyons Ferry	191,854	208,632	293,256
	Summer	Wells	116,396	–	–
	Summer	Ringold	–	55,752	–
	Summer	Touchet River	–	–	5,212
		Walla Walla total	308,251	264,385	298,469
Yakima	Summer	Ringold	21,726	–	–
	Summer	Wells	18,201	–	–
	Summer	Yakima River	112,641	72,039	–
		Yakima total	152,569	72,039	0
ESU total		All stocks	852,978	789,063	786,451

[*] Averages are calculated by time period to facilitate comparison of release levels since the last BRT review (NMFS 1999b) with previous levels.

proportion of wild fish in those tributaries in recent years in comparison to the estimated fraction of wild fish in the total run entering the Deschutes River for those years. In addition, estimated natural-origin returns to the main stem or lower tributary roughly track the returns to the Warm Springs River in time, in spite of large differences in estimated hatchery contributions in some years. Additional information is needed to clarify the potential impact of outside hatchery-origin fish to natural production in the system. Categorizations of Middle Columbia River steelhead ESU hatchery stocks (SSHAG 2003) can be found in Appendix B, Table B-3.

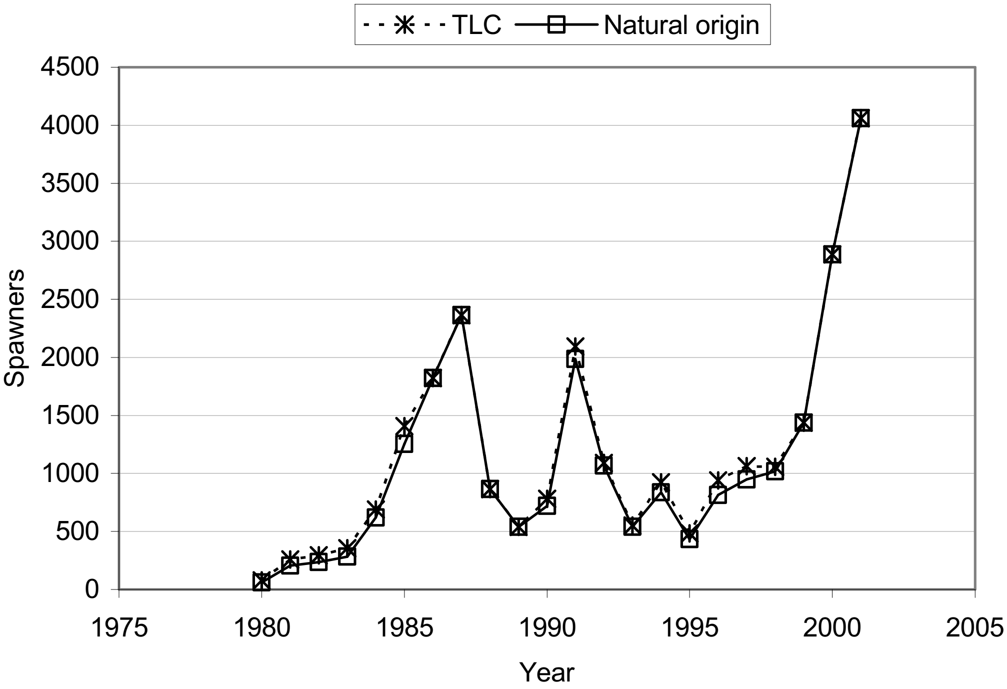

Figure 138. Yakima River steelhead spawning escapement estimates, 1980–2001. Source: From Washington Department of Fish and Wildlife database (see Appendix A, Table A-2). Based on Prosser Dam count.

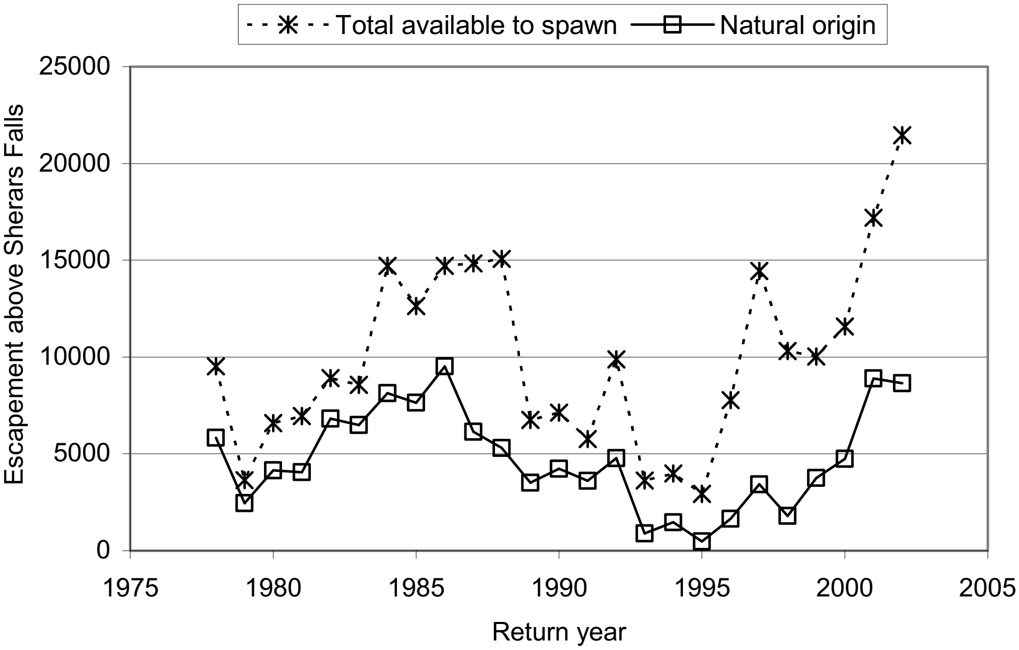

Figure 139. Deschutes River steelhead escapement estimates over Sherars Falls, 1978–2002. Sources: Run size estimates based on Oregon Department of Fish and Wildlife mark-recapture analysis. Hatchery:wild ratios based on returns to Pelton Ladder and Warm Springs National Fish Hatchery (see Chilcote 2001, 2002).

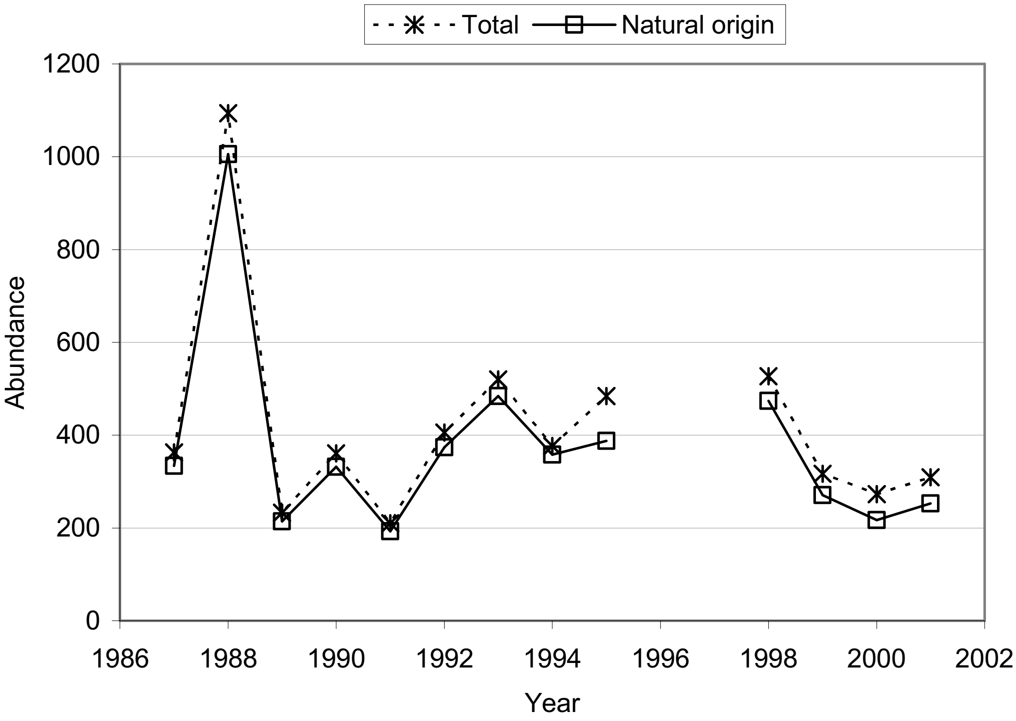

Figure 140. Touchet River steelhead escapement estimates, 1987–2001. Source: Estimates based on spawning ground surveys upstream of Dayton, Washington, from James and Scheeler (2001).

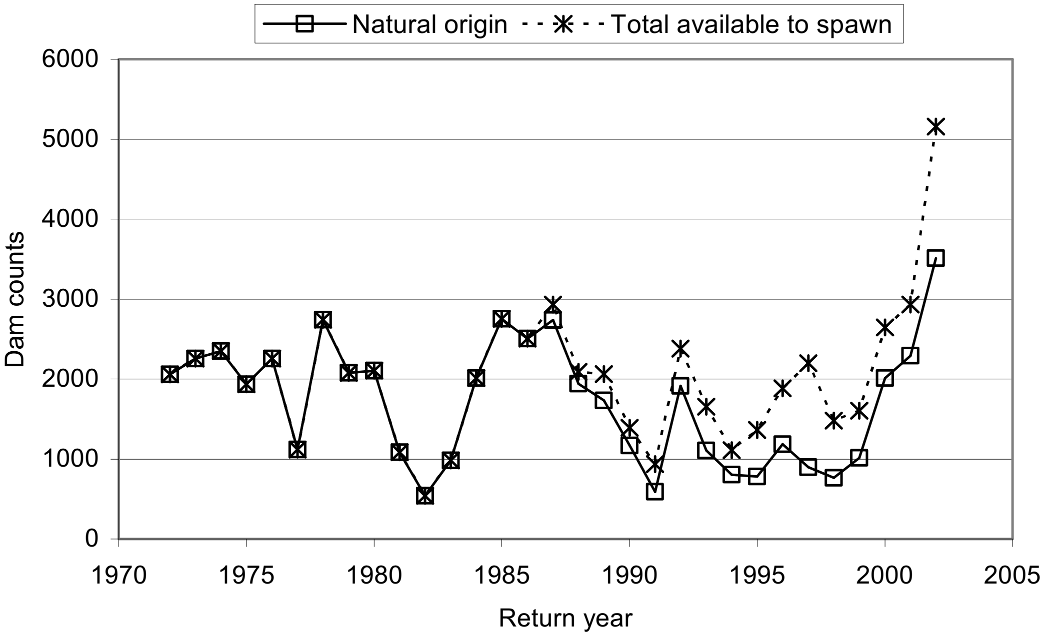

Figure 141. Umatilla River steelhead counts at Three Mile Dam, 1966–2002. Source: Chilcote (2001).

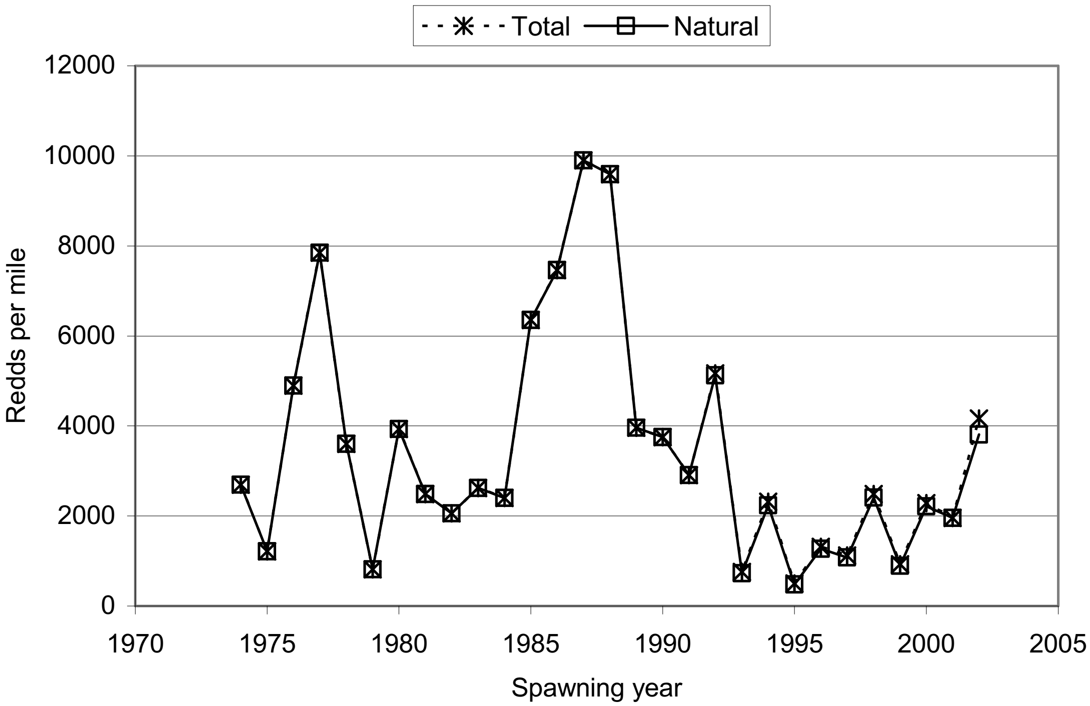

Figure 142. Upper John Day River steelhead estimates, based on annual redd counts, 1974–2002. Source: Chilcote (2002).

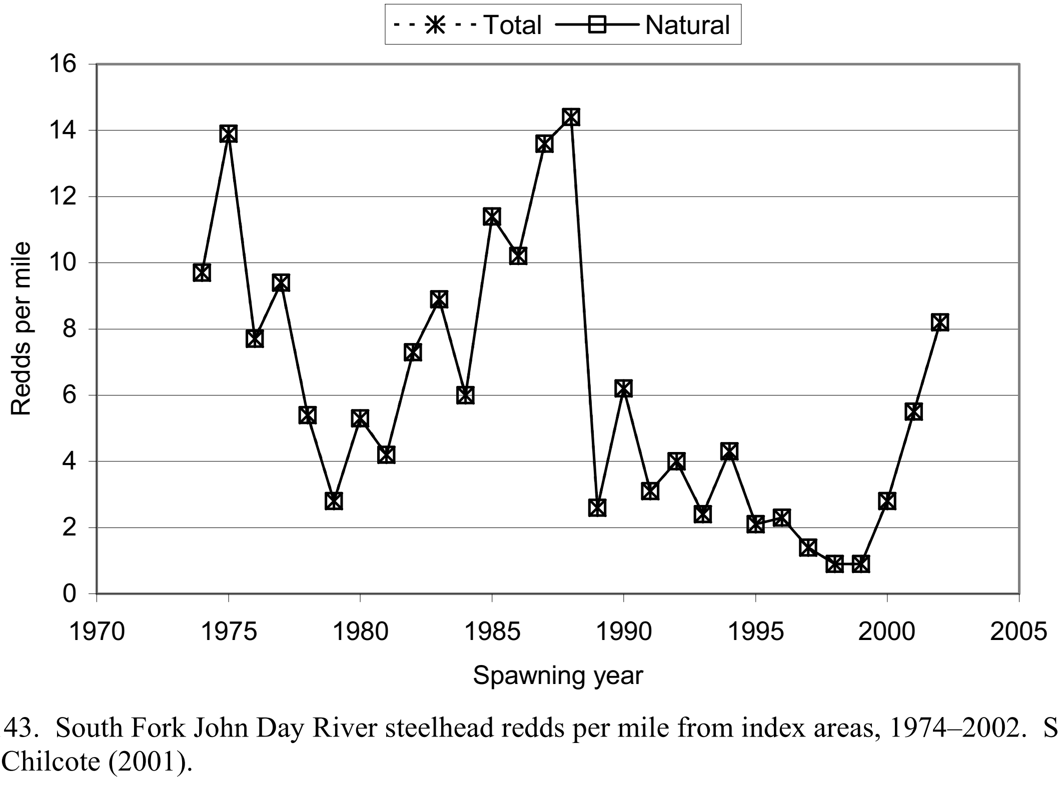

Figure 143. South Fork John Day River steelhead redds per mile from index areas, 1974–2002. Source: Chilcote (2001).

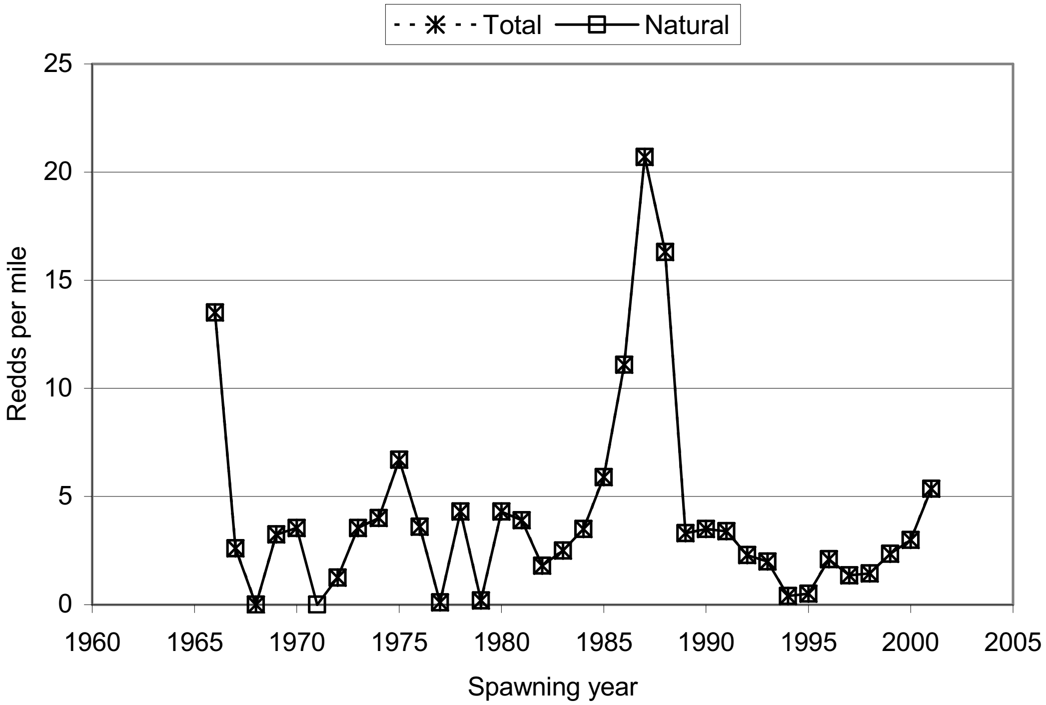

Figure 144. Lower mainstem John Day River steelhead redds per mile from index areas, 1965–2001. Source: Chilcote (2001).

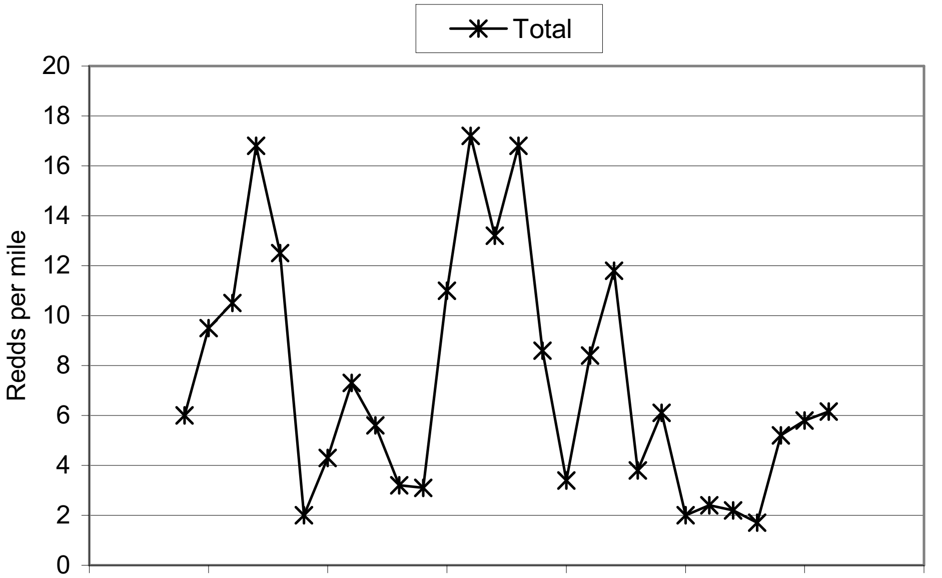

Figure 145. Middle Fork John Day River steelhead redds per mile from index areas, 1974–2001. Source: Chilcote (2001).

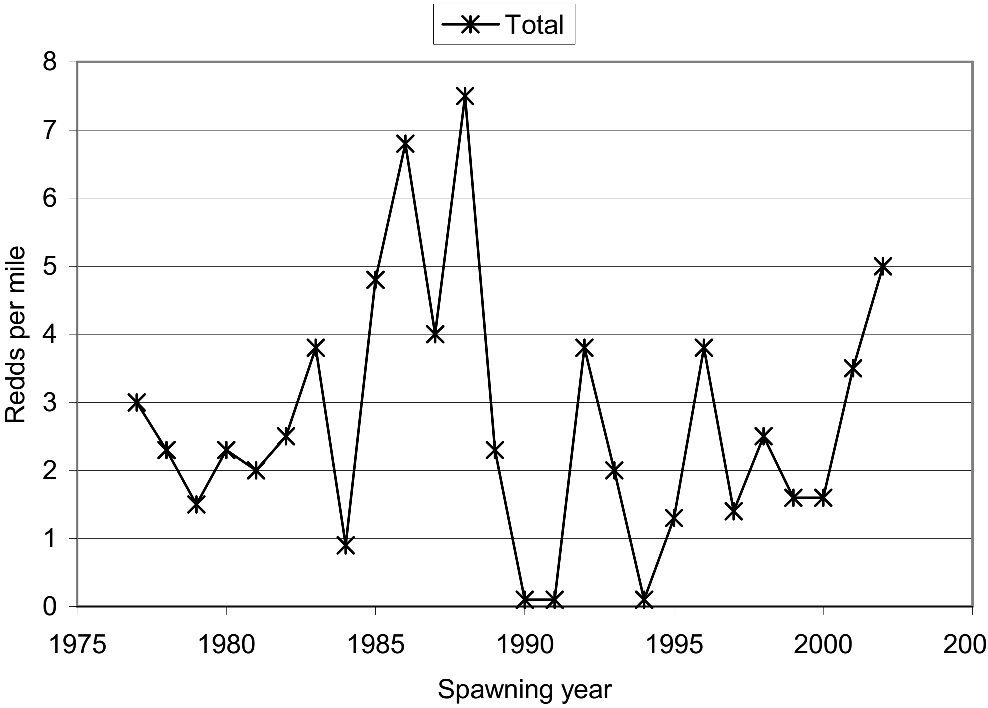

Figure 146. Upper North Fork John Day River steelhead redds per mile from index areas, 1977–2002. Source: Chilcote (2001).

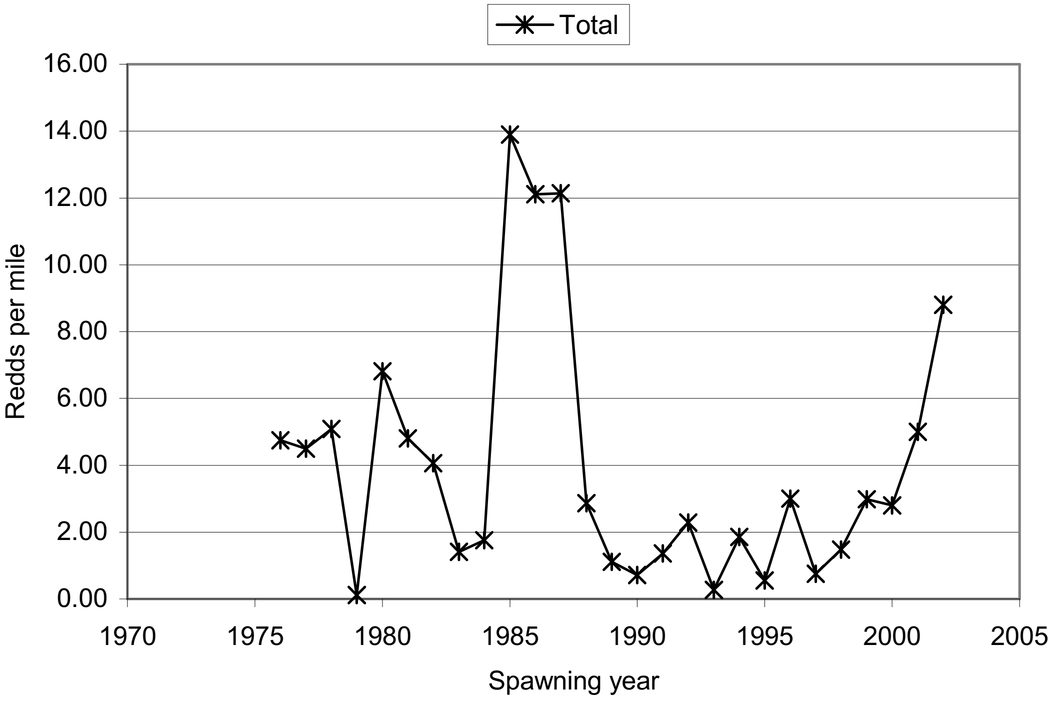

Figure 147. Lower North Fork John Day River steelhead redds per mile from index areas, 1976–2002. Source: Chilcote (2001).

18. Lower Columbia River Steelhead ESU

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 1998c). 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.

Listing status: Threatened.

New Data and Updated Analyses

New data available for this update included recent spawner data, additional data on the fraction of hatchery-origin spawners, recent harvest rates, updated hatchery release information and a compilation of data on resident *O. mykiss*. For many Washington Chinook salmon populations, the WDFW has conducted analyses using the EDT model (Busack and Rawding 2003), which predicts fish population performance based on data about reach-specific habitat attributes (http://www.olympus.net/community/dungenesswc/EDT-primer.pdf). New analyses for this update include the designation of demographically independent populations, recalculation of previous BRT metrics with additional years' data, estimates of median annual growth rate (λ) under different assumptions about the reproductive success of hatchery fish, and estimates of current and historically available stream kilometers.

Historical Population Structure

As part of its effort to develop viability criteria for lower Columbia River steelhead, the WLC-TRT identified historical demographically independent populations (Myers et al. 2002). Population boundaries are based on an application of the VSP definition by McElhany et al. (2000). Myers et al. hypothesized that the ESU historically consisted of 17 winter-run populations and 6 summer-run populations, for a total of 23 populations (Figures 148 and 149).

The WLC-TRT partitioned Lower Columbia River steelhead ESU populations into a number of strata based on major life history characteristics and ecological zones (McElhany

Table 41. Historical population structure and abundance statistics for Lower Columbia River steelhead ESU populations, by ecological zone and major life history type.

Life history[a]	Ecological zone[b]	Population	Years of data for recent means[c]	Recent geometric mean total spawners	Recent arithmetic mean total spawners	Recent arithmetic mean percent hatchery-origin spawners
Winter run	Cascade	Cispus River				
		Tilton River	2002	2,787	2,787	73%
		Upper Cowlitz River				
		Lower Cowlitz River			– No data –	
		Coweeman River	1998–2002	466	490	50%
		South Fork Toutle River	1998–2002	504	554	2%
		North Fork Toutle River	1998–2002	196	207	0%
		Kalama River	1998–2002	726	797	0%
		North Fork Lewis			– No data –	
		East Fork Lewis		Index data only; no abundance means available		
		Salmon Creek			– No data –	
		Washougal River	1998–2002	323	376	0%
		Clackamas River	1997–2001	560	717	41%
		Sandy River	1997–2001	977	997	42%
	Columbia Gorge	Lower gorge tributaries			– No data –	
		Upper gorge tributaries			– No data –	
		Hood River	1996–2000	756	792	52%
Summer run	Cascade	Kalama River	1999–2003	474	633	32%
		North Fork Lewis			– No data –	
		East Fork Lewis	1999–2003	434	514	25%
		Washougal River	1999–2003	264	313	8%
	Columbia Gorge	Wind River	1999–2003	472	535	5%
		Hood River	1996–2000	931	1,003	83%

[a] Life history types are based on traits related to run timing.

[b] Ecological zones are based on ecological community and hydrodynamic patterns.

[c] Time series used for the summary statistics are referenced in Appendix B, Table B-4.

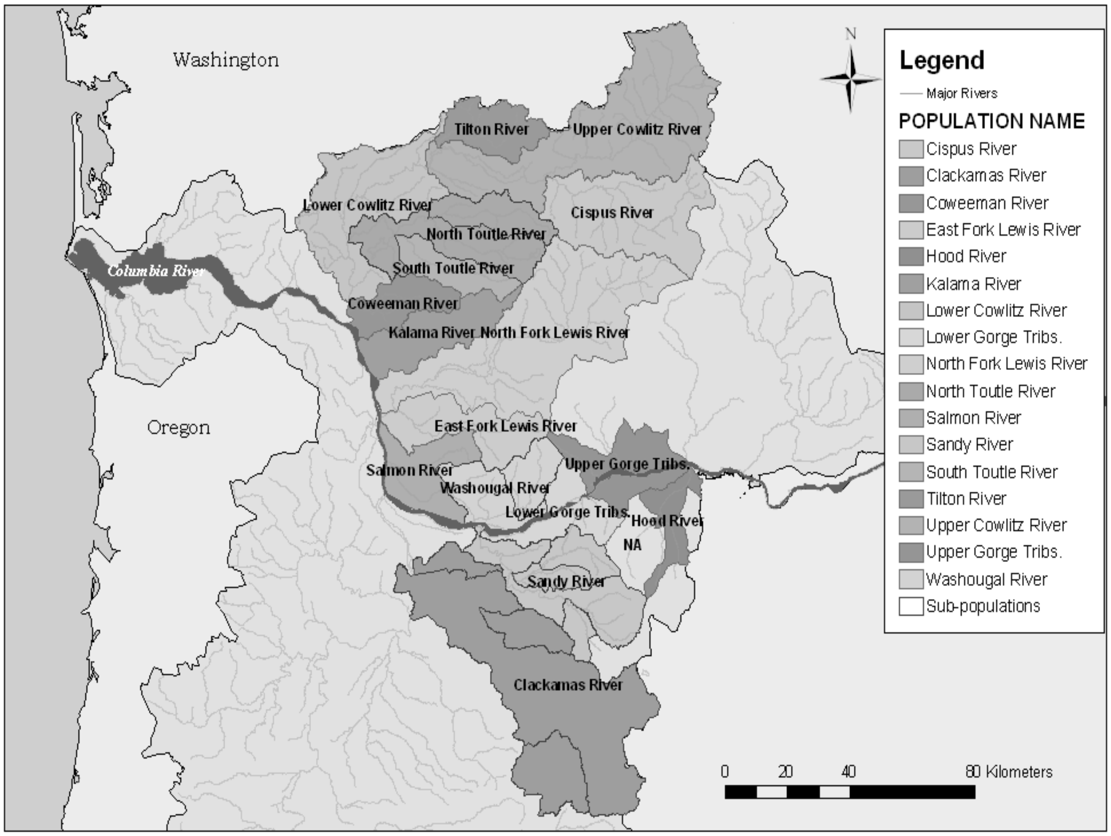

Figure 148. Historical populations of winter-run steelhead in the Lower Columbia River steelhead ESU. Source: Myers et al. (2002).

et al. 2003). WLC-TRT analysis suggests that a viable ESU would need multiple viable populations in each stratum. The strata and associated populations are identified in Table 41.

Abundance and Trends

Reference citations for abundance time series and related data are presented in Appendix B, Table B-4. Recent abundance of total spawners, and recent fraction of hatchery-origin spawners for Lower Columbia River steelhead ESU populations are summarized in Table 41. The abundance means in Table 41 are for total spawners; they include both natural- and hatchery-origin fish. Natural-origin fish had parents that spawned in the wild, as opposed to hatchery-origin fish, whose parents were spawned in a hatchery. A number of the populations have a substantial fraction of hatchery-origin spawners in the spawning areas and are hypothesized to be sustained largely by hatchery production. Exceptions are the Kalama, North and South Fork Toutle, and East Fork Lewis winter-run populations, which have few hatchery fish spawning in natural spawning areas. These populations have relatively low recent mean abundance estimates; the largest is the Kalama River, with a geometric mean of 726 spawners.

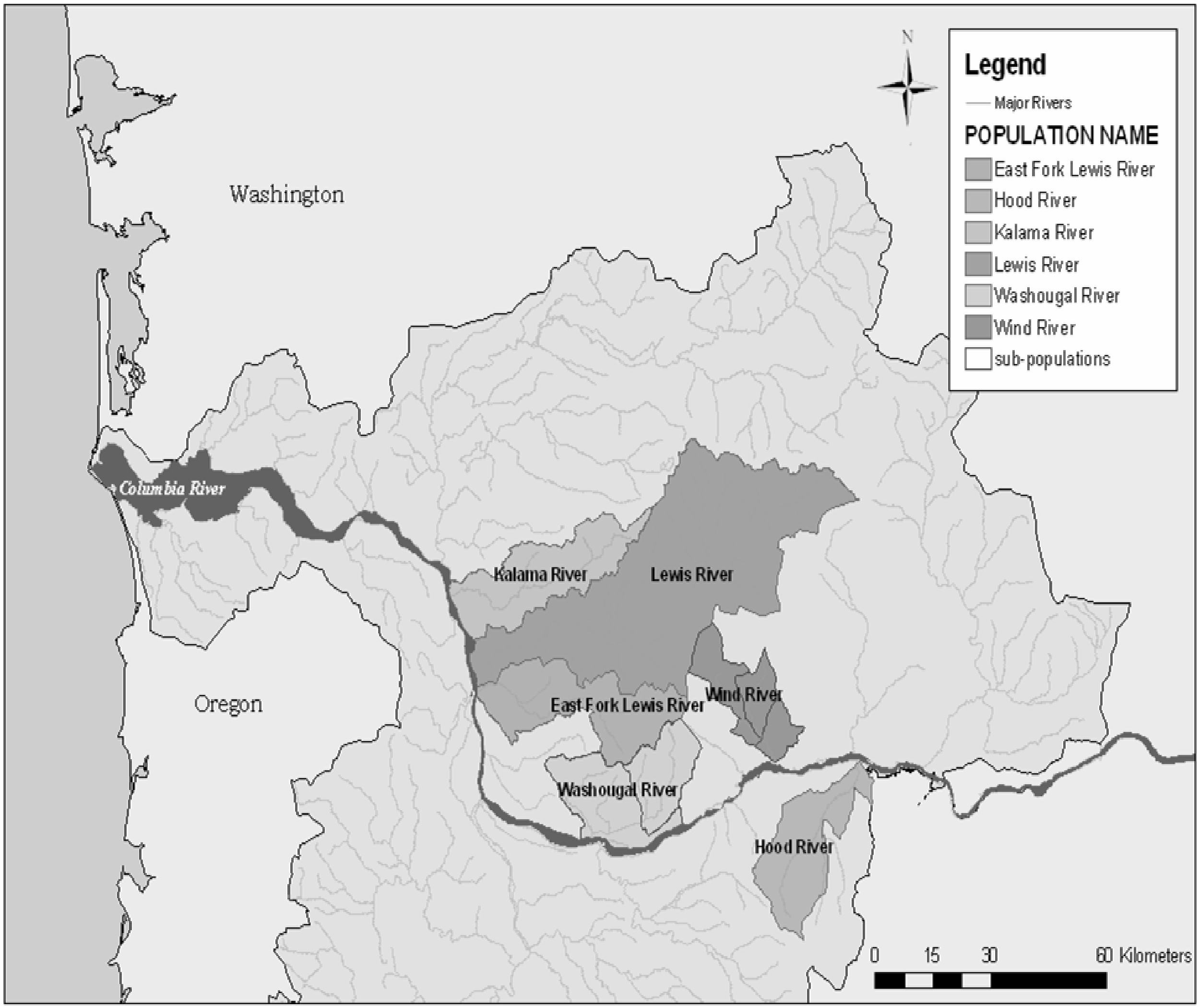

Figure 149. Historical populations of summer–run steelhead in the Lower Columbia River steelhead ESU. Source: Myers et al. (2002).

The pooled estimate of abundance for the historical Cispus, Tilton, and upper Cowlitz river populations has the highest recent total spawner abundance in the Lower Columbia River steelhead ESU, as well as the largest fraction of hatchery-origin spawners. The hatchery-origin spawners are part of a reintroduction program to establish steelhead above Cowlitz Falls Dam, the uppermost of three impassable dams on the mainstem Cowlitz River (Serl and Morrill 2002). Adults are collected below the most downstream dam (Mayfield) and trucked above Cowlitz Falls Dam. Downstream survival of juvenile steelhead though the dams and reservoirs is considered negligible, so juveniles are collected at Cowlitz Falls Dam and trucked downstream.

The current collection efficiency of juveniles at Cowlitz Falls Dam is considered too low for the reintroduction to be self-sustaining.[18]

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[18] See Footnote 9.

Where data are available, Figures 150–170 present the abundance time-series information for each population. We give two types of time-series figures. The first type plots abundance against time (Figures 150, 152, 154, 156, 158, 160, 162–166, 168, 170). Where possible, two lines are presented on the abundance figure: One line is the total number of spawners (or total count at a dam), and the other line is the number of fish of natural origin. In cases for which data were not available to distinguish between natural- and hatchery-origin spawners, only total spawner (or dam count) information is presented in order to give a sense of abundance levels, overall trend, variability patterns, and fraction of hatchery-origin spawners.

The second type of figure presents the total number of spawners (natural- and hatchery-origin) and number of preharvest recruits produced by those spawners by broodyear (Figures 151, 153, 155, 157, 159, 161, 167, 169, and 171). Dividing the number of preharvest recruits by the number of spawners for the same time period would yield an estimate of the preharvest recruits per spawner. These figures require harvest and age-structure information; therefore they could be produced for only a limited number of populations. These figures can indicate whether preharvest recruitment, and the degree to which harvest management has the potential to recover populations, has changed. If the preharvest recruitment line is consistently below the spawner line, the population would not be replacing itself, even in the absence of all harvest.

Summary statistics on population trends and growth rate are presented in Tables 42–45 and Figures 172–174. The methods for estimating trends and growth rate (λ) are described in Section 2. The majority of populations have a long-term trend of less than 1, indicating that the population is in decline. In addition, for most populations the probability is high that the true trend/growth rate is less than 1 (Table 43). When growth rate is estimated, assuming that hatchery-origin spawners have a reproductive success equal to that of natural-origin spawners, all the populations have a negative growth rate except the North Fork Toutle River winter run, which had very few hatchery-origin spawners (Figure 170). The North Fork Toutle population is still recovering from the 1980 eruption of Mount St. Helens and is still at low abundance (recent mean of 196 spawners). Previous status reviews cataloged the potential reasons for these declines; they include habitat degradation, deleterious hatchery practices, and climate-driven changes in marine survival.

Rawding (2003) suggests a major factor driving the decline observed in the available time series are marine conditions, and that marine survival is largely responsible for the increases observed in the last few years. He poses as an important question: What will happen to lower Columbia River steelhead when ocean conditions cycle back to less-productive regimes? Because this issue applies to many ESUs, it is discussed in Section 1, Introduction.

Table 42. Long-term trend and growth rate for a subset of Lower Columbia River steelhead ESU populations for which adequate data are available (95% confidence intervals are in parentheses).

				Median growth rate (λ)[c]	
Run	**Population**	**Years for trend and λ[α]**	**Trend of total spawners[b]**	**Hatchery = 0[d]**	**Hatchery = wild[e]**
Winter	Coweeman	1987–2002	0.916	0.908	0.782
			(0.847–0.990)	(0.792–1.041)	(0.678–0.903)
	South Fork Toutle	1984–2002	0.917	0.938	0.933
			(0.876–0.961)	(0.830–1.059)	(0.821–1.061)
	North Fork Toutle	1989–2002	1.135	1.062	1.062
			(1.038–1.242)	(0.915–1.233)	(0.915–1.233)
	Kalama	1977–2002	0.998	1.010	0.916
			(0.973–1.023)	(0.913–1.117)	(0.824–1.019)
	Clackamas	1958–2001	0.979	0.971	0.949
			(0.966–0.993)	(0.901–1.047)	(0.877–1.027)
	Sandy	1978–2001	0.940	0.945	0.828
			(0.919–0.960)	(0.850–1.051)	(0.741–0.925)
Summer	Kalama	1977–2003	0.928	0.981	0.712
			(0.889–0.969)	(0.889–1.083)	(0.642–0.790)
	Washougal	1986–2003	0.991	1.003	0.996
			(0.942–1.043)	(0.884–1.138)	(0.872–1.138)
	Washougal	1989–2003	0.973	0.983	0.937
			(0.921–1.028)	(0.853–1.134)	(0.807–1.089)

[a] The long-term analysis used the entire data set.

[b] The trend estimate is for total spawners. It includes both natural- and hatchery-origin fish.

[c] The λ calculation is an estimate of what the natural growth rate would have been after accounting for hatchery-origin spawners. The λ estimate is calculated under two hypotheses about the reproductive success of hatchery-origin spawners.

[d] Hatchery fish are assumed to have zero reproductive success.

[e] Hatchery fish are assumed to have the same relative reproductive success as natural-origin fish.

EDT-based estimates of historical abundance

The WDFW has conducted analyses of the Lower Columbia River Chinook salmon ESU populations using the EDT model (Busack and Rawding 2003). WDFW populated this model with estimates of historical habitat condition, which produced the estimates of average historical abundance shown in Table 46. There is a great deal of unquantified uncertainty in the EDT historical abundance estimates, and interpreting these data should include this uncertainty. In addition, the habitat scenarios evaluated as “historical” may not reflect historical distributions, because some areas that were historically accessible but currently are blocked by large dams are omitted from the analyses, and some areas that were historically inaccessible but recently became passable because of human intervention are included. The EDT outputs are provided here to give a sense of historical abundance of populations relative to each other and an estimate of historical abundance relative to current abundance.

Table 43. Short-term trend and growth rate for a subset of Lower Columbia River steelhead ESU populations for which adequate data are available (95% confidence intervals are in parentheses).

Run	Population	Years for trend[a]	Trend of total spawners[b]	Median growth rate (λ)[c]	
				Hatchery = 0[d]	**Hatchery = wild[e]**
Winter	Coweeman	1990–2002	0.941 (0.818–1.083)	0.920 (0.803–1.055)	0.787 (0.682–0.909)
	South Fork Toutle	1990–2002	0.939 (0.856–1.130)	0.933 (0.826–1.054)	0.929 (0.817–1.056)
	North Fork Toutle	1990–2002	1.086 (0.999–1.018)	1.038 (0.894–1.206)	1.038 (0.894–1.206)
	Kalama	1990–2002	1.004 (0.923–1.091)	0.984 (0.890–1.088)	0.922 (0.829–1.025)
	Clackamas	1990–2001	0.914 (0.806–1.036)	0.875 (0.812–0.943)	0.830 (0.767–0.898)
	Sandy	1990–2001	0.889 (0.835–0.946)	0.866 (0.797–0.985)	0.782 (0.700–0.874)
Summer	Kalama	1990–2003	0.855 (0.756–0.968)	0.900 (0.816–0.994)	0.664 (0.598–0.737)
	Washougal	1990–2003	1.024 (0.951–1.104)	1.029 (0.907–1.168)	0.960 (0.841–1.097)
	Wind	1990–2003	0.989 (0.931–1.049)	0.995 (0.863–1.148)	0.903 (0.777–1.049)

[a] Short-term data sets include data from 1990 to the most recent available year.

[b] The trend estimate is for total spawners. It includes both natural- and hatchery-origin fish.

[c] The λ calculation is an estimate of what the natural growth rate would have been after accounting for hatchery-origin spawners. The λ estimate is calculated under two hypotheses about the reproductive success of hatchery-origin spawners.

[d] Hatchery fish are assumed to have zero reproductive success.

[e] Hatchery fish are assumed to have the same relative reproductive success as natural-origin fish.

Table 44. Probability that the long-term abundance trend or growth rate of a subset of Lower Columbia River steelhead ESU populations is less than 1.

Run	Population	Years for trend and λ	Probability trend < 1	Probability λ < 1	
				Hatchery = 0[a]	**Hatchery = wild[b]**
Winter	Coweeman	1987–2002	0.985	0.936	1.000
	South Fork Toutle	1984–2002	0.999	0.884	0.899
	North Fork Toutle	1989–2002	0.005	0.063	0.063
	Kalama	1977–2002	0.574	0.405	0.971
	Clackamas	1958–2001	0.998	0.784	0.918
	Sandy	1978–2001	1.000	0.993	1.000
Summer	Kalama	1977–2003	0.999	0.613	1.000
	Washougal	1986–2003	0.644	0.476	0.526
	Wind	1989–2003	0.848	0.639	0.889

[a] Hatchery-origin fish are assumed to have zero reproductive success.

[b] Hatchery-origin fish are assumed to have reproductive success equivalent to that of natural-origin fish.

Table 45. Probability that the long-term abundance trend or growth rate of a subset of Lower Columbia River steelhead ESU populations is less than 1.

Run	Population	Years for trend	Probability trend < 1	Probability λ < 1	
				Hatchery = 0[a]	Hatchery = wild[b]
Winter	Coweeman	1990–2002	0.822	0.851	0.995
	South Fork Toutle	1990–2002	0.919	0.797	0.812
	North Fork Toutle	1990–2002	0.026	0.135	0.135
	Kalama	1990–2002	0.463	0.593	0.846
	Clackamas	1990–2001	0.929	0.849	0.929
	Sandy	1990–2001	0.999	0.991	1.000
Summer	Kalama	1990–2003	0.991	0.849	1.000
	Washougal	1990–2003	0.249	0.349	0.757
	Wind	1990–2003	0.659	0.538	0.989

[a] Hatchery-origin fish are assumed to have zero reproductive success.

[b] Hatchery-origin fish are assumed to have reproductive success equivalent to that of natural-origin fish.

Table 46. Estimates of historical abundance for a subset of Lower Columbia River steelhead ESU populations, based on the EDT model.

Life history	Population	EDT estimate of historical abundance
Winter run	Coweeman River	2,243
	Lower Cowlitz River	1,672
	South Fork Toutle River	2,627
	North Fork Toutle River	3,770
	Kalama River	554
	North Fork Lewis River	713
	East Fork Lewis River	3,131
	Salmon Creek	–
	Washougal River	2,497
	Lower Columbia Gorge tributaries	793
	Upper Columbia Gorge tributaries	243
	Hood River	–
Summer run	Kalama River	3,165
	East Fork Lewis River	422
	Washougal River	1,419
	Wind River	2,288

Loss of habitat from barriers

Steel and Sheer (2003) conducted an analysis to assess the number of stream kilometers historically and currently available to salmon populations in the lower Columbia River (Table 46). Stream kilometers usable by salmon are determined based on simple gradient cutoffs and the presence of impassable barriers. Barriers with passage limited to trap-and-haul are considered impassable for this analysis. This approach will overestimate the number of usable stream kilometers because it does not consider habitat quality (other than gradient). However, the analysis does indicate that for some populations the number of stream habitat kilometers currently accessible is greatly reduced from the historical condition.

Resident *O. mykiss* Considerations

The available information on resident *O. mykiss* populations within the Lower Columbia River steelhead ESU is summarized in Table 31 and Appendix B, Table B-1. The tables provide a broad overview of the distribution of case 1, 2, and 3 resident populations within the ESU. See the subsection, Resident Fish, in Section 1 for an explanation of the three cases and their relevance to ESU determinations. The subsection, Resident Fish, in Section 14, Background and History of Steelhead Listings, discusses how the BRT considered resident fish in risk analyses.

Table 47. Loss of habitat from barriers in the Lower Columbia River steelhead ESU.

Run	**Population**	**Potential current habitat**[a]	**Potential historical habitat (km)**[b]	**Current to historical habitat ratio**[c]
Winter	Cispus River	0	87	0%
	Coweeman River	85	102	84%
	Lower Cowlitz River	542	674	80%
	Upper Cowlitz River	6	358	2%
	Tilton River	0	120	0%
	South Fork Toutle River	82	92	8%
	North Fork Toutle River	209	330	63%
	Kalama River	112	122	92%
	North Fork Lewis River	115	525	22%
	East Fork Lewis River	239	315	76%
	Salmon Creek	222	252	88%
	Washougal River	122	232	53%
	Clackamas River	919	1,127	82%
	Sandy River	295	386	76%
	Lower Columbia Gorge tributaries	46	46	99%
	Upper Columbia Gorge tributaries	31	31	100%
	Hood River	138	138	99%
Summer	Kalama River	49	54	90%
	North Fork Lewis River	78	83	94%
	East Fork Lewis River	87	364	24%
	Washougal River	181	236	77%
	Wind River	84	164	51%
	Hood River	36	41	90%
Total		3,678	5,879	63%

[a] The potential current habitat is the kilometers of stream below all currently impassable barriers between a gradient of 0.5% and 4%.

[b] The potential historical habitat is the kilometers of stream below historically impassable barriers between a gradient of 0.5% and 4% (summer) and 0.5% and 6% (winter).

[c] The current to historical:habitat ratio is the percent of the historical habitat that is currently available.

Kostow (2003) reviewed information on the abundance and distribution of resident *O. mykiss* for the Lower Columbia River steelhead ESU and found no quantitative estimates of abundance for resident *O .mykiss* in any Lower Columbia River ESU population. However, information and analysis on the distribution and relative abundance of resident *O. mykiss* is available and suggests that resident *O. mykiss* numerically dominate the Wind River basin and the West Fork Hood River basin. However, resident populations are considered less common in other portions of the Hood River basin. Residents are considered common in the Collowash subbasin of the Clackamas River, though rare or possibly absent in other parts of the basin below natural barriers. Resident *O. mykiss* are considered abundant above the Bull Run dams (1929) in the Sandy River basin, Merwin Dam (1931) in the Lewis River basin, and Mayfield Dam (1963) in the Cowlitz River basin, but are rare or absent elsewhere in these basins. We are not aware of specific information relevant to the ESU status of case 3 resident populations above the dams in the Cowlitz, Lewis, or Sandy rivers. Resident *O. mykiss* are probably common in the upper portions of the Kalama and Washougal River basins, but rare in the lower portions. Resident *O. mykiss* are considered absent from all the smaller lower Columbia River tributaries that have small patches of spawning anadromous *O. mykiss*. Cutthroat trout (*O. clarki*) tend not to co-occur with resident *O. mykiss* and appear to have historically been the predominant resident trout species in many of the lower Columbia River tributaries.

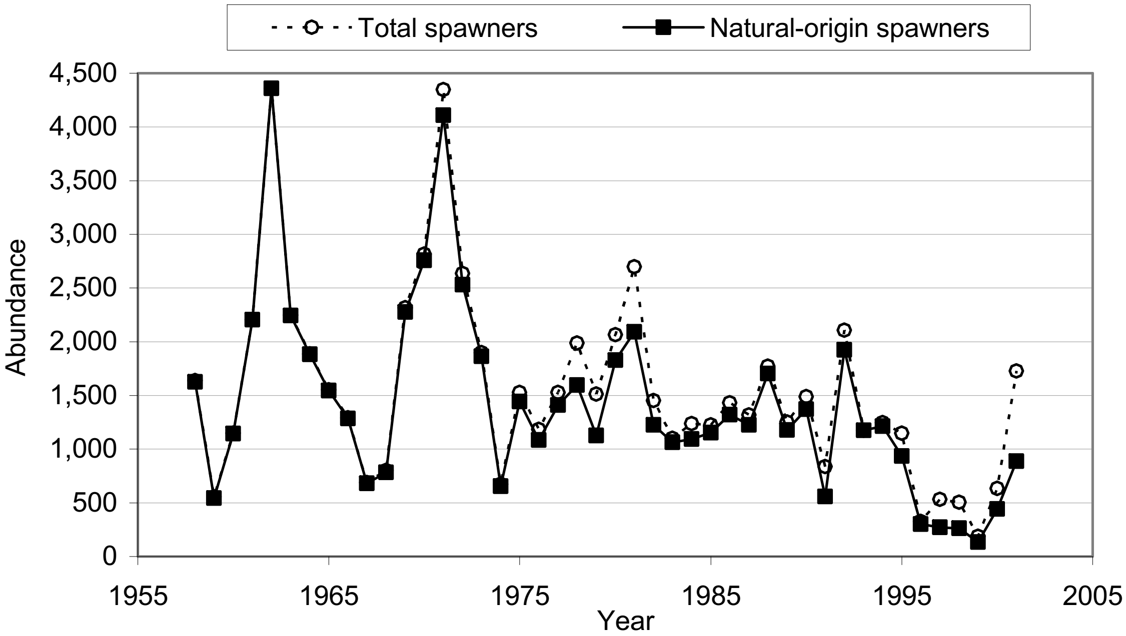

Figure 150. Winter-run steelhead abundance at North Fork Dam on the Clackamas River, 1958–2001. Source: Data from Cramer (2002a).

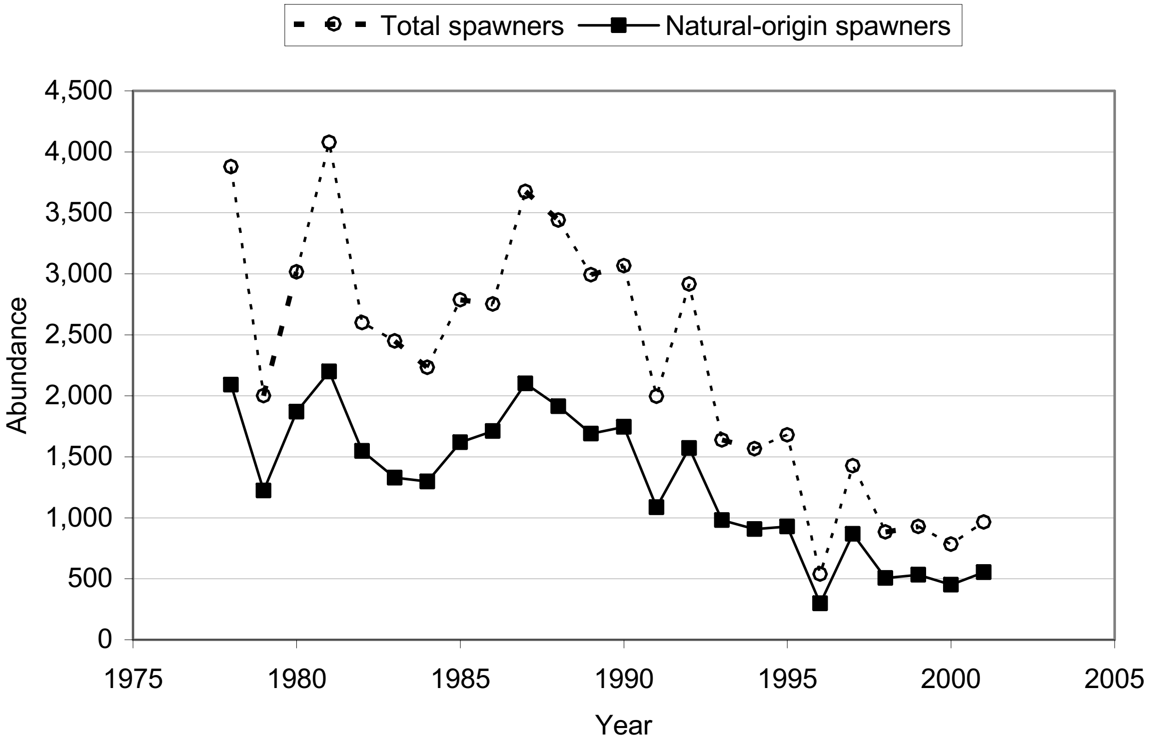

Figure 151. Preharvest recruits and spawners for winter-run steelhead estimated from counts at North Fork Dam on the Clackamas River, 1958–2001.

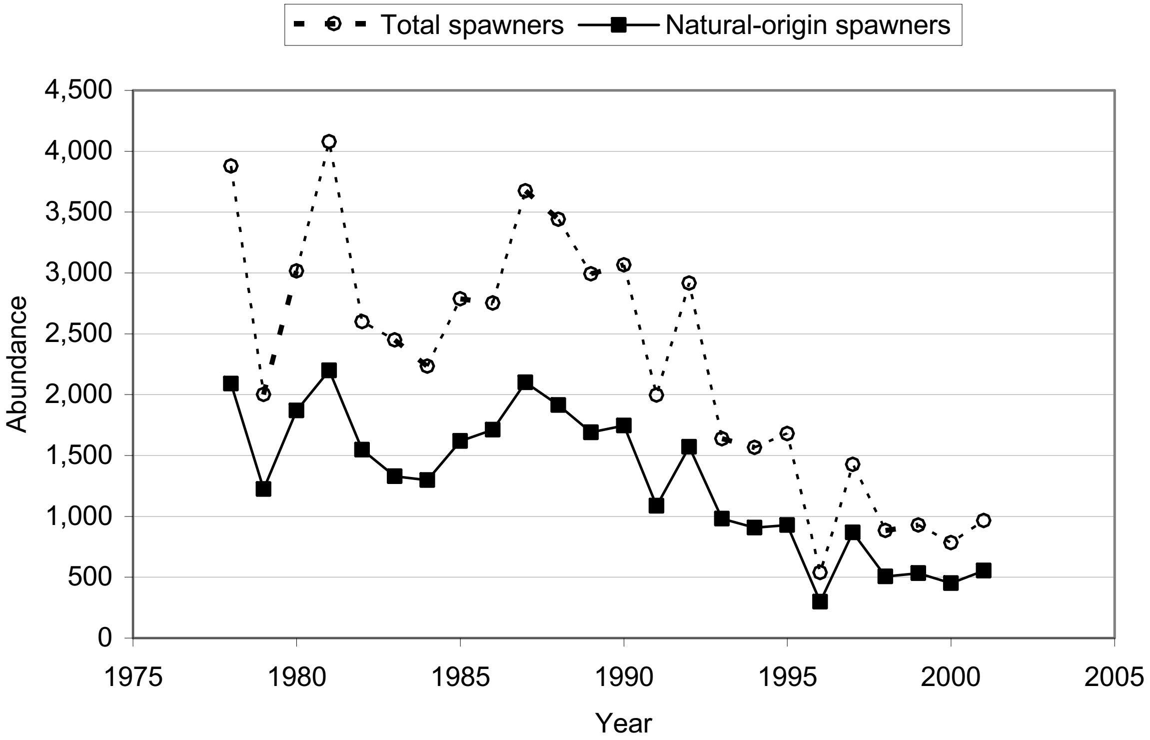

Figure 152. Winter-run steelhead abundance at Marmot Dam on the Sandy River, 1978–2001. Source: Data from Cramer (2002b).

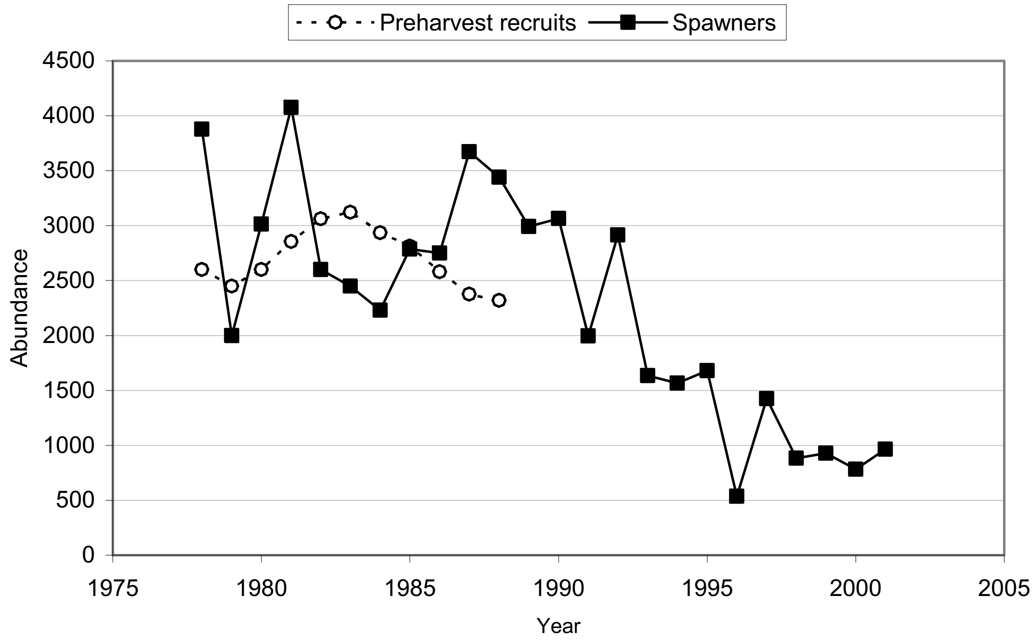

Figure 153. Preharvest recruits and spawners for winter-run steelhead estimated from counts at Marmot Dam on the Sandy River, 1978–2001.

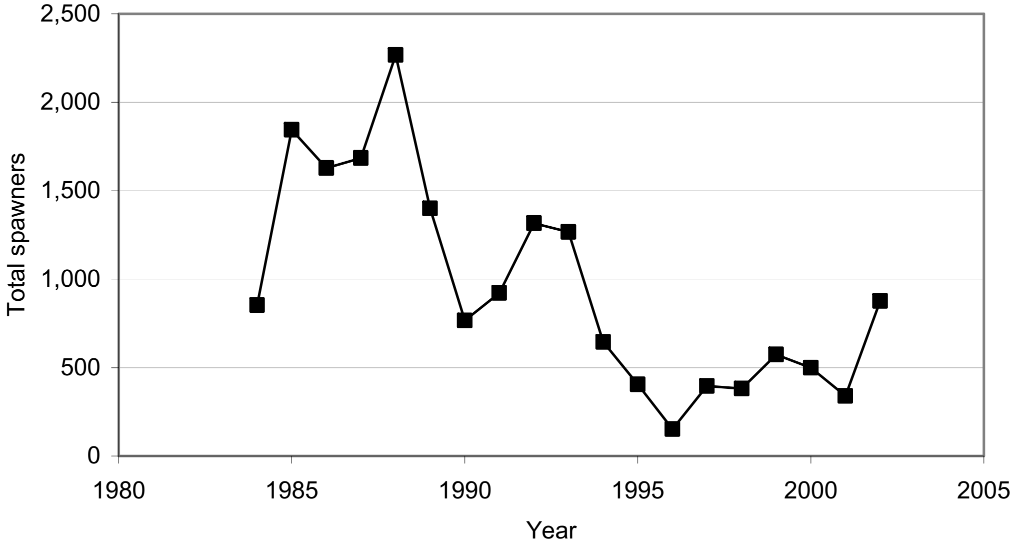

Figure 154. Estimate of winter-run steelhead spawner abundance in the South Fork Toutle River, 1984–2002. Approximately 2% of the total spawners are estimated to be of natural origin.

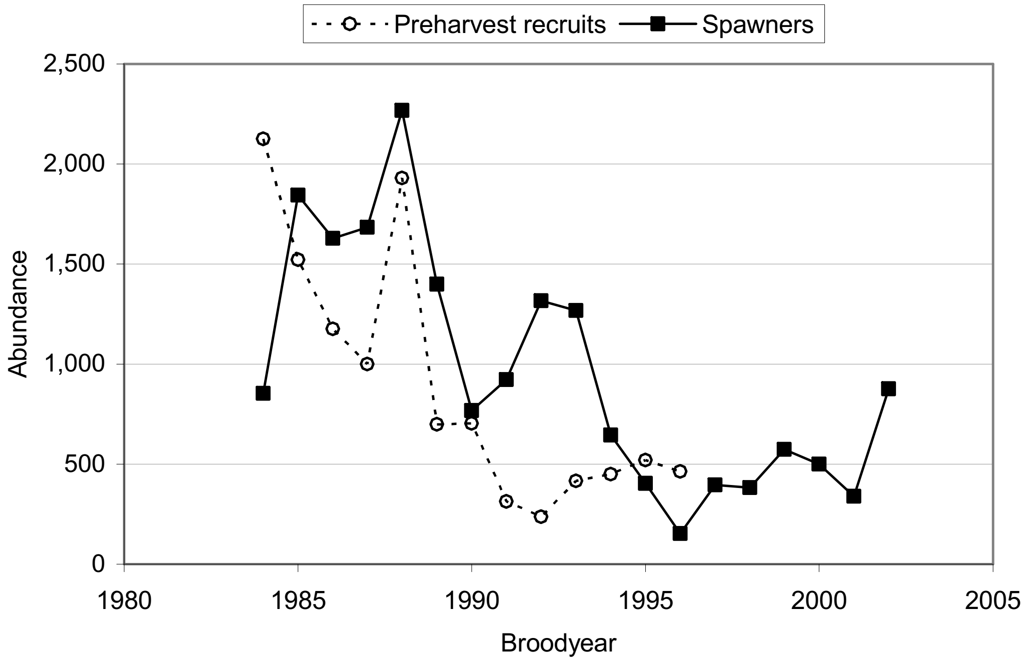

Figure 155. Estimate of winter-run steelhead preharvest recruits and spawners in the South Fork Toutle River, 1984–2002.

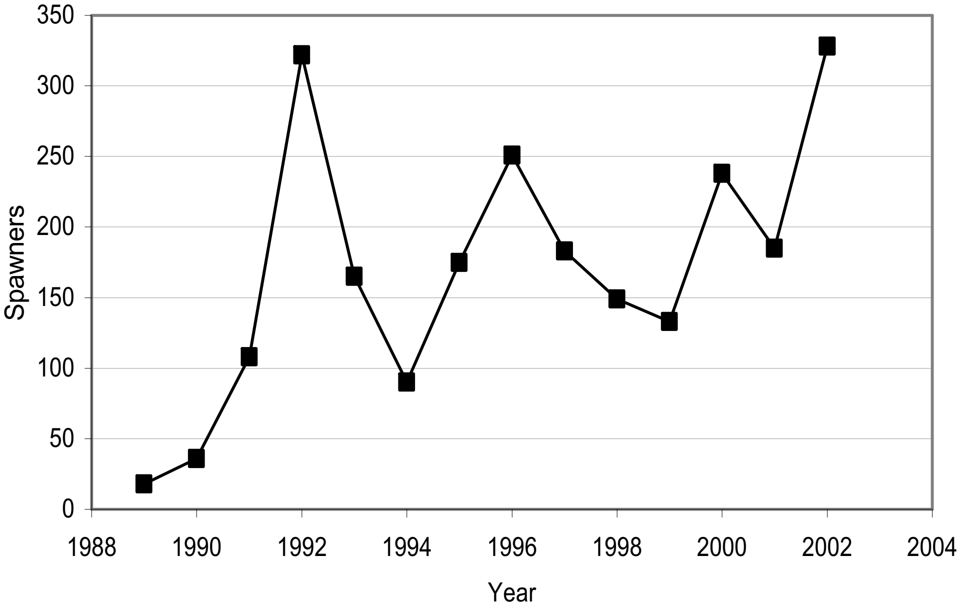

Figure 156. Estimate of winter-run steelhead abundance in the North Fork Toutle River. There are estimated to be no hatchery-origin spawners in the North Fork Toutle population, 1989–2002.

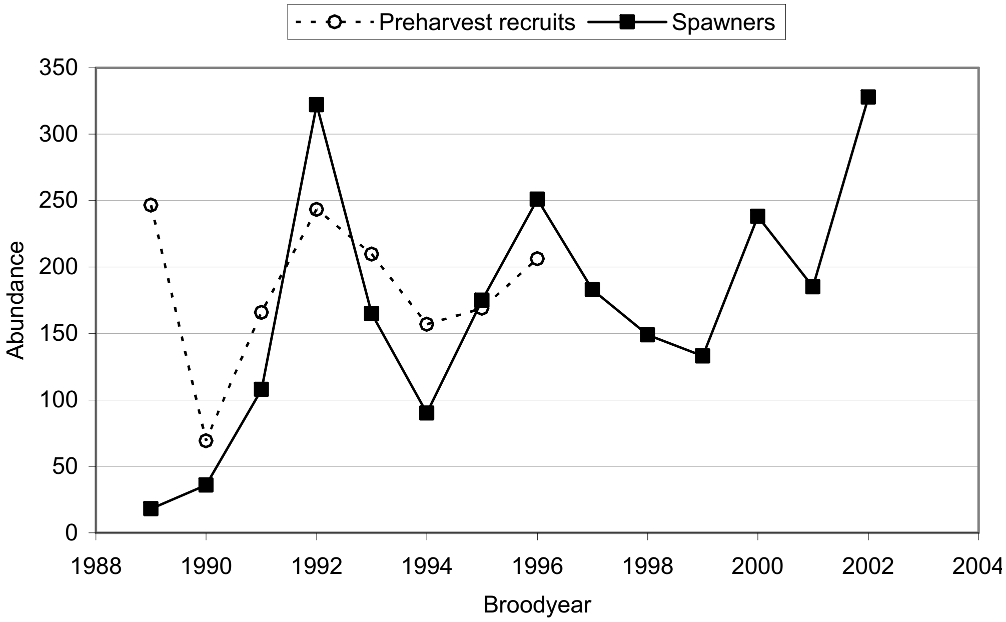

Figure 157. Estimate of winter-run steelhead preharvest recruits and spawners in the North Fork Toutle River, 1989–2002.

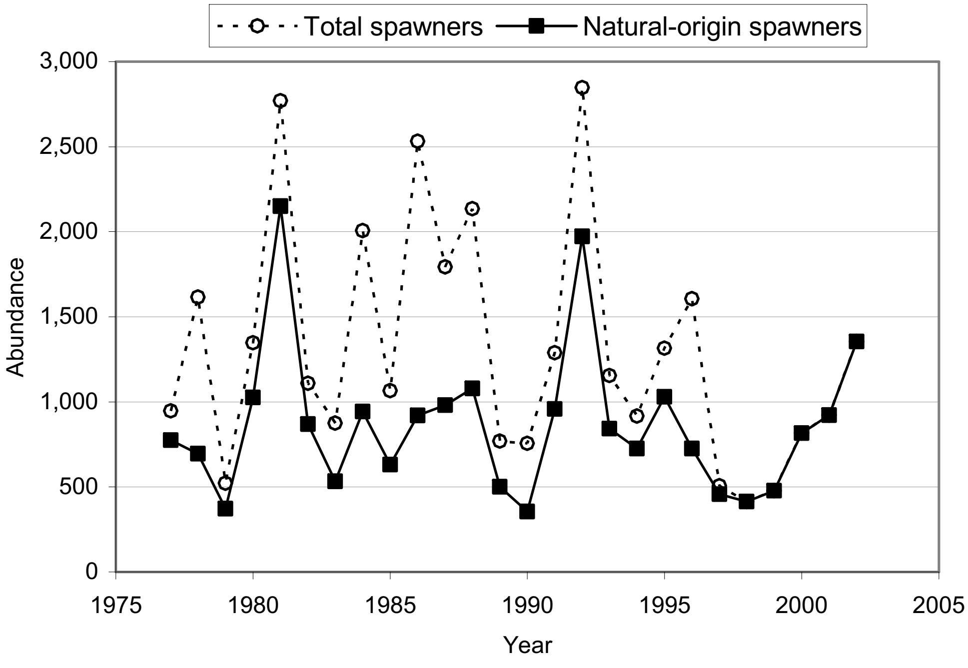

Figure 158. Estimate of winter-run steelhead abundance in the Kalama River, 1977–2002.

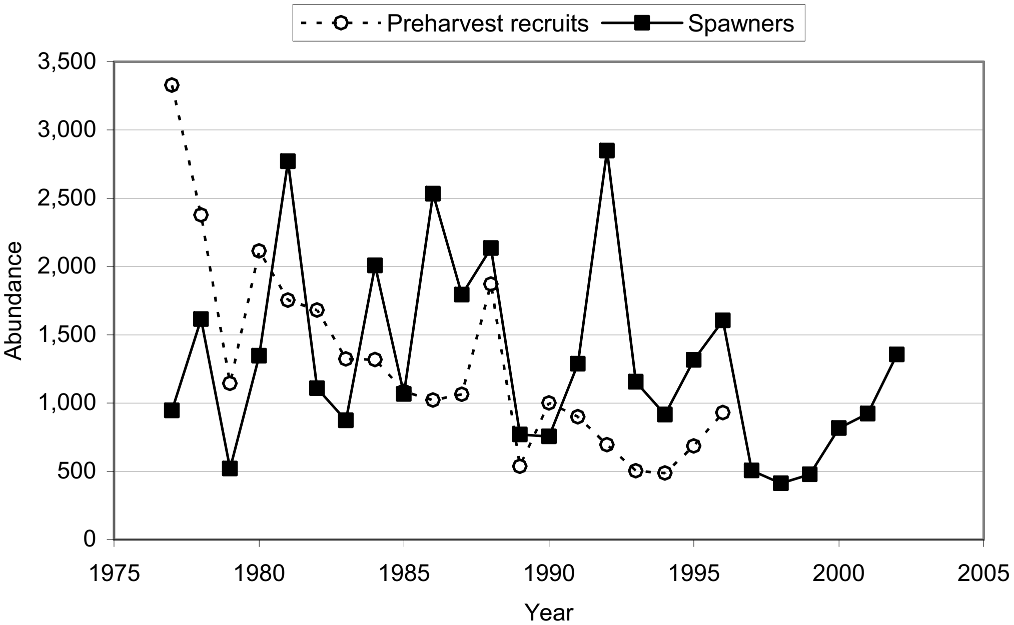

Figure 159. Estimate of winter-run steelhead preharvest recruits and spawners in the Kalama River, 1977–2002.

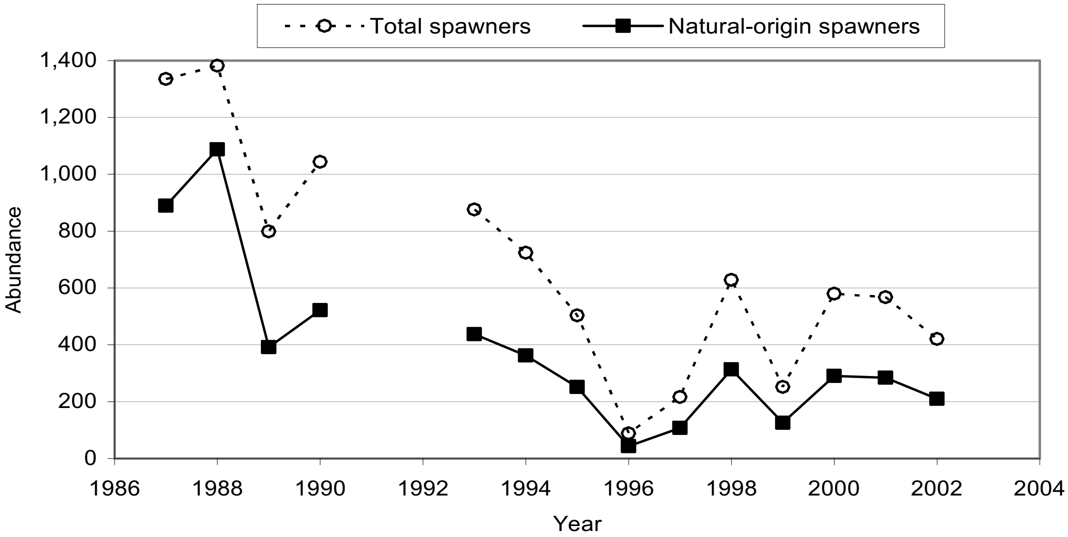

Figure 160. Estimate of winter-run steelhead abundance in the Coweeman River, 1987–2002.

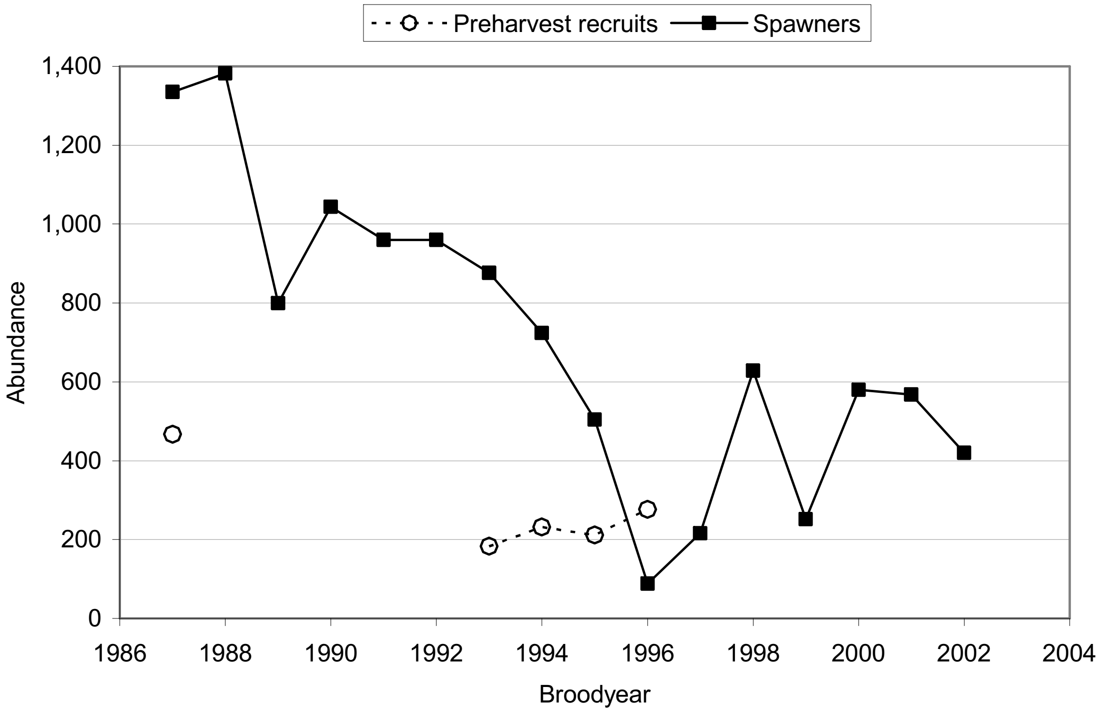

Figure 161. Estimate of winter-run steelhead preharvest recruits and spawners in the Coweeman River, 1987–2002.

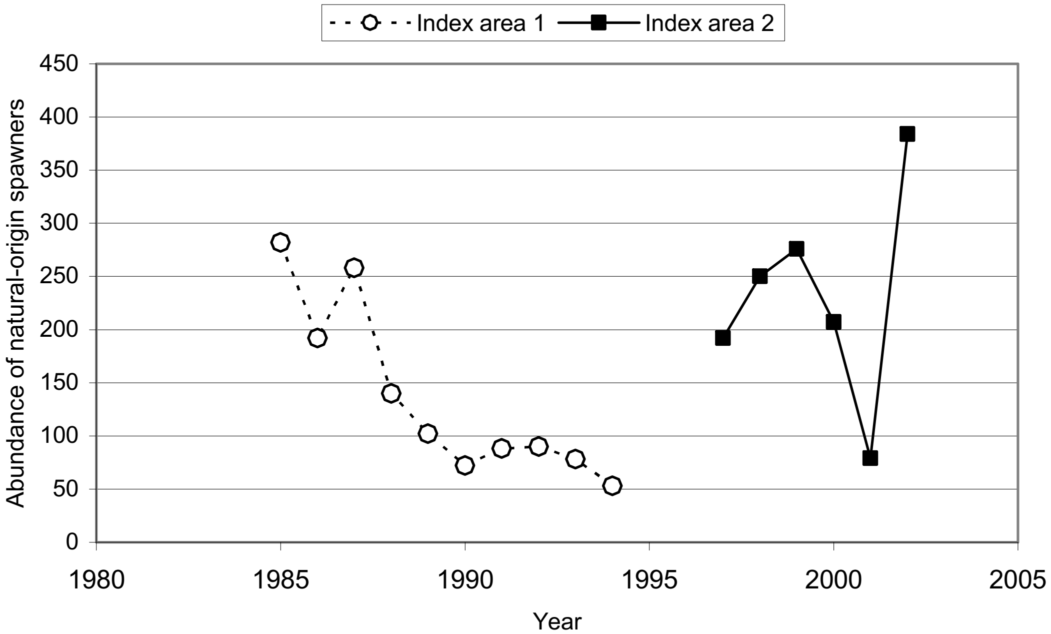

Figure 162. Index counts of natural-origin winter-run steelhead in the East Fork Lewis River. The two indexes are for different areas: they cannot be directly compared and cannot be used to create a more continuous time trend, 1985–2002.

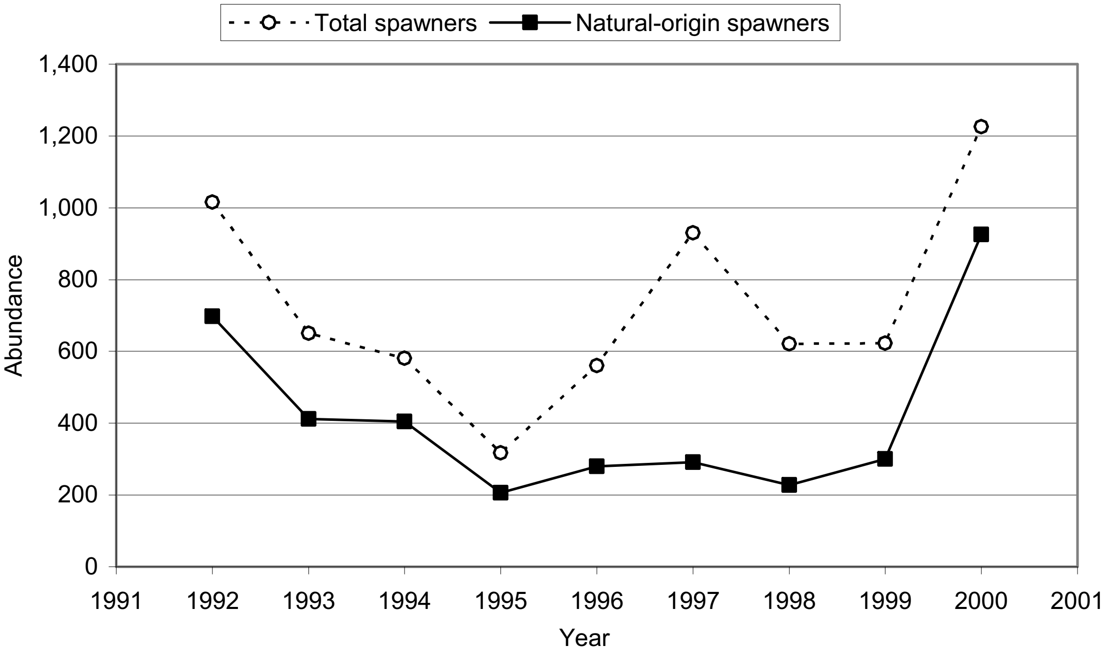

Figure 163. Estimate of winter-run steelhead abundance in the Hood River, 1992–2000.

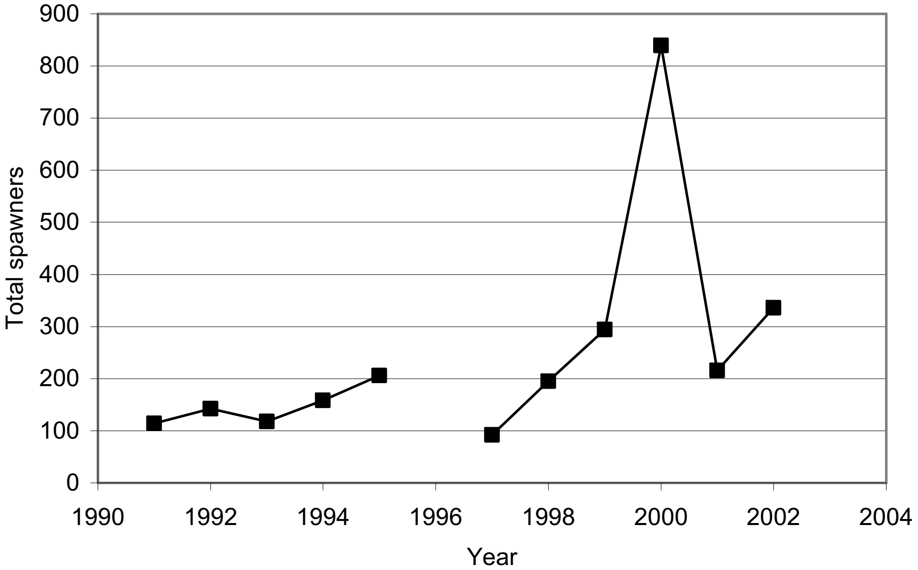

Figure 164. Estimate of winter-run steelhead abundance in the Washougal River. The percent of hatchery-origin spawners is considered minimal, 1991–2002.

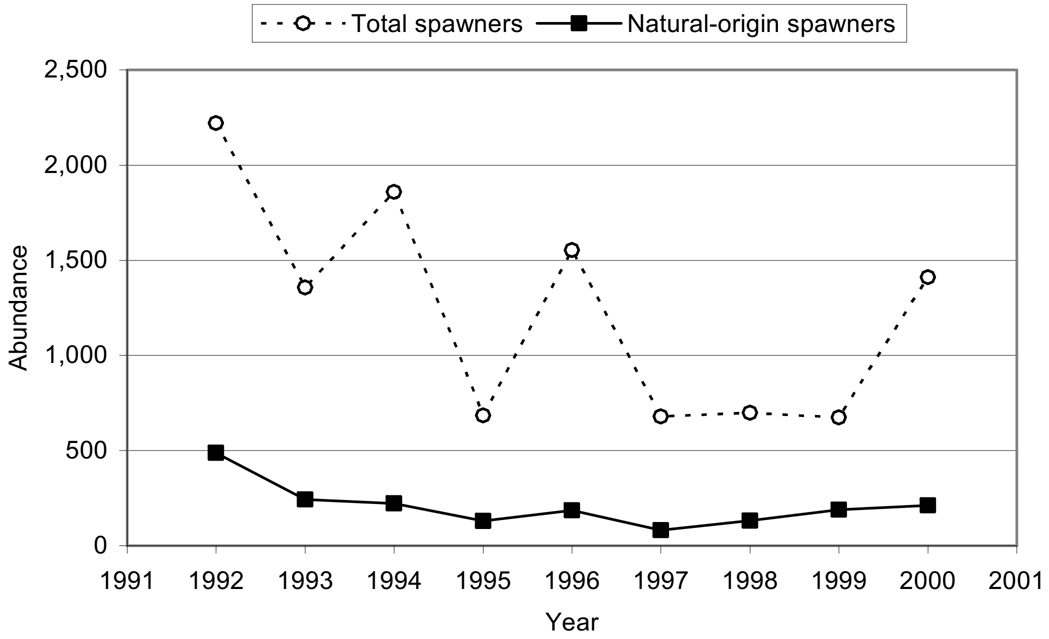

Figure 165. Estimate of summer-run steelhead abundance in the Hood River, 1992–2000.

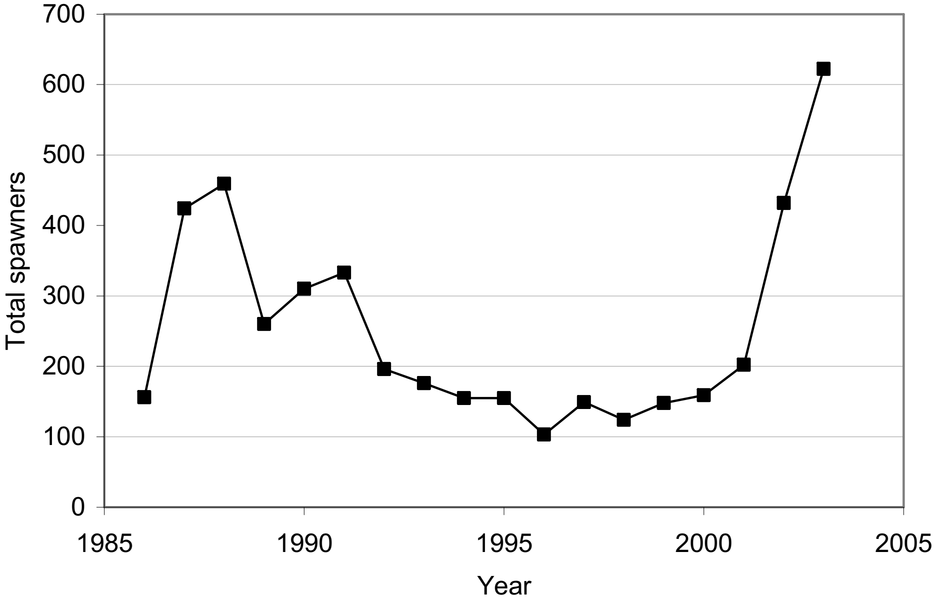

Figure 166. Estimate of the total summer-run steelhead abundance in the Washougal River, 1986–2003. The fraction of hatchery-origin fish is minimal (the average is approximately 3%).

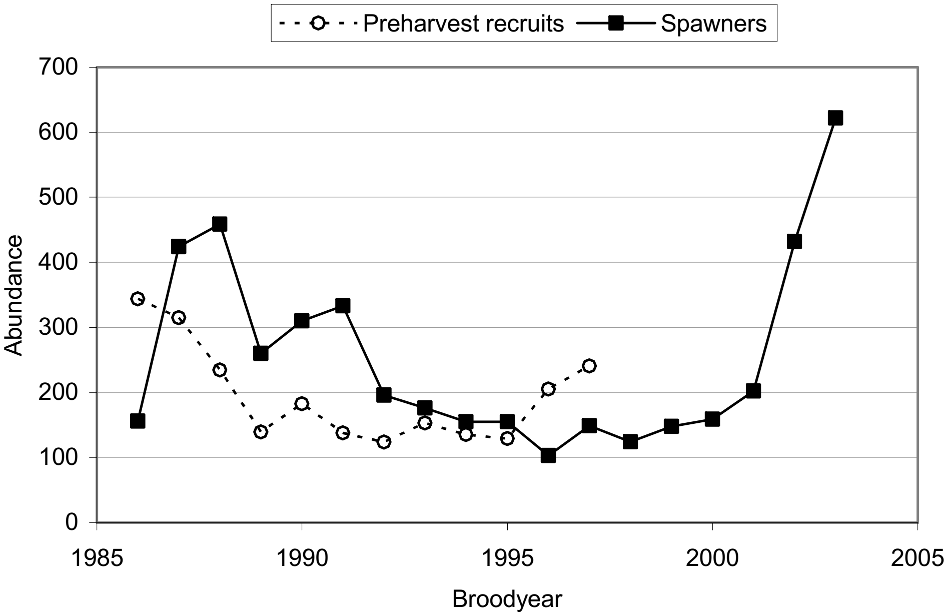

Figure 167. Estimate of summer-run steelhead preharvest recruits and spawners in the Washougal River, 1986–2003.

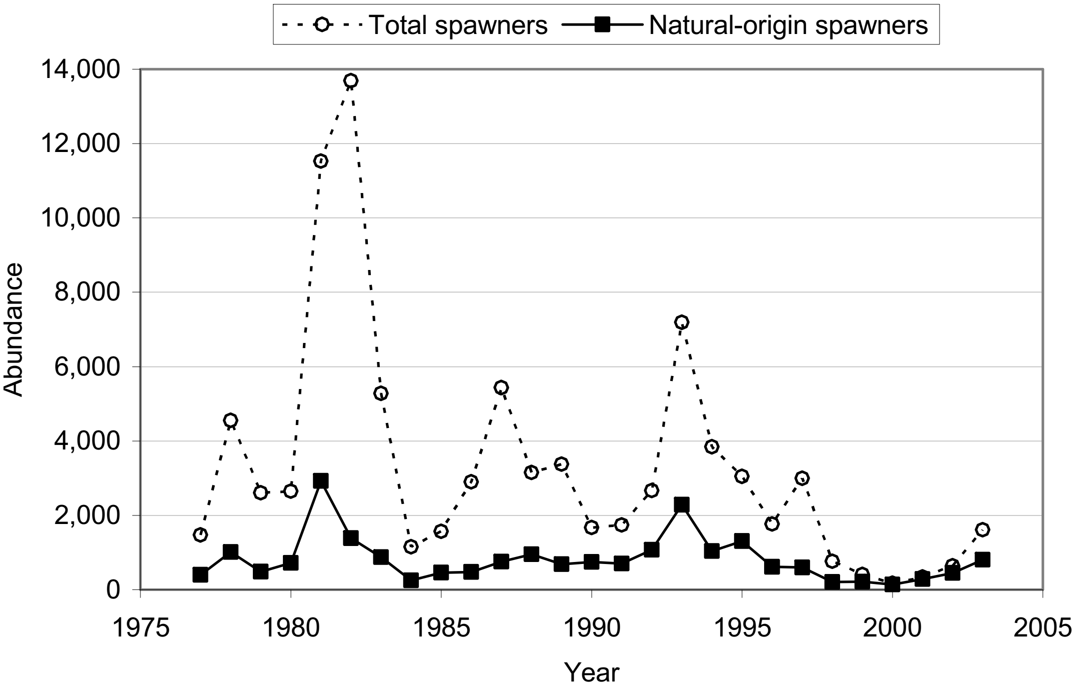

Figure 168. Estimate of summer-run steelhead abundance in the Kalama River, 1977–2003.

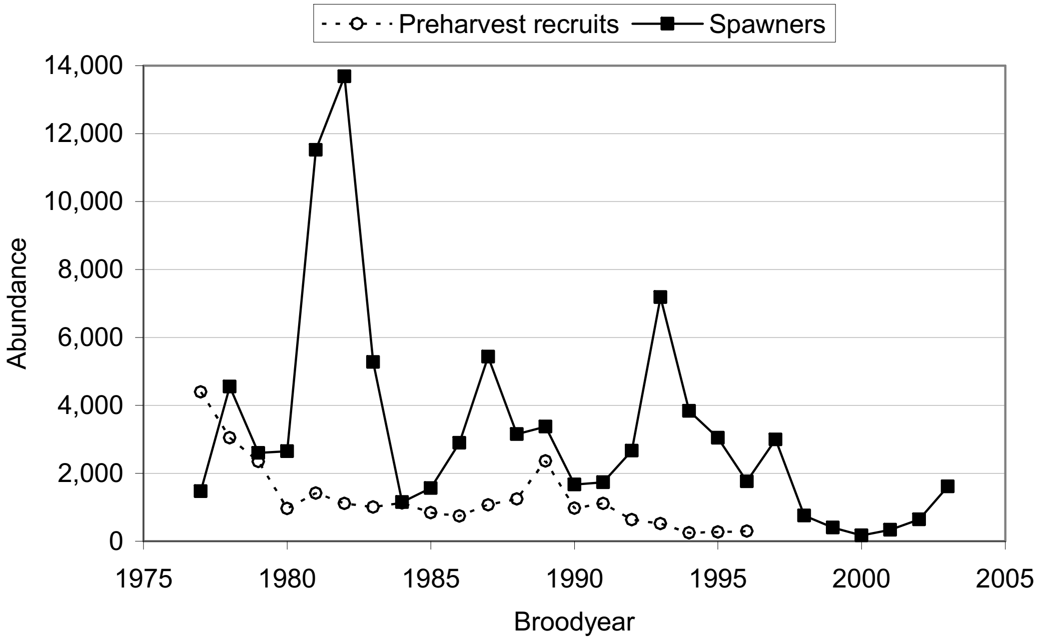

Figure 169. Estimate of summer-run steelhead preharvest recruits and spawners in the Kalama River, 1977–2003.

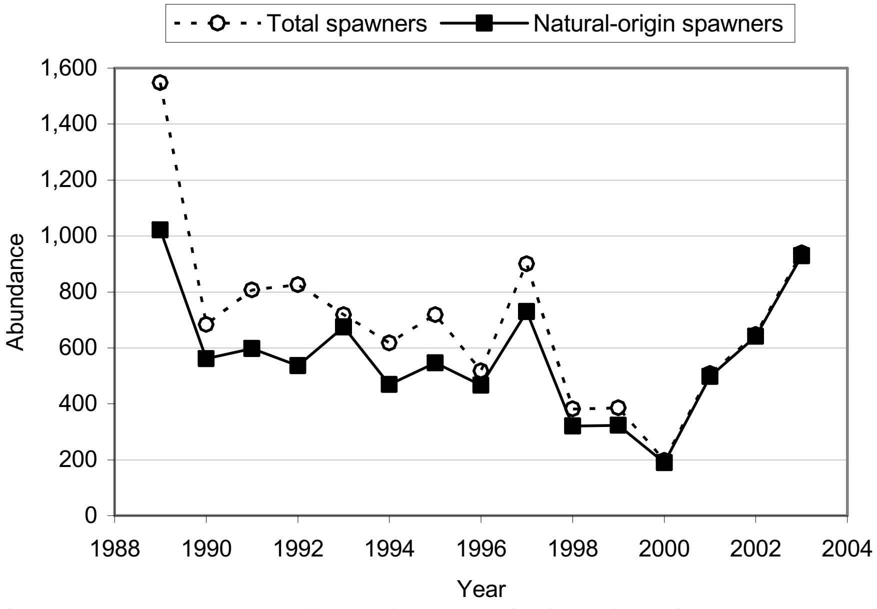

Figure 170. Estimate of summer-run steelhead abundance in the Wind River, 1989–2003.

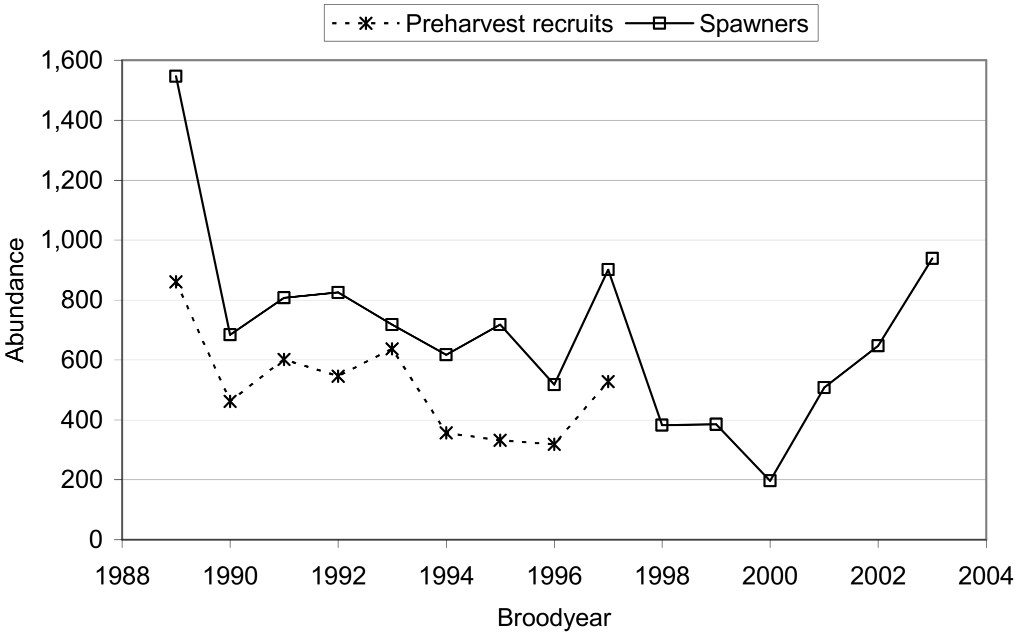

Figure 171. Estimate of summer-run steelhead preharvest recruits and spawners in the Washougal River, 1989–2003.

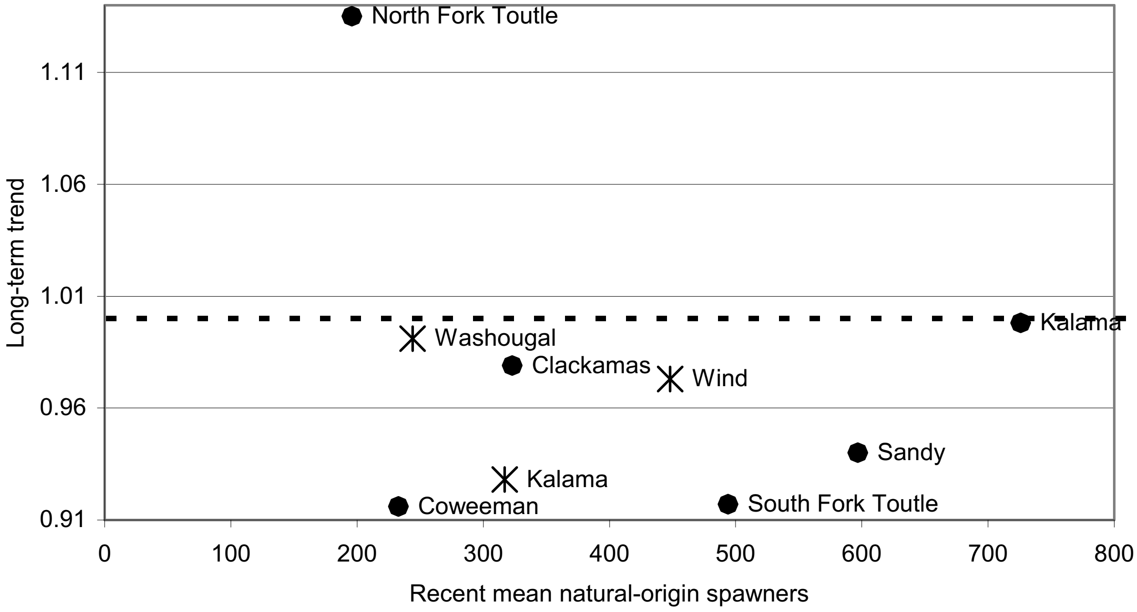

Figure 172. Lower Columbia River ESU steelhead long-term trend versus 5-year geometric mean abundance of natural-origin spawners: * = summer-run populations; --- = a flat trend of 1.

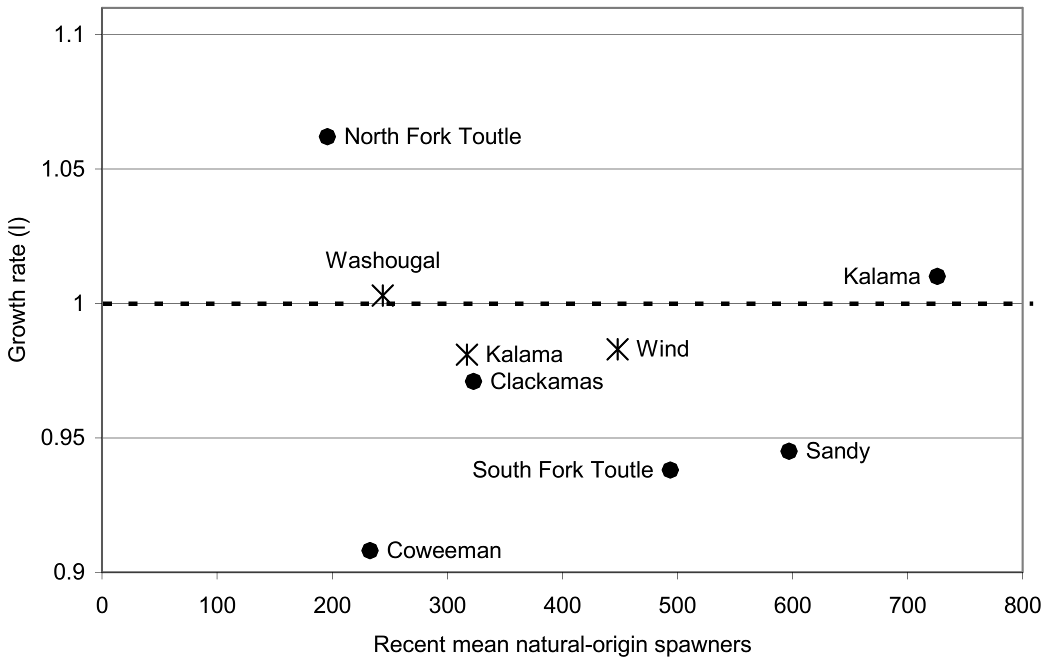

Figure 173. Lower Columbia River ESU steelhead long-term growth rate versus 5-year geometric mean abundance of natural-origin spawners. The growth rate is estimated assuming the reproductive success of hatchery-origin spawners is 0: * = summer-run populations; --- = a flat trend of 1.

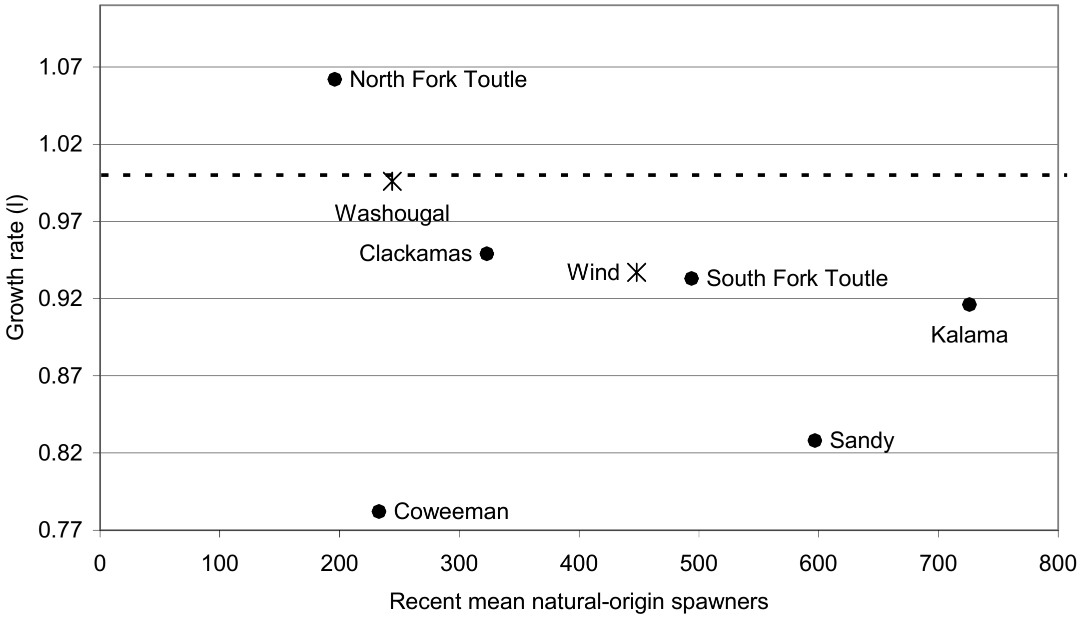

Figure 174. Lower Columbia River ESU steelhead long-term growth rate versus 5-year geometric mean abundance of natural-origin spawners. The growth rate is estimated assuming the reproductive success of hatchery-origin spawners is equivalent to that of natural-origin spawners: * = summer-run populations; --- = a flat trend of 1.

19. Upper Willamette River Steelhead ESU

Summary of Previous BRT Conclusions

NMFS initially reviewed the status of the Upper Willamette River steelhead ESU in 1996 (Busby et al. 1996); the most recent review occurred 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 wild winter-run steelhead. The previous BRT considered the loss of access to historical spawning grounds because of dams to be a major risk factor. The 1999 BRT reached a unanimous decision that the Upper Willamette River steelhead ESU was at risk is of becoming endangered in the foreseeable future.

Listing status: Threatened.

New Data and Updated Analyses

New data for the Upper Willamette River steelhead ESU include redd counts and dam/weir counts through 2000, 2001, or 2002 and estimates of hatchery fraction and harvest rates through 2000. New analyses for this update include the designation of demographically independent populations, and estimates of current and historically available stream kilometers.

Historical Population Structure

As part of its effort to develop viability criteria for Upper Willamette River ESU steelhead, the WLC-TRT identified historical demographically independent populations (Myers et al. 2002). Population boundaries are based on application of the VSP definition by McElhany et al. (2000). Myers et al. (2002) hypothesized that the ESU historically consisted of at least four populations (Mollala, North Santiam, South Santiam, and Calapooia) and possibly a fifth (Coast Range) (Figure 175). There is some uncertainty about the historical existence of a population in the Coast Range. The populations Myers et al. identified are used as the units for the new analyses in this report.

Abundance and Trends

Willamette Falls

The number of winter-run steelhead passing over Willamette Falls from 1971 to 2002 is shown in Figure 176. All steelhead in the ESU must pass Willamette Falls. Two groups of winter-run steelhead currently exist in the upper Willamette River. The late winter-run steelhead exhibit the historical phenotype adapted to passing the seasonal barrier at Willamette Falls. The falls were laddered, and hatchery early winter-run steelhead fish were released above the falls.

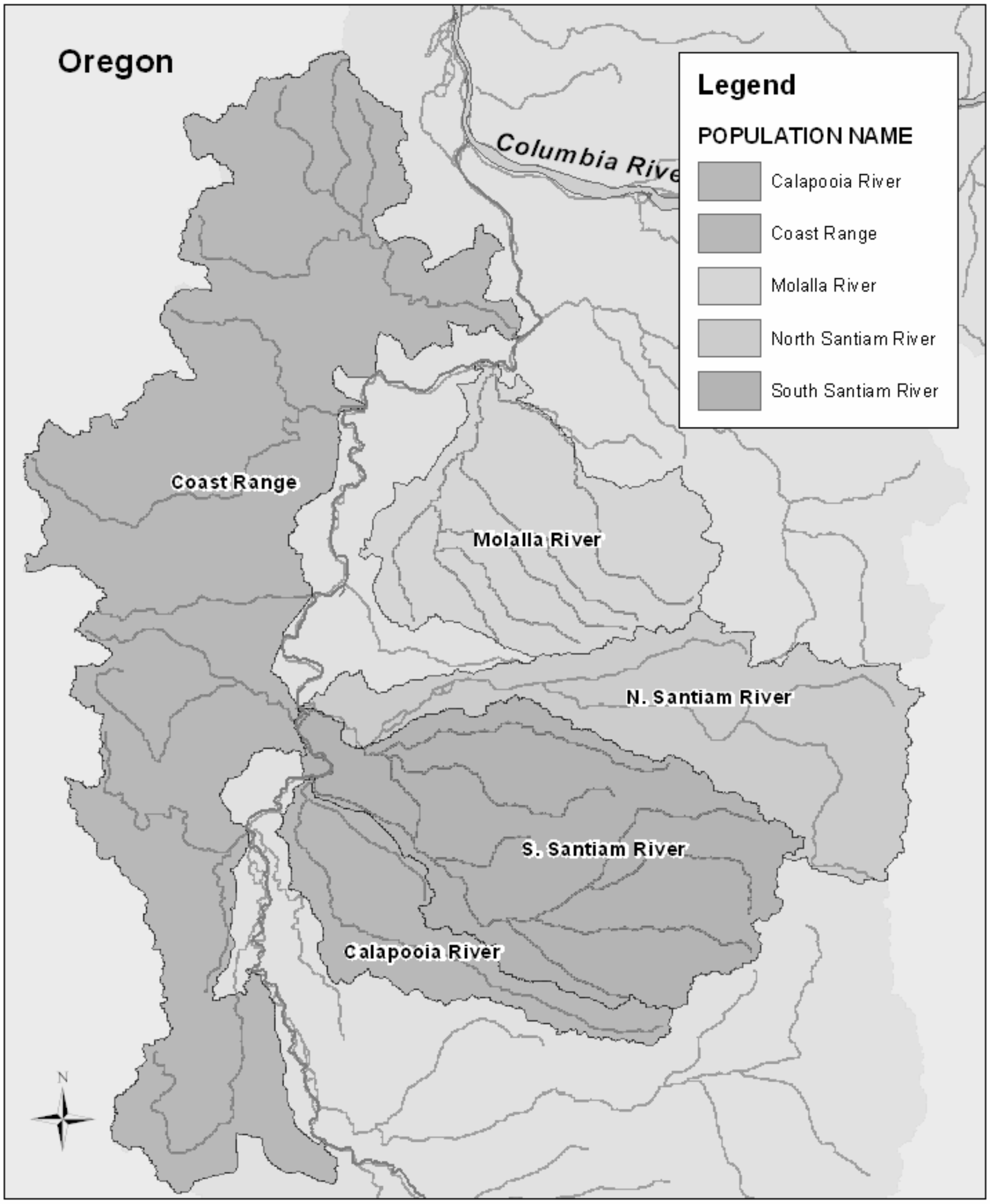

Figure 175. Map of historical Upper Willamette River steelhead ESU populations.

The early run fish were derived from Columbia River basin steelhead outside the Willamette River and are considered nonnative. The release of winter-run hatchery steelhead in the Willamette River was recently discontinued (Table 48), but some early winter-run steelhead are still returning from the earlier hatchery releases and from any natural production of the early run fish that has been established. Table 48 shows the combined early and late returns and only the native late run. Nonnative summer-run hatchery steelhead are also released into the upper Willamette River, but these numbers are not included on the table. The geometric mean of late-returning steelhead passing Willamette Falls over the years 1998–2002 is 5,819 steelhead; the arithmetic mean over the same period is 6,765 steelhead.

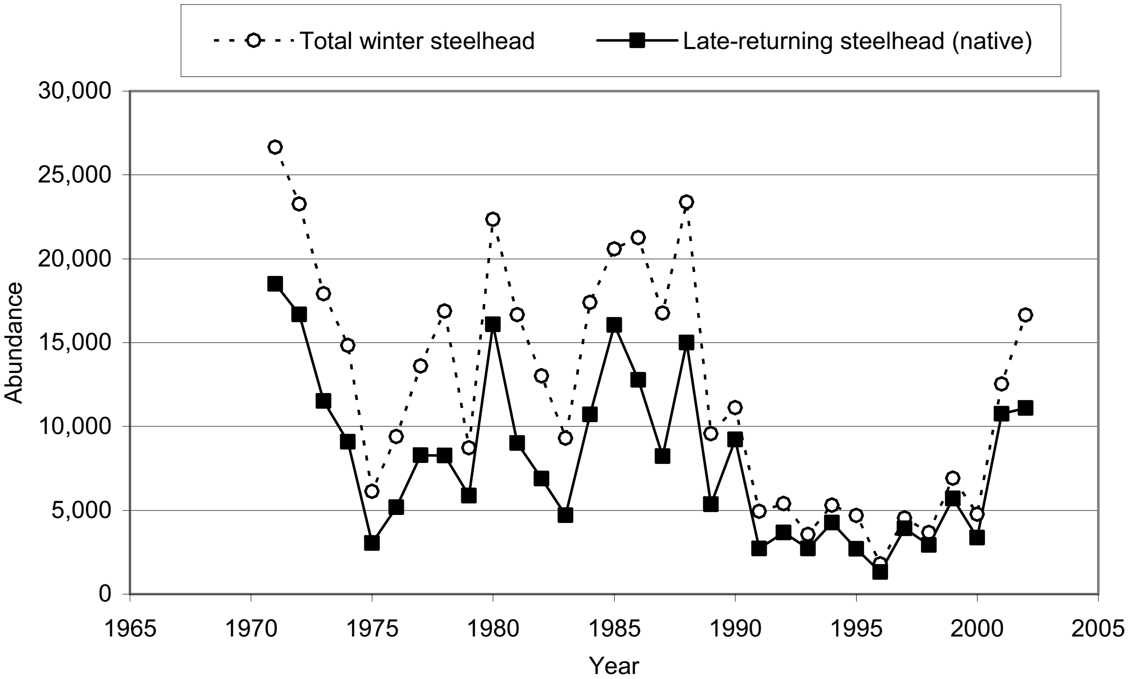

Figure 176. Counts of winter-run steelhead at Willamette Falls, 1971–2002.

Table 48. Releases of winter-run steelhead for the final years that winter-run steelhead were stocked in the Willamette River.*

Population	Last year winter-run steelhead released
Mollala River	1999
North Santiam River	1998
South Santiam River	1989
Calapooia River	No hatchery

* Stocking of steelhead in the Willamette River was discontinued. However, winter-run hatchery fish were still returning over the period of the available time series and summer-run steelhead continue to be stocked in the Willamette. This table shows the last year of winter-run releases in each of the basins.

The available time-series data for individual Upper Willamette River steelhead ESU populations consist of redd count index surveys, one dam count (Foster Dam), and one hatchery trap count (Minto Trap). At one time, ODFW applied an algorithm involving the redd surveys and the length of available stream miles to apportion the fish passing Willamette Falls into individual populations. This approach appears to have been dropped in 1997, and there are currently no estimates of the absolute total numbers of spawners in the individual populations. The status of individual populations is discussed below.

Molalla

A time series of redds-per-mile data from the Molalla River shows a declining trend from 1980 to 2000 (Table 49 and Figure 177). Estimates of the fraction of hatchery-origin spawners

Table 49. Trends in redds-per-mile surveys of Upper Willamette River ESU winter-run steelhead populations (95% confidence intervals are in parentheses).

Population	Years of data	Long-term trend[a] in redds per mile	Probability long-term trend < 1	Short-term trend[b] in redds per mile	Probability short-term trend < 1
Mollala	1980–2000	0.947 (0.918–0.977)	0.999	0.972 (0.867–1.090)	0.705
North Santiam	1980–2001	0.941 (0.906–0.977)	0.999	0.962 (0.845–1.095)	0.740
South Santiam	1980–2001	0.936 (0.904–0.970)	1.000	0.917 (0.811–1.037)	0.926
Calapooia	1980–2001	0.968 (0.933–1.003)	0.964	1.053 (0.935–1.149)	0.229

[a] Long-term trends use the entire data set.

[b] Short-term trends use data from 1990 through the most recent year.

for this population are shown in Figure 183; the estimated harvest rate is shown in Figure 184. The populations show a declining trend over the available time series.

North Santiam

A time series of redds-per-mile data from the North Santiam River shows a declining trend from 1980 to 2001 (Figure 178). A time series also exists for the Minto trap on the North Santiam (Figure 179). Minto is a hatchery acclimation-and-release site, so it is assumed that the majority of fish trapped at this site over the time series are of hatchery origin. Estimates of the fraction of hatchery-origin spawners for this population are shown in Figure 183; the estimated harvest rate is shown in Figure 184.

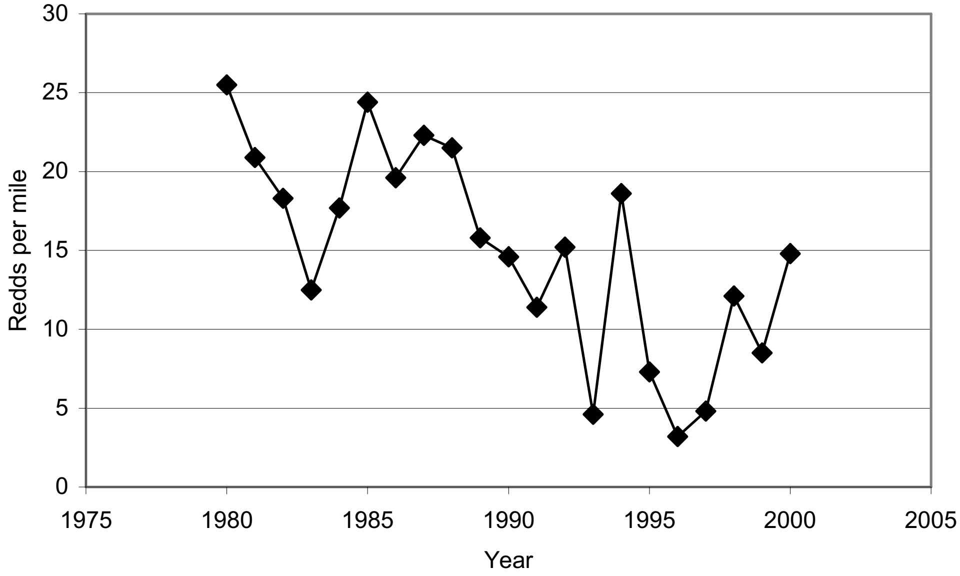

Figure 177. Redd surveys of winter-run steelhead in the Molalla River, 1980–2000.

South Santiam

Counts of winter-run steelhead at Foster Dam (RKm 77) from 1967 to 2002 are shown in Figure 180. A hatchery program was initiated in the 1980s, and hatchery-origin fish were identified at the dam facility. Redd surveys are also conducted below Foster Dam (Figure 181). Estimates of the fraction of hatchery-origin spawners for this population below Foster Dam are shown in Figure 183; the estimated harvest rate is shown in Figure 184.

Calapooia River

A time series of redds-per-mile data from the Calapooia River shows a declining trend from 1980 to 2001 (Figure 182). Estimates of the fraction of hatchery-origin spawners for this population are shown in Figure 183; the estimated harvest rate is shown in Figure 184.

West side tributaries

No time series or current counts of spawner abundance for the west side tributaries population are available. It is questionable whether a self-sustaining steelhead population ever existed in the west side tributaries. There is assumed to be little, if any, natural production of steelhead in these tributaries.

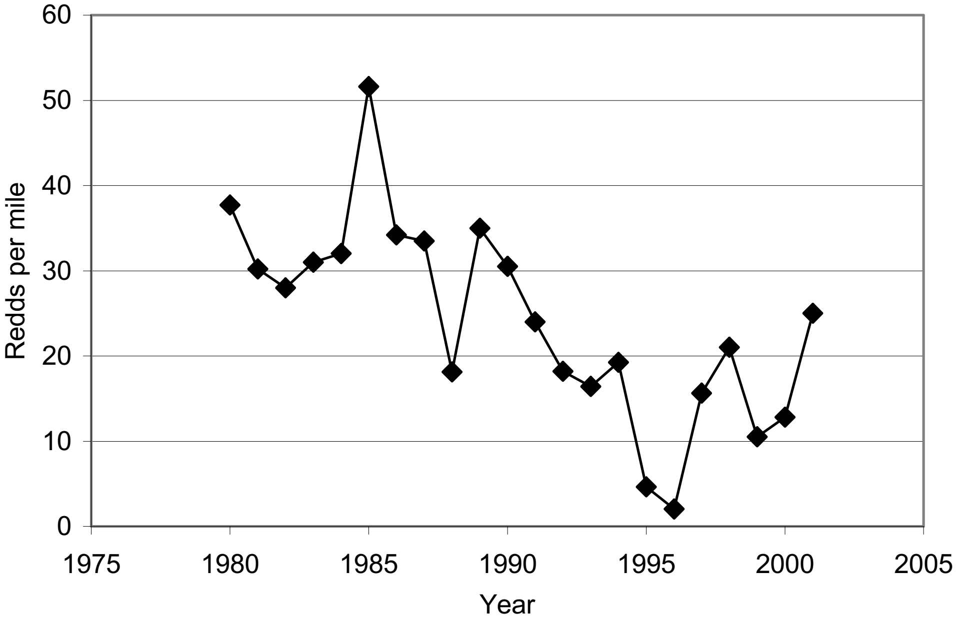

Figure 178. Redd surveys of winter-run steelhead in the North Santiam River, 1980–2001.

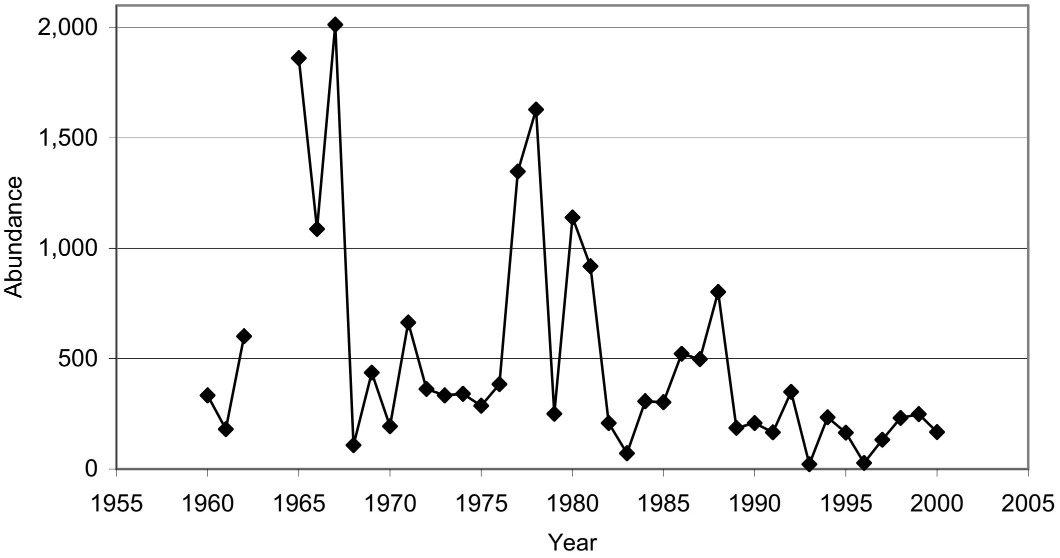

Figure 179. Counts of winter-run steelhead at the Minto Trap on the North Santiam River, 1960–2000. Minto Trap is a hatchery-acclimation pond and release site.

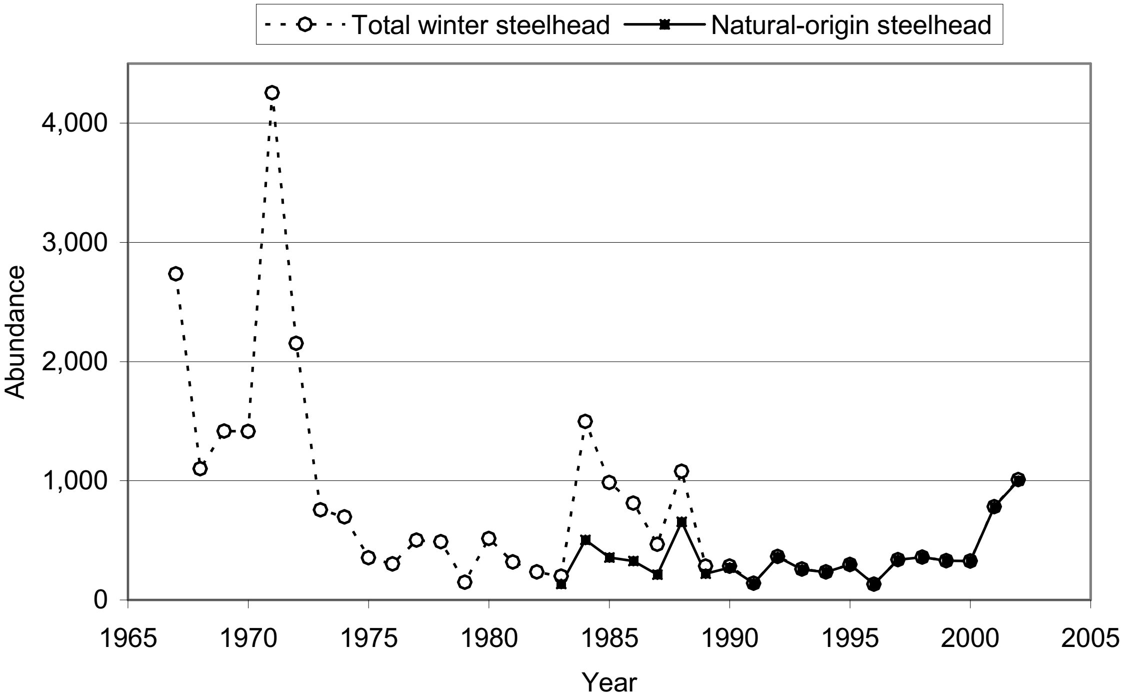

Figure 180. Counts of winter-run steelhead at Foster Dam on the South Santiam River (RKm 77), 1967–2002.

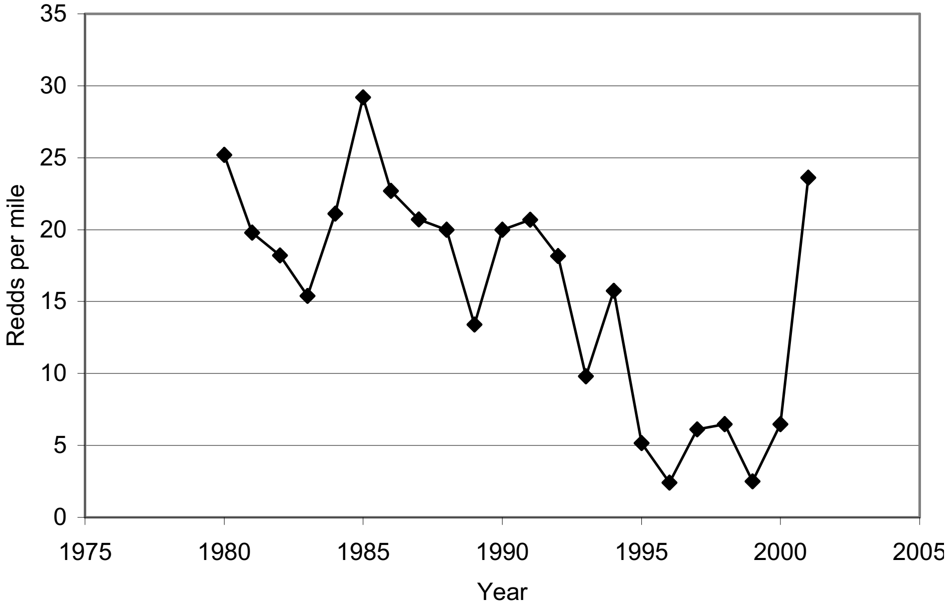

Figure 181. Redd surveys of winter-run steelhead in the South Santiam River below Foster Dam, 1980–2001.

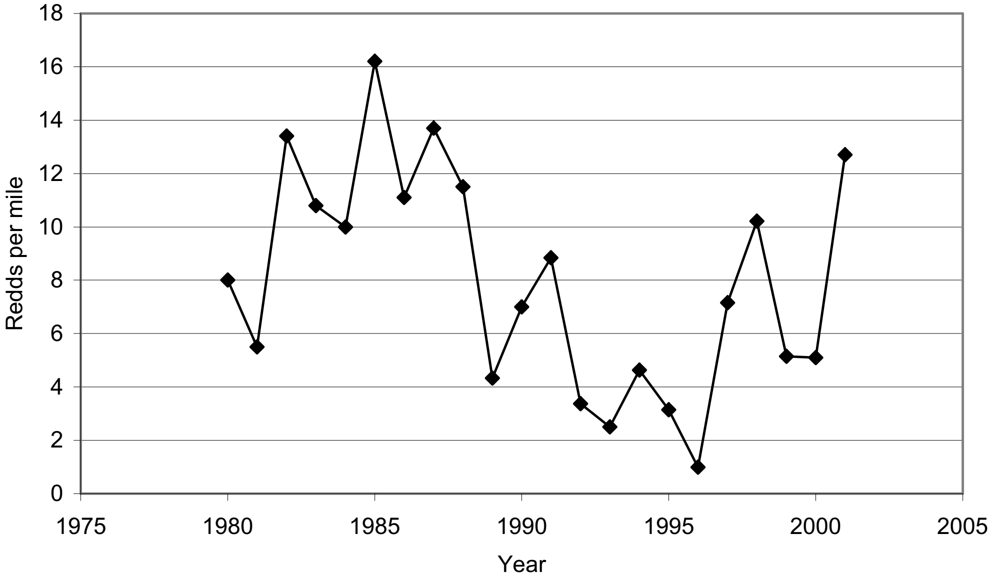

Figure 182. Redd surveys of winter-run steelhead in the Calapooia River, 1980–2001.

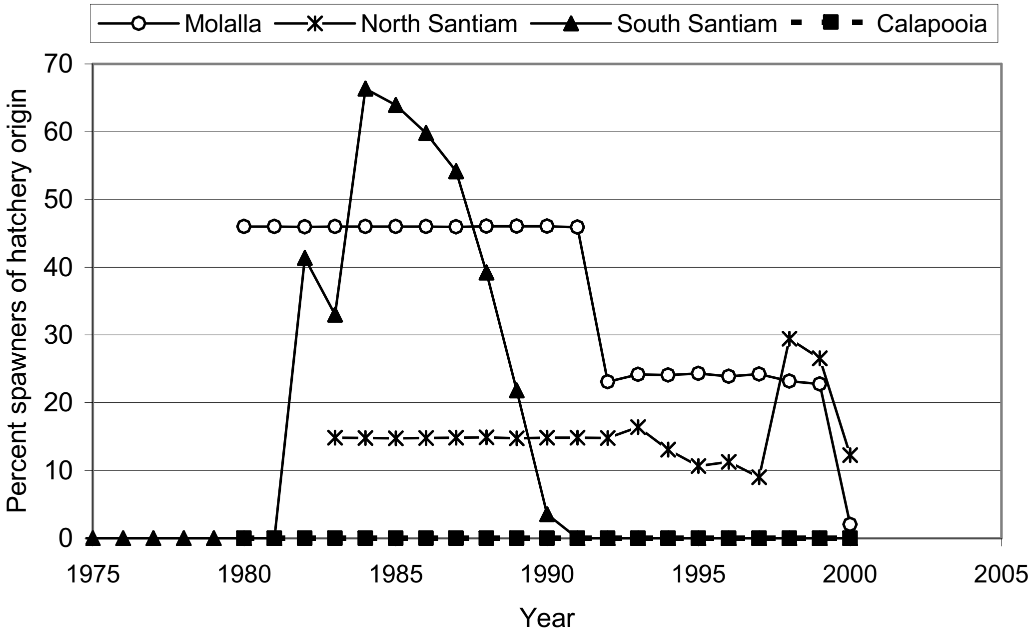

Figure 183. Estimates of the fraction of hatchery-origin spawners in populations of Upper Willamette River ESU winter-run steelhead (Chilcote 2001), 1980–2000. Winter-run steelhead are not currently released into the upper Willamette River.

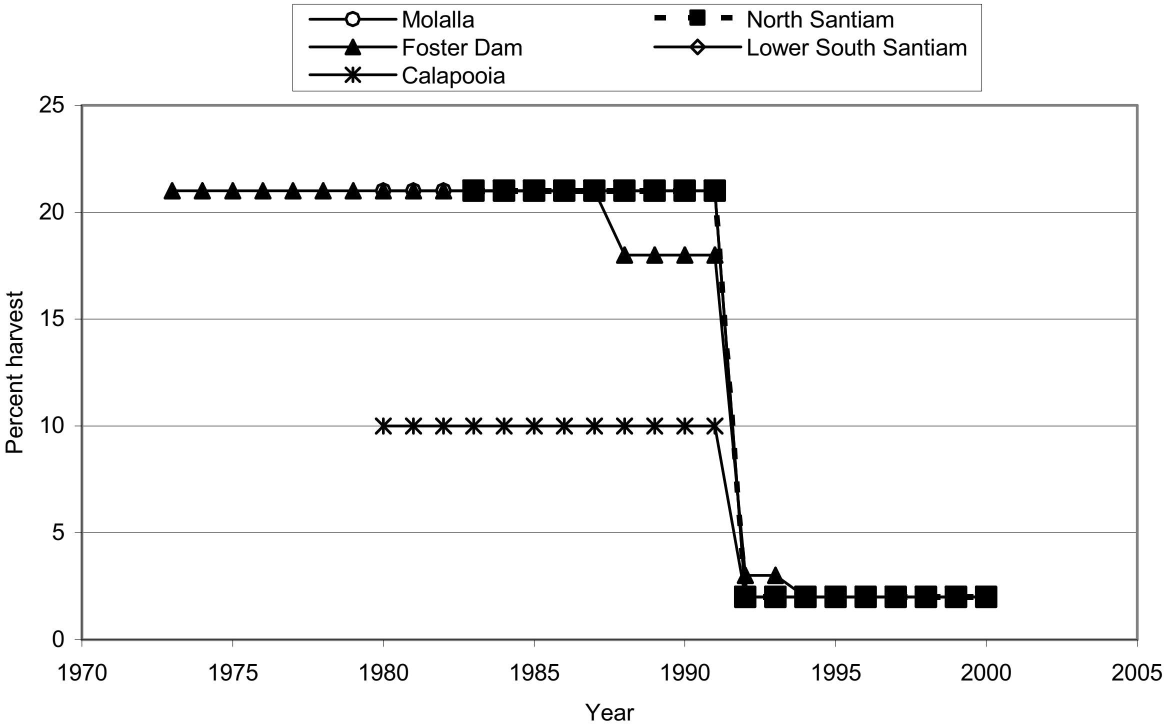

Figure 184. Estimates of the harvest rate on populations of Upper Willamette River ESU winter-run steelhead, 1973–2000. Source: Chilcote (2001).

Loss of Habitat from Barriers

Steel and Sheer (2003) conducted an analysis to assess the number of stream kilometers historically and currently available to salmon populations in the Upper Willamette River steelhead ESU (Table 50). Stream kilometers usable by salmon are determined based on simple gradient cutoffs and on the presence of impassable barriers. This approach will overestimate the number of usable stream kilometers, because it does not consider habitat quality (other than gradient). However, the analysis does indicate that for some populations the number of stream habitat kilometers currently accessible is greatly reduced from the historical condition.

Resident *O. mykiss* Considerations

The available information on resident *O. mykiss* populations within the Upper Willamette River steelhead ESU is summarized Appendix B, Table B-1, which provides a broad overview of the distribution of case 1, 2, and 3 resident populations within the ESU. See the subsection, Resident Fish, in Section 1 for an explanation of the three cases and their relevance to ESU determinations. The subsection, Resident Fish, in Section 12, discusses how resident fish are considered in risk analyses.

Kostow (2003) reviewed information on the abundance and distribution of resident *O. mykiss* for the Upper Willamette River steelhead ESU and found no quantitative estimates of abundance for resident *O. mykiss* in any upper Willamette River population. However, expert opinion indicates that resident *O. mykiss* are rare in this ESU. Cutthroat trout (*O. clarki)* are found throughout much of the Willamette River basin and tend not to co-occur with resident *O. mykiss*. Resident *O. mykiss* in the Middle Fork Willamette and McKenzie rivers might normally be considered to be case 1, because there are no obvious barriers to anadromous access to these areas. Nevertheless, no evidence shows steelhead historically inhabited these basins,

Table 50. Historical populations of Upper Willamette River ESU steelhead and loss of habitat from barriers.

Population	Potential current habitat (%)[a]	Potential historical habitat (km)[b]	Current to historical habitat ratio[c]
Mollala River	524	827	63
North Santiam River	210	347	61
South Santiam River	581	856	68
Calapooia River	203	318	64
West side tributaries	1,376	2,053	67

[a] The potential current habitat is the kilometers of stream below all currently impassable barriers between a gradient of 0.5% and 4%.

[b] The potential historical habitat is the kilometers of stream below historically impassable barriers between a gradient of 0.5% and 6%.

[c] The current:historical habitat ratio is the percent of the historical habitat that is currently available.

and the resident fish in these basins are morphologically distinctive (being known locally as "McKenzie redsides," Kostow 2003). These upper basin resident fish are also genetically quite different from Upper Willamette ESU steelhead, and they are not considered part of the Upper Willamette River steelhead ESU (NMFS 1999b).

Resident or residualized rainbow trout are found above the dams on the North and South Santiam rivers: historically, these areas were the primary production areas for steelhead in this ESU. We are not aware of specific information relevant to the ESU status of these case 3 resident populations. Resident *O. mykiss* are found in the numerous small waterfalls that exist in the headwater regions of this ESU.

ESU Summary

Based on the updated information provided in this report, information contained in previous Upper Willamette River steelhead ESU status reviews, and preliminary analyses by the WLC-TRT, we could not conclusively identify a single population that is naturally self-sustaining. All populations are relatively small, with the recent mean abundance of the entire ESU at less than 6,000. Over the period of the available time series, most of the populations were in decline. The recent elimination of winter-run hatchery production will allow estimation of the natural productivity of populations in the future, but the presence of hatchery-origin spawners confounds available time series. On a positive note, the counts all indicated an increase in abundance in 2001, likely at least in part as a result of improved marine conditions. The issue of changing marine conditions, which is an issue for many ESUs, is discussed in Section 1.

20. Northern California Steelhead ESU

Summary of Previous BRT Conclusions

The Northern California steelhead ESU inhabits coastal basins from Redwood Creek (Humboldt County) southward to the Gualala River (Mendocino County) (Busby et al. 1996). Within this ESU, both summer run,[19] winter run, and half-pounders[20] have been found. Summer-run steelhead are found in the Mad, Eel, and Redwood rivers; the Middle Fork Eel River population is their southernmost occurrence. Half-pounders are found in the Mad and Eel rivers. Busby et al. (1996) argued that when summer- and winter-run steelhead co-occur within a basin, they were more similar to each other than either is to the corresponding run type in other basins. Thus, Busby et al. (1996) considered summer- and winter-run steelhead to comprise a single ESU.

Listing status: Threatened.

Summary of Major Risks and Status Indicators

Risks and limiting factors

The previous status review (Busby et al. 1996) identified two major barriers to fish passage: Mathews Dam on the Mad River and Scott Dam on the Eel River. Numerous other blockages on tributaries were also thought to occur. Poor forest practices and poor land use practices, combined with catastrophic flooding in 1964, were thought to have caused significant declines in habitat quality that persisted up to the date of the status review. These effects include sedimentation and loss of spawning gravels. Nonnative Sacramento pikeminnow (*Ptychocheilus grandis*) had been observed in the Eel River basin and could be acting as predators on juvenile steelhead, depending on thermal conditions leading to niche overlap of the two species (see also Brown and Moyle 1981 and 1997, Harvey et al. 2002, Reese and Harvey 2002).

Status indicators

Historical estimates (pre-1960s) of steelhead abundance for the Northern California steelhead ESU are few (Table 51). The only time-series data are dam counts of winter-run steelhead in the upper Eel River (Cape Horn Dam, 1933–1975), winter-run steelhead in the Mad

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[19] Some researchers consider summer- and fall-run steelhead to be separate runs within a river, while others do not consider these groups to be different. For this review, summer and fall run are considered stream-maturing steelhead and will be referred to as summer-run steelhead (see McEwan 2001b for additional details).

[20] A half-pounder is a sexually immature, usually small steelhead that returns to freshwater after spending less than a year in the ocean (Kesner and Barnhart 1972, Everest 1973).

Table 51. Summary of historical abundance (average counts) for steelhead in the Northern California steelhead ESU (see also Figure 185).

		Average count						
Basin	**Site**	**1930s**	**1940s**	**1950s**	**1960s**	**1970s**	**1980s**	**Reference**
Eel River	Cape Horn Dam	4,390	4,320	3,597	917	721	1,287	Grass (1995b)
Eel River	Benbow Dam	13,736	18,285	12,802	6,676	3,355	–	
Mad River	Sweasy Dam	3,167	4,720	2,894	1,985	–	–	

River (Sweasy Dam, 1938–1963), and combined counts of summer- and winter-run steelhead in the South Fork Eel River (Benbow Dam, 1938–1975; see Figure 185a). More recent data are snorkel counts of summer-run steelhead made in the middle fork of the Eel River since 1966 (with some gaps in the time series).[21] Some "point" estimates of mean abundance exist—in 1963, CDFG estimated steelhead abundance for many rivers in the ESU (Table 52). CDFG attempted to estimate a mean count over the interval 1959 to 1963, but in most cases 5 years of data were not available, and estimates were based on fewer years (CDFG 1965); the authors state that "estimates given here which are based on little or no data should be used only in outlining the major and critical factors of the resource" (CDFG 1965). The previous BRT (Busby et al. 1996) considered the above data sets in making their risk assessment.

Although the data were relatively few, the data that did exist suggested the following to the BRT: 1) population abundances were low relative to historical estimates (1930s dam counts; see Table 51, and Figure 185); 2) recent trends were downward (except for a few small summer-run stocks; see Figures 185 and 186); and 3) summer-run steelhead abundance was "very low." The BRT was also concerned about negative influences of hatchery stocks, especially in the Mad River (Busby et al. 1996). Finally, the BRT noted that the status review included two major sources of uncertainty: lack of data on run sizes throughout the ESU and the genetic heritage of winter-run steelhead in the Mad River.

Listing Status

Status was formally assessed in 1996 (Busby et al. 1996), updated in 1997 (NMFS 1997b), and updated again in 2000 (Adams 2000). Although other steelhead ESUs were listed as threatened or endangered in August 1997, NMFS allowed steelhead in the Northern California steelhead ESU to remain a candidate species pending an evaluation of state and federal conservation measures. A "North Coast Steelhead Memorandum of Agreement" (MOA) with the State of California listed a number of proposed actions, including a change in harvest regulations, a review of California hatchery practices, implementation of habitat restoration activities, implementation of a comprehensive monitoring program, and numerous revisions to rules on forest practices. These revisions would be expected to improve forest condition on non-federal lands. In March 1998, NMFS announced its intention to reconsider the previous

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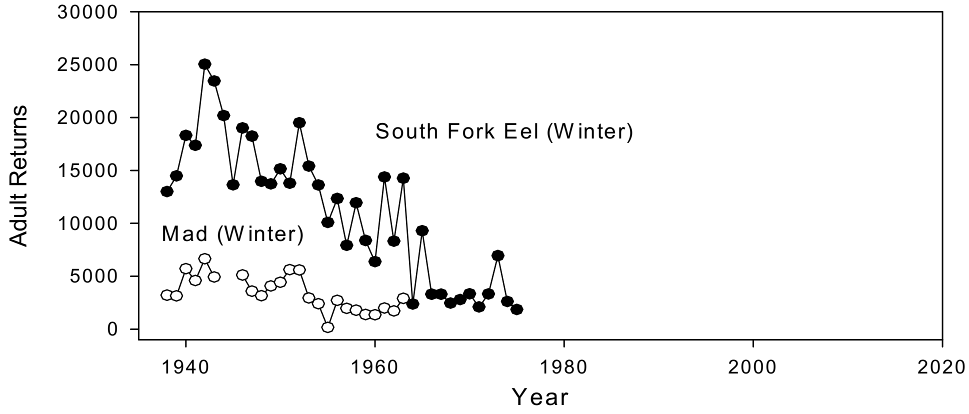
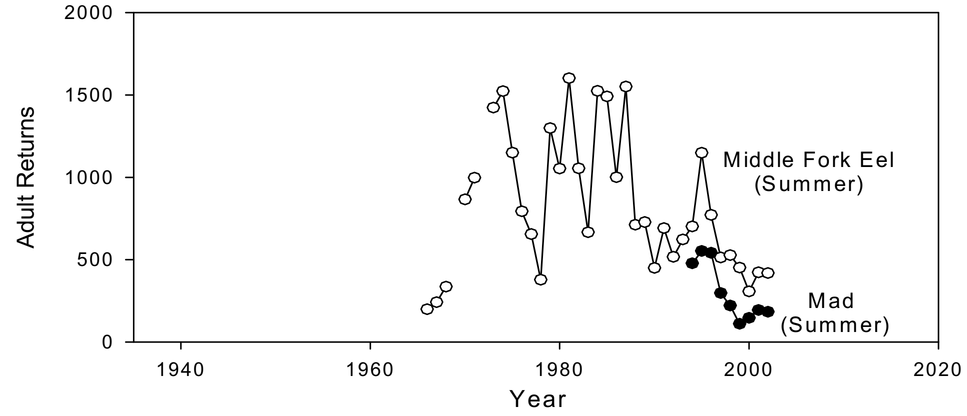
[21] S. Harris and W. Jones, California Department of Fish and Game, Willits, CA. Pers. commun., 20 September 2002.

A) Historic Winter Runs



B) Summer Runs (excl. Redwood Creek)



C) Small Runs - Redwood and Freshwater Creeks

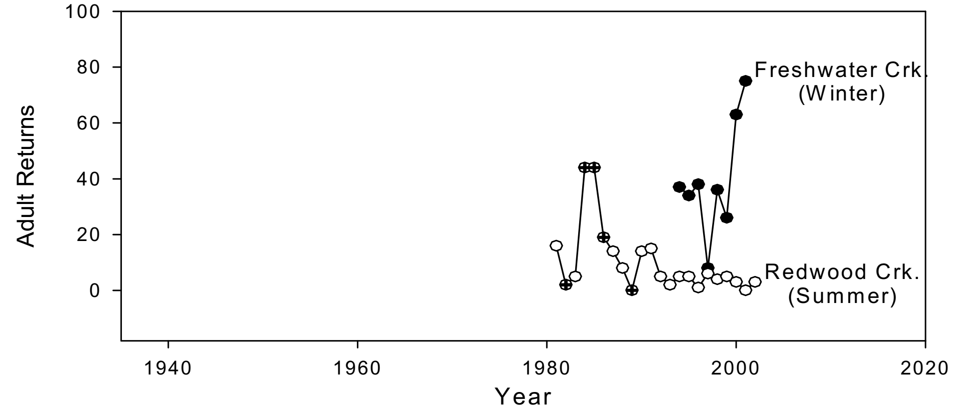


Figure 185. Time-series data for the Northern California steelhead ESU: a. historical data from winter runs on the Mad River and South Fork Eel River; b. summer run on the Middle Fork Eel and Mad Rivers; c. summer-run steelhead in Redwood Creek, and winter-run steelhead in Freshwater Creek, Humboldt County. Data from 1982, 1984–1986, and 1989 represent minimum estimates. Note the three different scales of the *y* axes.

Table 52. Historical estimates (1963) of number of spawning steelhead for rivers in the Northern California steelhead ESU. Source: Data from CDFG (1965).

Stream	**Estimate**[*]
Redwood Creek	10,000
Mad River	6,000
Eel River (total)	82,000
Eel River	(10,000)
Van Duzen River (Eel)	(10,000)
South Fork Eel River	(34,000)
North Fork Eel River	(5,000)
Middle Fork Eel River	(23,000)
Mattole River	12,000
Ten Mile River	9,000
Noyo River	8,000
Big River	12,000
Navarro River	16,000
Garcia River	4,000
Gualala River	16,000
Other Humboldt County streams	3,000
Other Mendocino County streams	20,000
Total	198,000

[*] Estimates are considered by CDFG (1965) to be notably uncertain.

no-listing decision. On 6 October 1999, the California Board of Forestry failed to take action on the forest practices rules, and the NMFS Southwest Region (SWR) regarded this failure as a breach of the MOA, despite the fact that other state agencies, such as the CDFG, had complied with the MOA. The Northern California steelhead ESU was listed as threatened in June 2000.

New Data and Updated Analyses

There are four significant sets of new information regarding status:

1. Updated time-series data exist for the Middle Fork Eel River (summer-run steelhead, snorkel counts; see Figure 185b).
2. New data collection efforts were initiated in 1994 in the Mad River (summer-run steelhead, snorkel counts; Figure 185b) and in Freshwater Creek (winter-run steelhead, weir counts; Figure 185c), a small stream emptying into Humboldt Bay.
3. Numerous reach-scale estimates of juvenile abundance have been made extensively throughout the ESU.
4. Harvest regulations have been substantially changed since the last status review. Analyses of this information are described below.

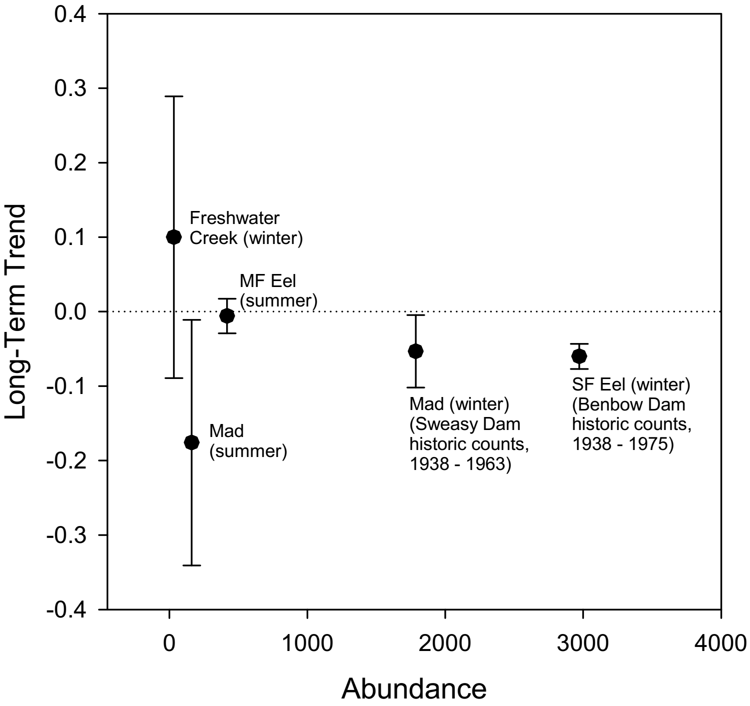


Figure 186. Trends versus abundance for the time-series data from Figure 185. Note that neither set of dam counts (Sweasy Dam, Benbow Dam) has any recent data. Vertical bars are 95% confidence intervals.

Updated Eel River Data

The time-series data for the Middle Fork Eel River are snorkel counts of summer-run steelhead, made for fish in the holding pools of the entire main stem of the middle fork.[22] Most adults in the system are thought to oversummer in these holding pools. An estimate of λ over the interval 1966 to 2002 was made using the method of Lindley (2003), a random-walk-with-drift model fitted using Bayesian assumptions. The estimate of λ is 0.98, with a 95% confidence interval of (0.93, 1.04) (Table 53).[23] The overall trend in the data is downward in both the long and short term (Figure 185b).

New Time Series

The Mad River time series consists of snorkel counts for much of the main stem below Ruth Dam. Some counts include the entire main stem; other years include only data from land owned by Simpson Timber Company. In the years with data from the entire main stem, fish from Simpson Timber land make up at least 90% of the total count. The time series from Freshwater Creek is composed of weir counts. Estimates of λ were not made for either time series because there were too few years of data to make meaningful estimates.

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[22] See Footnote 21.

[23] Note that Lindley (2003) defines $\lambda \approx \exp(\mu + \sigma 2/2)$, whereas Holmes (2001) defines $\lambda \approx \exp(\mu)$; see Lindley (2003) for meaning of the symbols.

Vital statistics for these and other existing time series are given in Table 53; trend versus abundance is plotted in Figure 186.

Juvenile Data

Data on juvenile abundance were collected at numerous sites using a variety of methods.[24] Many of the methods involve selection of reaches thought to be "typical" or "representative" steelhead habitat; other reaches were selected because they were thought to be typical coho habitat, and steelhead counts were made incidental to coho counts. In general, the field crew made electro-fishing counts (usually multiple-pass, depletion estimates) of the young-of-the-year and 1+ age classes. Most of the target reaches were sampled several years in a row; thus there are a large number of short time series. Although methods were always consistent within a time series, they were not necessarily consistent across time series.

Because there are so few adult data on which to base a risk assessment of this ESU, we chose to analyze these juvenile data. However, we note that they have limited usefulness for understanding the status of the adult population, due to nonrandom sampling of reaches within stream systems, nonrandom sampling of populations within the ESU, and a general lack of estimators shown to be robust for estimating fish density within a reach. In addition, even if the BRT used more rigorous methods, there is no simple relationship between juvenile and adult numbers (Shea and Mangel 2001), the latter being the usual currency for status reviews. Table 54 describes the possible ways that one might translate juvenile trends into inferences about adult trends.

To estimate a trend from the juvenile data, the data within each time series were log-transformed then normalized, so that each datum represented a deviation from the mean of that specific time series. The normalization is intended to prevent spurious trends that could arise from the diverse methods used to collect the data. Then, the time series were grouped into units thought to plausibly represent independent populations; the grouping was based on watershed structure. Finally, within each population a linear regression was done for the mean deviation versus year. The estimator for time trend within each grouping is the slope of the regression line. The minimum number of observations per time series is 6 years (other assessments in this status review place the cutoff at 10 years). The general lack of data on the Northern California steelhead ESU prompted us to consider these data sets despite their brevity. This procedure resulted in 10 independent populations for which a trend was estimated. Both upward and downward trends were observed (Figure 187). We tested the null hypothesis that abundances were stable or increasing. It was not rejected (H0: slope >0; $p < 0.32$ via one-tailed t-test against expected value). However, it is important to note that a significance level of 0.32 implies a probability of 0.32 that the ESU is stable or increasing, and a probability of $1 – 0.32 = 0.68$ that the ESU is declining; thus the odds are more than 2:1 that the ESU has been declining during the past 6 years. This conclusion requires the assumption that the assessed populations 1) are indeed

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[24] See Appendix B, Table B-4, for a list of streams and reference information.

Table 53. Summary of time-series data for the Northern California steelhead ESU.

		5-year mean[a]					
Population	**Time series**	**Record**	**Minimum**	**Maximum**	**λ[b]**	**Long-term trend (95% confidence interval)**	**Short-term trend (95% confidence interval)**
Middle Fork Eel River summer run	1966–2002	418	384	1,246	0.98 (0.93, 1.04)	–0.006 (–0.029, 0.017)	–0.067 (–0.158, 0.024)
Mad River summer run	1994–2002	162	162	384	Insufficient data	–0.176 (–0.341, –0.012)	–0.176 (–0.341, –0.121)
Freshwater Creek winter run	1994–2001	32	25	32	Insufficient data	0.099 (–0.289, 0.489)	0.099 (–0.289, 0.489)
Redwood Creek summer run	1981–2002	3	Figure 186[c]		Insufficient data	See Figure 185	–0.775 (–1.276, –0.273)
South Fork Eel River winter run[d]	1938–1975	–	2,743	20,657	0.98 (0.92, 1.02)	–0.060 (–0.077, –0.043)	No recent data
Mad River winter run[e]	1938–1963	–	1,140	5,438	1.00 (0.93, 1.05)	–0.053 (–0.102, –0.005)	No recent data

[a] Geometric means. The value 0.5 was used for years in which the count was 0.

[b] Lambda was calculated using the method of Lindley (2003). Note that a population with λ greater than 1.0 can nevertheless be declining, due to environmental stochasticity.

[c] Certain years have minimum run sizes, rather than unbiased estimates of run size, rendering the time series unsuitable for some of the estimators.

[d] Historical counts made at Benbow Dam (see Appendix A, Table A-2).

[e] Historical counts made at Sweasy Dam (see Appendix A, Table A-2).

Table 54. Interpretation of data on juvenile trends for Northern California steelhead ESU.

		Inference made about adult trends		
		Increasing	**Level**	**Decreasing**
Observed juvenile trends	Increasing	Possible, if no density dependence in the smolt/oceanic phase. The most parsimonious inference.	Possible, if density dependence occurs in the juvenile over-wintering phase, or in the smolt/oceanic phase.	Possible, if oceanic conditions are deteriorating markedly at the same time that reproductive success per female is improving.
	Level	Possible, if oceanic conditions are improving for adults, but juveniles undergo density dependence.	Possible. The most parsimonious inference.	Possible, if oceanic conditions are deteriorating.
	Decreasing	Unlikely, but could happen over the short term due to scramble competition at the spawning/redd phases.	Possible, if river habitat is deteriorating and there was strong, pre-existing density dependence in the oceanic phase.	Likely. The most parsimonious inference.

independent populations rather than plausibly independent populations, and 2) were randomly sampled from all populations in the ESU (in fact they were "haphazardly" sampled).

Possible Changes in Harvest Impacts

Since the original status review of Busby et al. (1996), regulations concerning sport fishing have been changed in a way that probably reduces extinction risk for the ESU. The CDFG (2002a) has prohibited sport harvest in the ocean, and ocean harvest is a rare event,[25] so effects on extinction risk are negligible. For freshwaters (CDFG 2002b), all streams are closed to fishing year round except for special listed streams as follows: Catch-and-release angling is allowed year round excluding April and May in the lower main stem of many coastal streams. Most of these have a bag limit of one hatchery trout or steelhead during the winter months (Albion River, Alder Creek, Big River, Cottoneva Creek, Elk Creek, Elk River, Freshwater Creek, Garcia River, Greenwood Creek, Little River in Humboldt County, Gualala River, Navarro River, Noyo River, Ten Mile River, and Usal Creek); in a few, the one-fish bag limit extends to the entire season (Bear River and Redwood Creek in Humboldt County). The Mattole River has a slightly more restricted catch-and-release season, with zero bag limit year round.

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[25] M. Mohr, Southwest Fisheries Science Center, Santa Cruz, CA. Pers. commun., 15 October 2002.

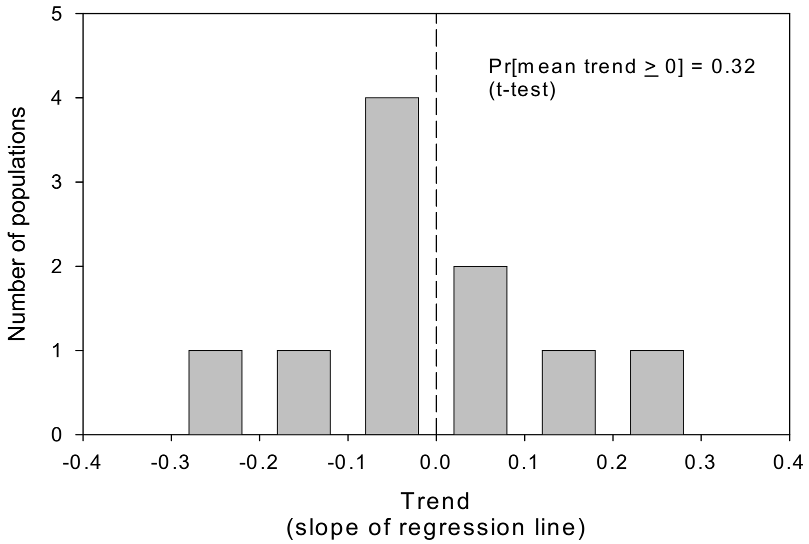

Figure 187. Distribution of trends in juvenile density for 10 independent populations within the Northern California steelhead ESU (see text for description of methods). Trend is measured as the slope of a regression line through a time series; values less than 0 indicate decline; values greater than 0 indicate increase. Assuming that the populations were randomly drawn from the ESU as a whole, the hypothesis that the ESU is stable or increasing cannot be statistically rejected ($p = 0.32$), but is only half as likely as the hypothesis that the ESU is declining ($p = 1 - 0.32 = 0.68$).

The two largest systems are the Mad and Eel rivers. The mainstem Mad River is open over a very long stretch, except for April and May. Bag limit is two hatchery trout or steelhead; other stretches have zero bag limit or are closed to fishing. Above Ruth Dam, an impassable barrier, the bag limit is five trout per day. The Eel River's main stem and south fork are open to catch-and-release over large stretches, year round in some areas and closed April and May in others. The Middle Fork Eel River is open for catch-and-release except midsummer and late fall/winter. In the upper middle fork and many of its tributaries, summer fisheries have bag limits of two or five, with no stipulated restriction on hatchery or wild. In the Van Duzen, a major tributary of the mainstem Eel, a summer fishery allows a bag limit of five above Eaton Falls (CDFG 2002b). Elsewhere, some summer trout fishing is allowed, generally with a two or five bag limit. Cutthroat trout have a bag limit of two from a few coastal lagoons or estuaries.

At catch-and-release streams, all wild steelhead must be released unharmed. There are significant restrictions on gear used for angling. The CDFG monitors angling effort and catch-per-unit-effort in selected basins by way of a "report card" system, in which sport anglers self-report their catch, gear used, and so forth, and in selected other basins by way of creel censuses.

Although the closure of many areas and institution of catch-and-release elsewhere is expected to reduce extinction risk for the ESU, this risk reduction cannot be estimated with existing data (due to the fact that natural abundance is not being estimated). After the federal listing decisions, NMFS requested that CDFG prepare a Fishery Management and Evaluation Plan for the listed steelhead ESUs in California. This has not yet been done for the Northern California steelhead ESU.

Resident *O. mykiss* Considerations

Resident (nonanadromous) populations of *O. mykiss* were assigned to one of three categories for the purpose of provisionally determining ESU membership (see subsection, Resident Fish, in Section 1, Introduction, for a description of the three categories and default assumptions about ESU membership). The third category consists of resident populations that are separated from anadromous conspecifics by recent man-made barriers such as dams without fish ladders. No default assumption about ESU membership was possible for case 3 populations, so we consider them here case by case according to available information.

As of this writing few data show an occurrence of resident populations and even fewer genetic relationships. A provisional survey of the occurrence of case 3 populations in the Northern California steelhead ESU (see Appendix, B, Table B-2) revealed the following: In the watersheds inhabited by this ESU, 8% of stream kilometers lie behind two major recent barriers—Scott Dam on the Eel River and Robert Matthews Dam on the Mad River (Appendix B, Table B-2). (Major barriers are defined as blocking access to watersheds with areas of 259 sq. km [100 sq. mi.] or greater.) Case 3 populations are documented to occur above both dams and there is ongoing stocking of hatchery fish in the Mad River above the dam. No such records of stocking were uncovered for the Eel River above Scott Dam. There do not appear to be any relevant genetic studies of these case 3 populations.

New Hatchery Information

California hatchery stocks being considered for inclusion in the Northern California steelhead ESU are those from Mad River Hatchery, Yager Creek Hatchery, and the North Fork Gualala River Steelhead Project. The stocks and their associated hatcheries were assigned to one of three categories for the purpose of determining ESU membership at some future date (see subsection, Artificial Propagation, in Section 1 for a description of the three categories and related issues regarding ESU membership). To make the assignments, data about broodstock origin, size, management, and genetics were gathered from fisheries biologists and are summarized below.

Mad River Hatchery (Mad River Steelhead, CDFG)

The Mad River Hatchery is located 20 km upriver near the town of Blue Lake (CDFG and NMFS 2001). The trap is located at the hatchery.

Broodstock origin and history

The hatchery was opened in 1970 and first released steelhead in 1971. The original steelhead releases were from adults taken at Benbow Dam on the South Fork Eel River. Between 1972 and 1974, broodstock at Mad River Hatchery were composed almost exclusively of steelhead from the South Fork Eel River. After 1974 returns to the hatchery supplied about 90% of the egg take; other eggs originated from Eel River steelhead. In addition, at least 500 adult steelhead from the San Lorenzo River were spawned at Mad River Hatchery in 1972. Progeny of these fish may have been planted in the basin. All subsequent broodyears are reported to have come from trapping at the hatchery.

Broodstock size/natural population size

An average of 5,536 adults were trapped from 1991 to 2002 and an average of 178 females were spawned during the broodyears from 1991 to 2002. There are no abundance estimates for the Mad River, but steelhead were observed to be widespread and abundant throughout the basin.

Management

Starting in 1998, steelhead are 100% marked, and fish are included in the broodstock in proportion to the numbers returned. The current production goals are 250,000 yearlings raised to 4 to 8 lb for release in March to May.

Population genetics

Allozyme data group Mad River samples with the Mad River Hatchery and then with the Eel River (Busby et al. 1996).

Category

The hatchery has been determined to belong in case 3. There have been no introductions since 1974, and naturally spawned fish are being included in the broodstock. However, there is still an out-of-basin nature to the stock (SSHAG 2003; see Appendix B, Table B-3).

Yager Creek Hatchery
(Yager Creek Steelhead [Pacific Lumber Company])

The Yager Creek trapping and rearing facility is located at the confluence of Yager and Cooper Mill creeks (tributaries of the Van Duzen River, which is a tributary of the Eel River).

Broodstock origin and history

The project was initiated in 1976. Adult broodstock are taken from Yager Creek, and juveniles are released in the Van Duzen River basin. As with all cooperative hatcheries, the fish are all marked, and hatchery fish are usually excluded from broodstock (unless wild fish are rare). There are no records of introductions to the broodstock.

Management

About 4,600 juvenile steelhead from Freshwater Creek (a tributary of Humboldt Bay) were released in the Yager Creek basin in 1993 (Busby et al. 1996). The current program goal is the restoration of Van Duzen River steelhead.

Population genetics

There are no genetic data for this hatchery.

Category

This hatchery was determined to belong to case 1. The broodstock has had no out-of-basin introductions, and hatchery fish are excluded from the broodstock (SSHAG 2003; see Appendix B, Table B-3).

North Fork Gualala River Hatchery
(Gualala River Steelhead Project, CDFG)

This project rears juvenile steelhead rescued from tributaries of the North Fork Gualala River. Rearing facilities are located on Doty Creek, a tributary of the Gualala River 12 miles from the mouth. Steelhead smolts resulting from this program are released in Doty Creek, the main stem of the Gualala River, and other locations in the drainage.

Broodstock origin and history

The project was started in 1981 and has operated sporadically since then. Juvenile steelhead are rescued from the North Fork Gualala River and reared at Doty Creek.

Management

The current program goal is restoration of Gualala River steelhead.

Population genetics

There are no genetic data for this hatchery.

Category

This hatchery was determined to belong to case 1. Usually only naturally spawned juveniles are reared at the facility (SSHAG 2003; see Appendix B, Table B-3).

21. Central California Coast Steelhead ESU

Summary of Previous BRT Conclusions

The Central California Coast steelhead ESU was determined to inhabit coastal basins from the Russian River (Sonoma County) to Soquel Creek (Santa Cruz County) inclusive (Busby et al. 1996). Also included in this ESU are populations inhabiting tributaries of San Francisco and San Pablo bays (though there is some uncertainty about the latter). The ESU is composed only of winter-run fish.

Listing status: Threatened.

Summary of Major Risks and Status Indicators

Risks and limiting factors

Busby et al. (1996) reported two significant habitat blockages: the Coyote and Warm Springs dams in the Russian River watershed. Data indicated that other smaller fish passage problems were widespread in the geographic range of the ESU. Other impacts noted in the status report were urbanization and poor land-use practices, catastrophic flooding in 1964 causing habitat degradation, and dewatering due to irrigation and diversion. The relative strengths of these various impacts has not been formally analyzed. Principal hatchery production in the region comes from the Warm Springs Hatchery on the Russian River and the Monterey Bay Salmon and Trout Project on a tributary of Scott Creek. At the time of the status review, other small private programs were producing steelhead in the range of the ESU and, as reported by Bryant (1994), were using stocks indigenous to the ESU, but not necessarily to the particular basin in which the program was located. There was no information on the actual contribution of hatchery fish to naturally spawning populations.

Status indicators

Busby et al. (1996) reported one estimate of historical (pre-1960s) abundance: Shapovalov and Taft (1954) described an average of about 500 adults in Waddell Creek (Santa Cruz County) for the 1930s and early 1940s. A bit more recently, Johnson (1964) estimated a run size of 20,000 steelhead in the San Lorenzo River before 1965, and CDFG (1965) estimated an average run size of 94,000 steelhead for the entire ESU, for the period 1959–1963 (see Table 55 for a breakdown of numbers by basin). The analysis by CDFG (1965) was compromised by the fact that, for many basins, the data did not exist for the full 5-year period of their analysis. The authors of CDFG (1965) state that “estimates given here which are based on little or no data should be used only in outlining the major and critical factors of the resource.”

Table 55. Summary of estimated run sizes for the Central California Coast steelhead ESU. Source: Reproduced from Busby et al. (1996), Tables 19 and 20.

River basin	Run size estimate	Year	Reference
Russian River	65,000	1970	CACSS (1988)
	1,750–7,000	1994	McEwan and Jackson (1996), CDFG (1994a)
Lagunitas Creek	500		CDFG (1994a)
	400–500	1990s	McEwan and Jackson (1996)
San Gregorio	1,000	1973	Coots (1973)
Waddell Creek	481	1933–1942	Shapovolov and Taft (1954)
	250	1982	Shuman (1994)*
	150	1994	Shuman (1994)*
Scott Creek	400	1991	Nelson (1994)
	<100	1991	Reavis (1991)
	300	1994	Titus et al. (2002)
San Vicente Creek	150	1982	Shuman (1994)*
	50	1994	Shuman (1994)*
San Lorenzo River	20,000	Pre-1965	Johnson (1964), SWRCB (1982)
	1,614	1977	CDFG (1982)
	>3,000	1978	Ricker and Butler (1979)
	600	1979	CDFG (1982)
	3,000	1982	Shuman (1994)*
	"few"	1991	Reavis (1991)
	<150	1994	Shuman (1994)*
Soquel Creek	500–800	1982	Shuman (1994)*
	<100	1991	Reavis (1991)
	50–100	1994	Shuman (1994)*
Aptos Creek	200	1982	Shuman (1994)*
	<100	1991	Reavis (1991)
	50–75	1994	Shuman (1994)*

* The basis for the estimates provided by Shuman (1994) appears to be questionable.

Recent data for the Russian and San Lorenzo rivers (Reavis 1991, CDFG 1994a, Shuman 1994; see Table 55) suggested that these basins had populations smaller than 15% of their size 30 years earlier. These two basins were thought to have originally contained the two largest steelhead populations in the Central California steelhead ESU.

A status review update in 1997 (NMFS 1997b) concluded that slight increases in abundance occurred in the 3 years following the status review. However, the analyses on which these conclusions were based had various problems, including inability to distinguish hatchery and wild fish, unjustified expansion factors, and variance in sampling efficiency on the San Lorenzo River. Presence-absence data compiled by P. Adams[26] indicated that most (82%)

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[26] P. Adams, Southwest Fisheries Science Center, Santa Cruz, CA. Pers. commun., 17 October 2002.

sampled streams (a subset of all historical steelhead streams) had extant populations of juvenile *O. mykiss*.

Previous BRT Conclusions

The original BRT concluded that the ESU was in danger of extinction (Busby et al. 1996). The BRT considered extirpation especially likely in Santa Cruz County and in the tributaries to San Pablo and San Francisco bays. The BRT suggested that abundance in the Russian River (the largest system inhabited by the ESU) has declined sevenfold since the mid-1960s, but abundance appeared to be stable in smaller systems. Two major sources of uncertainty were 1) few data on run sizes, which necessitated that the listing be based on indirect evidence, such as habitat degradation; and 2) uncertainty regarding genetic heritage of populations in tributaries to San Francisco and San Pablo bays, causing uncertainty in the delineation of the geographic boundaries of the ESU. A status review update (NMFS 1997b) concluded that conditions had improved slightly, and that the ESU was not presently in danger of extinction but was likely to become so in the foreseeable future. (Minorities supported both more and less extreme views on extinction risk.) Uncertainties in the update mainly revolved around sampling efforts that were inadequate for detecting status or trends of populations inhabiting various basins.

The BRT formally assessed the status of steelhead in 1996 (Busby et al. 1996). NMFS updated the original status review in 1997 (NMFS 1997b) and listed the Central California Coast steelhead ESU as threatened in August 1997.

New Data and Updated Analyses

There are two significant sets of new information regarding status: 1) numerous reach-scale estimates of juvenile abundance have been made for populations of the ESU, and 2) harvest regulations have been substantially changed since the last status review. Analyses of this information are described below.

Juvenile Data

Data on juvenile abundance have been collected at a number of sites using a variety of methods (D. W. Alley & Associates 1994, 1995, 1997, 1998, 1999, 2000, 2002a, 2002b; Smith 1992, 1994a, 1994b, 1994c, 1996a, 1996b, 1996c, 1997, 1998a, 1998b, 1998c, 1999, 2000a, 2000b, 2001a, 2001b, 2002). Many of the methods involve the selection of reaches thought to be “typical” or “representative” steelhead habitat. In general, the field crew made electro-fishing counts (usually multiple-pass, depletion estimates) of the young-of-the-year and 1+ age classes. Most of the target reaches were sampled several years in a row; thus there are a large number of short time series. Although methods were always consistent within a time series, they were not necessarily consistent across time series.

Because there are so few adult data on which to base a risk assessment of this ESU, we chose to analyze these juvenile data. However, we note that they have limited usefulness for understanding the status of the adult population, due to nonrandom sampling of reaches within stream systems, nonrandom sampling of populations within the ESU, and a general lack of estimators shown to be robust for estimating fish density within a reach. In addition, even if more rigorous methods had been used, there is no simple relationship between juvenile numbers and adult numbers (Shea and Mangel 2001), the latter being the usual currency for status reviews. Table 54 describes the various possible ways that one might translate juvenile trends into inferences about adult trends.

To estimate a trend in the juvenile data, the data within each time series were log-transformed and then normalized, so that each datum represented a deviation from the mean of that specific time series. The normalization is intended to prevent spurious trends that could arise from the diverse set of methods used to collect the data. Then, the time series were grouped into units thought to plausibly represent independent populations; the grouping was based on watershed structure. Finally, within each population, a linear regression was done for the mean deviation versus year. The estimator for time trend within each grouping is the slope of the regression line. The minimum number of observations per time series is 6 years (other assessments in this status review place the cutoff at 10 years). The general lack of data on the Central California Coast steelhead ESU prompted us to consider these data despite the brevity of some series.

This procedure resulted in five independent populations for which a trend was estimated: the San Lorenzo River, Scott Creek, Waddell Creek, Gazos Creek, and Redwood Creek in Marin County. Only downward trends were observed in the five populations (Figure 188). The mean trend across all populations was significantly less than 0 (H0: slope > 0; $p < 0.022$ via one-tailed t-test against expected value). This outcome suggests an overall decline in juvenile abundance, but it is important to note that such a conclusion requires the assumptions that the assessed populations 1) are indeed independent populations rather than plausibly independent populations, and 2) were randomly sampled from all populations in the ESU (they are probably better regarded as having been haphazardly sampled).

Possible Changes in Harvest Impacts

Since the original status review of Busby et al. (1996), regulations concerning sport fishing have been changed in a way that probably reduces extinction risk for the ESU. The CDFG has prohibited sport harvest in the ocean (2002a), and ocean harvest is a rare event.[27] For freshwaters (CDFG 2002b), all coastal streams are closed to fishing year round, except for special listed streams that allow catch-and-release angling or summer trout fishing. Catch-and-release angling with restricted timing (generally, winter season Sundays, Saturdays, Wednesdays, and holidays) is allowed in the lower main stems of many coastal streams south of San Francisco (Aptos Creek, Butano Creek, Pescadero Creek, San Gregorio Creek, San Lorenzo River, Scott Creek, Soquel Creek). Notably, for a while Waddell Creek in Santa Cruz County had a five-per-day bag limit during the winter, for the short reach between Highway 1 and the ocean. This bag limit was reduced to zero in the supplementary regulations issued in a separate document (CDFG 2002b). Catch-and-release is allowed year round, except April and May, in the lower parts of Salmon Creek in Sonoma County and Walker Creek in Marin County.

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[27] See Footnote 25.

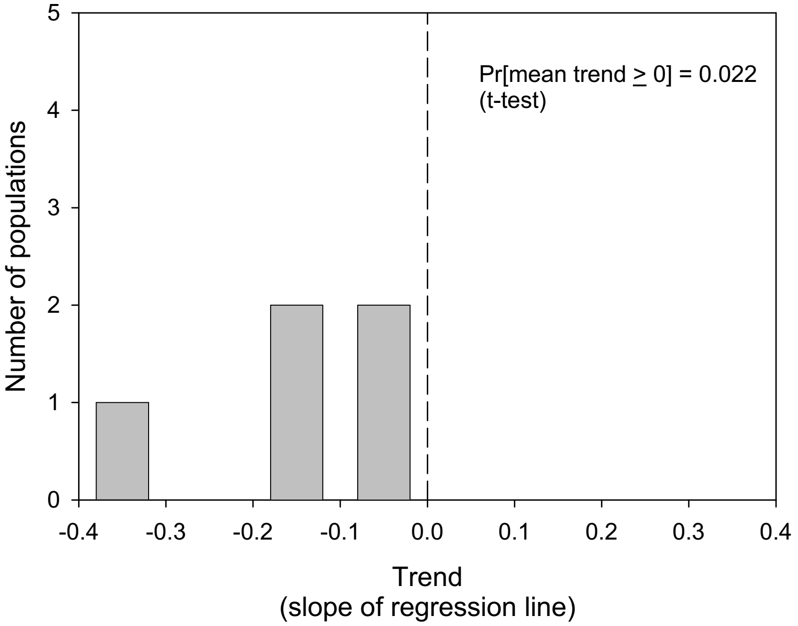

Figure 188. Distribution of trends in juvenile densities for five independent populations within the Central California Coast steelhead ESU (see text for description of methods). Trend is measured as the slope of a regression line through a time series; values less than 0 indicate decline; values greater than 0 indicate increase. Assuming that the populations were randomly drawn from the ESU as a whole, the hypothesis that the ESU is stable or increasing can be statistically rejected (p = 0.022), implying an overall decline.

Russian Gulch in Sonoma County has similar regulations except that one hatchery fish may be taken in the winter.

The Russian River is the largest system and probably originally supported the largest steelhead population in the Central California Coast steelhead ESU. The main stem is currently open all year and has a bag limit of two hatchery steelhead or trout. Above the confluence with the East Branch it is closed year round. Santa Rosa Creek and Laguna Santa Rosa, Sonoma County tributaries to the Russian River, have a summer catch-and-release fishery.

Tributaries to the San Francisco Bay system have less restricted fisheries. All streams in Alameda, Contra Costa, and Santa Clara counties (east and south bay) have summer fisheries with a bag limit of five, except for special cases that are closed all year (Mitchell Creek, Redwood Creek in Alameda County, San Francisquito Creek and tributaries, and Wildcat Creek). In the north Bay, the lower main stem of the Napa River has catch-and-release year round except April and May; there is a bag limit of one hatchery steelhead or trout. Upper Sonoma Creek and tributaries have a summer fishery with bag limit of five. Summer trout fishing is allowed in some lakes and reservoirs or in tributaries to lakes, generally with two or five bag limit.

For catch-and-release streams, all wild steelhead must be released unharmed. There are significant restrictions on gear used for angling. The CDFG has prepared a draft Fishery

Management and Evaluation Plan (CDFG 2001c), which argues that the upper limit of increased mortality due to sport fishing is about 2.5% in all populations. This estimate is based on an estimated mortality rate of 5% once a fish is hooked, which is consistent with a published metaanalysis of hooking mortality (Schill and Scarpella 1997). Experimental studies on the subject—from which the estimates are made—tend to measure mortality only for a period of a few days or a week after capture (e.g., Titus and Vanicek 1988).

The Fishery Management and Evaluation Plan contains no extensive plans for monitoring fish abundance. Although the closure of many areas and institution of catch-and-release elsewhere is expected to reduce extinction risk for the ESU, this risk reduction cannot be estimated quantitatively from the existing data sets, due to the fact that natural abundance is not being measured.

Resident *O. mykiss* Considerations

Resident (nonanadromous) populations of *O. mykiss* were assigned to one of three categories for the purpose of provisionally determining ESU membership (see subsection, Resident Fish, in Section 1 for a description of the three categories and default assumptions about ESU membership). The third category consists of resident populations that are separated from anadromous conspecifics by recent man-made barriers such as dams without fish ladders. No default assumption about ESU membership was possible for case 3 populations, so the BRT considers them case by case according to available information.

As of this writing few data show an occurrence of resident populations and even fewer genetic relationships. A provisional survey of the occurrence of case 3 populations in the Central California Coast steelhead ESU (see Appendix B, Table B-2) revealed the following: In the watersheds inhabited by this ESU, at least 26% of stream kilometers lie behind recent barriers, and a number of resident populations are known to occur above the barriers (Appendix B, Table B-2). One significant set of case 3 populations is in Alameda Creek, a tributary to San Francisco Bay. Nielsen (2003) examined mitochondrial DNA and microsatellite DNA of fish from four subbasins of Alameda Creek and found that three of the subpopulations were most similar to each other and were more similar to populations from other creeks within the ESU (Lagunitas and San Francisquito creeks) than they were to populations outside the ESU. This finding strongly suggests that these case 3 subpopulations should be considered part of the ESU. The fourth subpopulation, which occurred in Arroyo Mocho, was quite distinct and was more similar to Whitney hatchery stocks than it was to other subpopulations within the basin or even the wider ESU. Nielsen (2003) suggests that this population may either be a population of native rainbow trout with no association to anadromous forms, or has experienced significant genetic introgression from introduced hatchery stocks.

Gall et al. (1990) examined the genetics of two populations in tributaries to the upper San Leandro Reservoir on San Leandro Creek. This creek drains into the San Francisco Bay and is, interestingly, the type locality for coastal rainbow trout (*Salmo irideus*, now known as *Oncorhynchus mykiss irideus*) (Gall et al. 1990, Behnke 1992). Gall et al. (1990) analyzed genetic variability at 17 marker loci using electrophoresis and concluded that the populations truly belonged to the coastal subspecies of *O. mykiss* (i.e., ssp. *irideus*). However, their study was not designed to assess whether the populations were more similar to hatchery stocks than to nearby wild populations. They reported anecdotal observations that the fish make steelhead-like runs to and from the reservoir.

New Hatchery Information

California hatchery stocks being considered for inclusion in the Central California Coast steelhead ESU are those from Don Clausen Fish Hatchery and the Monterey Bay Salmon and Trout Project. The stocks and their associated hatcheries were assigned to one of three categories for the purpose of determining ESU membership at some future date (see subsection, Artificial Propagation, in Section 1, Introduction, for a description of the three categories and related issues regarding ESU membership). To make the assignments, data about broodstock origin, size, management, and genetics were gathered from fisheries biologists and are summarized below.

Don Clausen Fish Hatchery
(Warm Springs Steelhead, CDFG)

The hatchery and collection site is located on Dry Creek, 22 km above the confluence of Dry Creek and the Russian River and 75 river km from the ocean. In 1992, the Coyote Valley Fish Facility was opened at the base of Coyote Valley Dam on the East Fork Russian River, 157 km from the ocean. Both facilities trap fish on site. Coyote Valley fish are trapped and spawned there, but raised at Don Clausen Fish Hatchery. The Coyote Valley steelhead are imprinted for 30 days at the facility before release.

Broodstock origin and history

The hatchery was founded in 198, and the first released steelhead in 1982. The Coyote Valley Fish Facility was opened in 1992. Don Clausen Fish Hatchery has had few out-of-basin transfers into its broodstock. However, significant numbers of Mad River Hatchery steelhead have been released into the basin. In the earlier part of the century, steelhead from Scott Creek were released throughout the basin. Since the Coyote Valley Fish Facility has been constructed, broodstock has been trapped at the facility.

Broodstock and natural population size

At Don Clausen Fish Hatchery, an average of 3,301 fish were trapped and 244 females were spawned during the broodyears 1992–2002. At the Coyote Valley Fish Facility, an annual average of 1,947 steelhead were trapped from 1993 to 2002 and an average of 124 females spawned. There are no steelhead abundance estimates for the Russian River, but fish are observed to be widely distributed and plentiful (NMFS 2002d).

Management

As of 1998, steelhead have been 100% ad-clipped. Until broodyear 2000, both hatchery and naturally spawned fish were included in the broodstock in the proportion that they returned to the hatchery. Since then, only adipose-marked fish are spawned, and all unmarked steelhead are relocated into tributaries of Dry Creek. The production goal for Don Clausen Fish Hatchery is 300,000 yearlings released beginning in December, by size, with all fish released by April. The Coyote Valley Fish Facility's goal is 200,000 yearlings that volitionally release between January and March.

Category

The Don Clausen Fish Hatchery has been determined to belong to case 2 (SSHAG 2003; Appendix B, Table B-3). Although some out-of-ESU stocks were present in the basin, there have been no significant introductions since the hatchery began operations. The stock itself has only been cultivated for 20 years. The run is abundant and naturally spawned fish were included in the broodstock until 2000. Since that time only adipose-marked steelhead have been spawned.

Monterey Bay Salmon and Trout Project (Kingfisher Flat [Big Creek] Hatchery; Scott Creek Steelhead)

The Kingfisher Flat Hatchery is located on Big Creek, a tributary of Scott Creek, 6 km upstream from the mouth. Broodstock are taken by divers' netting adults, usually in Big Creek below the hatchery, but at times throughout the Scott Creek system (NMFS 2002e). Steelhead are also taken at a trap on the San Lorenzo River in Felton, California. San Lorenzo River steelhead are kept separately and released back into the San Lorenzo basin.

Broodstock origin and history

The Kingfisher Flat Hatchery began in 1975. However, California state hatchery activity near this site has a history that dates back to 1904 (Strieg 1991). The state hatchery program ended in 1942 due to flood damage. Under the California state hatchery program, Scott Creek steelhead were widely planted throughout coastal California, as they were thought to be an exceptionally healthy stock. The hatchery was damaged by floods in 1941–1942 and closed. There are limited records of introductions from Mount Shasta and Prairie Creek hatcheries into this broodstock.

In 1976, the Monterey Bay Salmon and Trout Project began operations at the Big Creek location. Since then, broodstock have been taken either in Scott Creek by divers or at a trap in the San Lorenzo River near Felton. Since that time, there have been no introductions into the broodstock. As with all cooperative hatcheries, the fish are all marked, and hatchery fish are usually excluded from broodstock. Fish are released in either Scott Creek or the San Lorenzo River, depending on the source of the broodstock.

Broodstock and natural population size

An average of 98 fish were trapped and 25 females spawned during the 1990–1996 broodyears. There are no abundance estimates for Scott Creek and the San Lorenzo River, but juveniles have been observed anecdotally to be widespread and abundant (NMFS 2002e).

Management

Starting in 2000, the practice of planting San Lorenzo fish into the North Fork Pajaro River basin was discontinued. Although the distance is only a matter of miles, it is across ESU boundaries. The current program goal is the restoration of local steelhead stocks.

Population genetics

Allozyme data groups the Scott Creek, San Lorenzo, and Carmel River stocks together (Busby et al. 1996). Collectively they fall within the "south-of-the-Russian-River" grouping.

Category

The hatchery was determined to fall into case 1 (SSHAG 2003; Appendix B, Table B-3). The stock has not had out-of-basin introductions in recent years, and hatchery fish are excluded from the broodstock.

22. South-Central California Coast Steelhead ESU

Summary of Previous BRT Conclusions

The geographic range of the South-Central California Coast steelhead ESU was determined to extend from the Pajaro River basin in Monterey Bay south to, but not including, the Santa Maria River basin near the town of Santa Maria. The ESU was separated from steelhead populations to the north on the basis of genetic data (mitochondrial DNA and allozymes) and from steelhead populations to the south on the basis of a general faunal transition in the vicinity of Point Conception. The genetic differentiation of steelhead populations within the same ESU, and the genetic differentiation between ESUs, appears to be greater in the south than in northern California or the Pacific Northwest; however the conclusion is based on genetic data from a small number of populations.

Summary of Major Risks and Status Indicators

Risks and limiting factors

Numerous minor habitat blockages were considered likely throughout the region. Other typical problems were thought to be dewatering from irrigation and urban water diversions and habitat degradation in the form of logging on steep erosive slopes, agricultural and urban development on floodplains and riparian areas, and artificial breaching of estuaries during periods when they are normally closed off from the ocean by a sandbar.

Status indicators

Historical data on the South-Central California Coast steelhead ESU are sparse. In the mid-1960s, the CDFG (1965) estimated that the ESU-wide run size was about 17,750 adults. No comparable recent estimate exists; however, recent estimates exist for five river systems (Pajaro, Salinas, Carmel, Little Sur, and Big Sur), indicating runs of fewer than 500 adults where previous runs had been on the order of 4,750 adults (CDFG 1965). Time-series data only existed for one basin (the Carmel River), and indicated a decline of 22% per year over the interval 1963 to 1993 (see Abundance in the Carmel River, page 271, for an update of this conclusion).

Many of the streams were thought to have somewhat to highly impassable barriers, both natural and anthropogenic, and in their upper reaches to harbor populations of resident trout. The relationship between anadromous and resident O. mykiss is poorly understood in this ESU, but was thought to play an important role in its population dynamics and evolutionary potential. A status review update conducted in 1997 (NMFS 1997b) listed numerous reports of juvenile O. mykiss in many coastal basins, but noted that the implications for adult numbers were unclear.

The review also discussed the fact that certain inland basins (the Salinas and Pajaro systems) are rather different ecologically from coastal basins.

Previous BRT Conclusions

The original BRT (Busby et al. 1996) concluded that the ESU was in danger of extinction, due to 1) low total abundance and 2) downward trends in abundance in those stocks for which data existed. The negative effects of poor land-use practices and trout stocking were also noted. The major area of uncertainty was the lack of data on steelhead run sizes, past and present. The status review update (NMFS 1997b) concluded that abundance had slightly increased in the years immediately preceding the review, but that overall abundance was still low relative to historical numbers. They also expressed concern that high juvenile abundance and low adult abundance observed in some data sets suggested that many or most juveniles were potentially resident fish (i.e., rainbow trout). The BRT convened for the update was nearly split on whether the fish were in danger of extinction, or currently not endangered but likely to become so in the foreseeable future, with the latter view holding a slight majority.

Listing status: Threatened.

New Data and Updated Analyses

There are three new significant pieces of information: 1) updated time-series data concerning dam counts made on the Carmel River (MPWMD 2001; see analyses section below for further discussion); 2) a comprehensive assessment of the current geographic distribution of *O. mykiss* within the ESU's historical range (Boughton and Fish 2003, see next paragraph); and 3) changes in harvest regulations since the last status review (see next subsection).

Current versus Historical Distribution

In 2002, an extensive study was made of steelhead occurrence in most of the coastal drainages between the northern and southern geographic boundaries of the South-Central California Coast steelhead ESU (Boughton and Fish 2003). Steelhead were considered to be present in a basin if adult or juvenile *O. mykiss* were observed in any stream reach that had access to the ocean (i.e., no impassable barriers between the ocean and the survey site), in any of the years 2000–2002 (i.e., within one steelhead generation). Of 36 drainages in which steelhead were known to have occurred historically, between 86% and 94% were currently occupied by *O. mykiss*. The range in the estimate of occupancy occurs because three basins could not be assessed due to restricted access. Of the vacant basins, two were considered to be vacant because they were dry in 2002, and one was found to be watered, but a snorkel survey revealed no *O. mykiss*. One of the "dry" basins—Old Creek—is dry because no releases were made from Whale Rock Reservoir; however, a landlocked population of steelhead is known to occur in the reservoir above the dam.

Occupancy was also determined for 18 basins with no historical record of steelhead occurrence. Three of these basins—Los Osos, Vicente, and Villa creeks—were found to be occupied by *O. mykiss*. It is somewhat surprising that no previous record of steelhead seems to exist for Los Osos Creek, near Morro Bay and San Luis Obispo.

The distribution of steelhead among the basins of the region is not much less than what occurred historically, so despite the widespread declines in habitat quality and population sizes, regional extirpations have not yet occurred. This conclusion rests on the assumption that juveniles inhabiting stream reaches with access to the ocean will undergo smoltification, and thus are truly steelhead.

Three analyses are made below: 1) a critical review of the historical run sizes cited in the previous status review, 2) an assessment of recent trends observed in the adult counts being made on the Carmel River; and 3) a summary of new sport-fishing regulations in the region.

Review of Historical Run Sizes

Estimates of historical sizes for a few runs were described in the previous status review (Busby et al. 1996), and are here reproduced in Table 56.

The recent estimates for the Pajaro River (1,500, 1,000, 2,000) were reported in McEwan and Jackson (1996), but the methodology and data set used to produce the estimates were not described. CACSS (1988) suggested an annual run size of 20,000 adults in the Carmel River in the 1920s, but gave no supporting evidence for the estimate. Their 1988 estimate of 2,000 adults also lacked supporting evidence. Meyer Resources (1988) provides an estimate of run size, but was not available for review at the time of this writing.

Snider (1983) examined the Carmel River and produced many useful data. In the abstract of his report he gave an estimate of 3,177 fish as the mean annual smolt production for 1964 through 1975; Busby et al. (1996) mistakenly cited this estimate as an estimate of run size. Snider's 3,177 figure may itself be a mistake, as it disagrees with information in the body of the report, which estimates annual smolt production in 1973 at 2,708 and in the year 1974 at 2,043. Snider (1983) gives adult counts for fish migrating upstream through the fish ladder at San Clemente Dam for 1964 through 1975 (data were not reported in Busby et al. [1996], but were apparently the basis for the 22% decline they reported). (See Figure 189 for the actual counts.)

Table 56. Estimates of historical steelhead run sizes from the previous status review (Busby et al. 1996).

River basin	Run size estimate	Year	Reference
Pajaro River	1,500	1964	McEwan and Jackson (1996)
	1,000	1965	McEwan and Jackson (1996)
	2,000	1966	McEwan and Jackson (1996)
Carmel River	20,000	1928	CACSS (1988)
	3,177	1964–1975	Snider (1983)
	2,000	1988	CACSS (1988)
	<4,000	1988	Meyer Resources (1988)

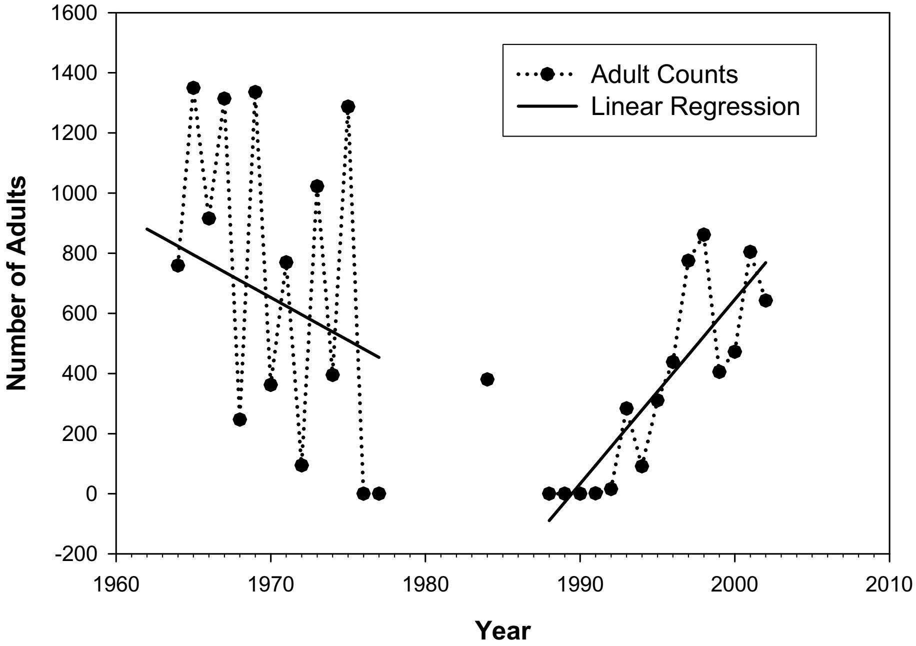

Figure 189. Adult steelhead counts at San Clemente Dam, Carmel River. Data from the Monterey Peninsula Water Management District. See Snider (1983) for methods of counting fish before 1980; these early data are subject to substantial observation error (note: the regression line is not significantly different from flat). The increase during the 1990s followed a severe drought (and concurrent dewatering of the main stem by a water district) in the late 1980s and early 1990s.

The mean run size from these data is 821 adults. To make these estimates, visual counts were made twice a day by reducing the flow through the ladder and counting the fish in each step; thus they may underestimate the run size by some unknown amount if fish moved completely through the ladder between counts (an electronic counter was used in 1974 and 1975 and presumably is more accurate). In addition, San Clemente Dam is 31 km from the mouth of the river, and a fraction of the run spawns below the dam (CDFG biologists estimate the fraction to be one third of the run, based on redd surveys).

Thus, much historical data used in the previous status review are highly uncertain. The most reliable data are the Carmel River Dam counts, which were not reported in the previous status review. Further analyses of these data are described below.

Abundance in the Carmel River

The Carmel River data are the only time series for the South-Central California Coast steelhead ESU. The data suggest that the abundance of adult spawners in the Carmel River has increased since the last status review (Figure 189). A continuous series of data exists for 1964 through 1977, although the data are probably incomplete to various degrees for each year (i.e., the counts are probably incomplete, and the year-to-year fluctuations may be mostly due to observation error rather than population variability). A regression line drawn through the data indicates a downward trend, but the trend is not statistically significant (slope = –28.45; R^2 = 0.075; F = 1.137; p = 0.304). The 22% decline reported by Busby et al. (1996) is apparently based on these data, in comparison with the low numbers of the early 1990s.

Continuous data have also been collected for the period 1988 through 2002. The beginning of this time series has counts of zero adults for 3 consecutive years, then shows a rapid increase in abundance. The trend is strongly upward (see Table 57). The time series is too short to make a reliable estimate of mean lambda. The observed positive trend could conceivably be due either to improved conditions (i.e., mean lambda greater than 1), substantial immigration or transplantation, or the transient effects of age structure. Improved conditions seem by far the most likely explanation, as the basin has been the subject of intensive fisheries management since the early 1990s. According to the Monterey Peninsula Water Management District, the entity conducting much of the restoration of the basin's steelhead fishery, the likely reasons for the positive trend are due to improved conditions, namely

> Improvements in streamflow patterns, due to favorable natural fluctuations … since 1995; … actively manag[ing] the rate and distribution of groundwater extractions and direct surface diversions within the basin; changes to Cal-Am's [dam] operations … providing increased streamflow below San Clemente Dam; improved conditions for fish passage at Los Padres and San Clemente Dams …; recovery of riparian habitats, tree cover along the stream, and increases in woody debris …; extensive rescues … of juvenile steelhead over the last ten years … ; transplantation of the younger juveniles to viable habitat upstream and of older smolts to the lagoon or ocean; and implementation of a captive broodstock program by Carmel River Steelhead Association and California Department of Fish & Game (CDFG), [including] planting … from 1991 to1994. (MPWMD 2001)

Even so, the rapid increase in adult abundance from 1991 (one adult) to 1997 (775 adults) seems too great to attribute simply to improved reproduction and survival of the local steelhead. There are a number of possibilities: substantial immigration or transplantation may have boosted abundance, or perhaps there was a large population of resident trout that has begun producing smolts at a higher rate under improved freshwater conditions. The transplantation hypothesis is thought unlikely: although transplantation of juveniles occurred (in the form of rescues from the lower main stem during periods in which it was dewatered), CDFG biologists consider the scale of these efforts to be too small to cause the large increase in run size that has been observed. The scale of immigration (i.e., straying) is not known but may be a significant factor. As for the role of resident trout in producing smolts, the phenomenon is known to occur but the environmental triggers have not yet been worked out. One hypothesis, congruent with the Carmel River situation, is that environmental conditions affect growth rate of juveniles, which affects

Table 57. Summary of time-series data for the South-Central California Coast steelhead ESU.

		5-year mean[a]					
Population	**Time series**	**Record**	**Min.**	**Max.**	**λ[b]**	**Long-term trend (95% confidence interval)**	**Short-term trend (95% confidence interval)**
Carmel River (winter run)	1962–2002	611	1.13	881	Insufficient data	0.488 (0.442, 0.538)[c]	0.488 (0.442, 0.538)

[a] Geometric means. The value 0.5 was used for years in which the count was zero.

[b] Lambda calculated using the method of Lindley (2003). Note that a population with λ greater than 1.0 can nevertheless be declining, due to environmental stochasticity.

[c] Exceptionally high observation error; not used in calculations.

propensity to smolt into the anadromous form. The rapid increase in adult abundance in the Carmel River system is thus very interesting. At this point two conclusions seem warranted:

1. Upon improvement of freshwater conditions such as those described above, the adult runs are capable of rapid increase in the South-Central California Coast steelhead ESU, due either to resilience of steelhead populations, high stray rates, or ability of resident trout to produce smolts. Either mechanism might allow the fish to rapidly take advantage of improved conditions, suggesting a high potential for rapid recovery in this ESU if the proper actions were taken.
2. Although some component of the increase is probably due to improved ocean conditions, it would be a mistake to assume comparable increases have occurred in other basins of the ESU, as they have not been the focus of such intensive management efforts.

Possible Changes in Harvest Impacts

Since the original status review of Busby et al. (1996), regulations concerning sport fishing have been changed in a way that probably reduces extinction risk for the South-Central California Coast steelhead ESU.

The CDFG (2002a) has prohibited sport harvest of steelhead in the ocean, and ocean harvest is a rare event,[28] so effects on extinction risk are probably negligible. For freshwaters, CDFG (2002b) describes the current regulations. Summer trout fishing is allowed in some systems, often with a two or five per bag limit. These areas include significant parts of the Salinas system (upper Arroyo Seco and Nacimiento above barriers, the upper Salinas, Salmon Creek, and the San Benito River in the Pajaro system all have a bag limit of five trout). Also included in the summer fisheries is the Carmel River above Los Padres Dam (bag limit is two trout, between 10 inches and 16 inches). A few other creeks have summer catch-and-release regulations. The original draft of the Fishery Management and Evaluation Plan (CDFG 2000a) recommended complete closure of the Salinas system to protect the steelhead there, but the final regulations did not implement this recommendation, allowing both summer trout angling and winter-run catch-and-release steelhead angling in selected parts of the system (CDFG 2002b).

The regulations allow catch-and-release winter-run steelhead angling in many of the river basins occupied by the South-Central California Coast steelhead ESU, specifying that all wild steelhead must be released unharmed. There are significant restrictions on timing, location, and gear used for angling. A recent draft of the Fishery Evaluation and Management Plan (CDFG 2001b) argues that the only mortality expected from a no-harvest fishery is from hooking and handling injury or stress. They estimate this mortality rate to be about 0.25–1.4%. This estimate is based on angler capture rates measured in other river systems throughout California (range of 5–28%), multiplied by an estimated mortality rate of 5% once a fish is hooked. The latter mortality estimate is consistent with a published metaanalysis of hooking mortality (Schill and Scarpella 1997), but experimental studies on the subject—from which the estimates are made—

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[28] See Footnote 25.

tend to measure mortality only for a period of a few days or a week after capture (e.g., Titus and Vanicek 1988).

The Fishery Management and Evaluation Plan contains no extensive plans for monitoring fish abundance. Although the closure of many areas and institution of catch-and-release elsewhere is expected to reduce extinction risk for the ESU, this risk reduction cannot be estimated quantitatively from the existing data, due to the fact that natural abundance is not being measured.

Resident *O. mykiss* Considerations

Resident (nonanadromous) populations of *O. mykiss* were assigned to one of three categories for the purpose of provisionally determining ESU membership (see subsection, Resident Fish, in Section 1 for a description of the three categories and default assumptions about ESU membership). The third category consists of resident populations that are separated from anadromous conspecifics by recent man-made barriers such as dams without fish ladders. No default assumption about ESU membership was possible for case 3 populations, so they are considered here case by case, according to available information.

As of this writing we have few data on occurrence of resident populations and even fewer on genetic relationships. A provisional survey of the occurrence of case 3 populations in the South-Central California Coast steelhead ESU (see Appendix B, Table B-2) revealed the following: There are four significant case 3 populations within the ESU's original geographic range (Appendix B, Table B-2)—two in the Salinas system, one behind Whale Rock Dam near Cayucos, and one behind the Lopez Reservoir on Arroyo Grande Creek. The two in the Salinas system occur behind the dams on the Nacimiento and San Antonio rivers, which currently block what were reported to be two of the three principal steelhead spawning areas in the basin (the other being in Arroyo Seco; Titus et al. [2002]). Resident populations occur above these dams and stocking is ongoing (Appendix B, Table B-2). A third major barrier occurs in the headwaters of the Salinas itself; stocking currently occurs above this dam. Steelhead reportedly spawned in these streams before the dam was built, but the runs were probably relatively small and sporadic.

The Whale Rock Reservoir has a resident population that is reported to make steelhead-like runs up several tributaries for spawning. The reservoir has an associated hatchery program (see the previous section for details on genetic studies, stocking records, and so on).

According to David Starr Jordan (cited in Titus et al. 2002), the area now blocked by the Lopez Dam on Arroyo Grande Creek was originally well known as a significant steelhead area. A resident population currently exists above this dam, and stocking is ongoing (Table B-1). We are not aware of any studies of the population's genetic affinities.

Minor Barriers

Defined here as blocking less than 259 sq. km (100 sq. mi.) of watershed, minor barriers are numerous within the geographic range of the South-Central California Coast steelhead ESU.

A nonzero number of case 3 populations undoubtedly exist above these barriers, but at the present time data are insufficient to make a comprehensive assessment.

New Hatchery Information

The only hatchery stock considered in the South-Central California Coast steelhead ESU is the one at Whale Rock Hatchery. This stock was assigned to one of three categories for the purpose of determining ESU membership at some future date (see subsection, Artificial Propagation, in Section 1 for a description of the three categories and related issues regarding ESU membership). To make the assignment, data about broodstock origin, size, management, and genetics were gathered from fisheries biologists and are summarized below.

Whale Rock Hatchery
(Whale Rock Steelhead, CDFG)

Whale Rock Reservoir was created in 1961 by placing a dam on Old Creek, 2 km upstream from the coast. Old Creek had supported a large steelhead run prior to construction of the dam, and these fish were presumably trapped behind the dam (the creek is usually dewatered below the dam so no population occurs there at all). Whale Rock Hatchery was established in 1992 as an effort to improve the sport fishery in the reservoir after anglers reported a decline in fishing success. The original Whale Rock broodstock (40 fish) were collected at a temporary weir placed in the reservoir at the mouth of Old Creek Cove (Nielsen 2003). Adult fish were trapped in the shallows of the reservoir using nets set during late winter and spring as the fish begin their migration upstream from the reservoir into Old Creek. The fish are held in an enclosure while they are monitored for ripeness. Eggs and sperm are collected from fish using nonlethal techniques, then the adult fish are returned to the reservoir. Fish were originally hatched and raised at the Whale Rock Hatchery located below the dam at the maintenance facility, but are now raised at the Fillmore Hatchery in Ventura County. The fry are cared for until September or November, at which time they are released back into the reservoir as 3- to 5-inch fingerling trout.

Broodstock origin and history

Hatchery operations began in 1992 and have been sporadic since. The project is a cooperative venture between CDFG and private parties. Fish were raised in 1992, 1994, 2000, and 2002.[29] All broodstock are taken from the reservoir.

Broodstock size/natural population size

An average of 121 fish were spawned. Spawning success has been poor. There are no population estimates for the reservoir, and the hatchery fish are not marked.

Management

The current program goal is to increase angling success in Whale Rock Reservoir.

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[29] H. Fish, Southwest Fisheries Science Center, Santa Cruz, CA. Pers. commun., 25 February 2003.

Population genetics

Neilsen et al. (1997) found that significant genetic relatedness occurs between the Whale Rock Hatchery stock and wild steelhead in the Santa Ynez River and Malibu Creek, two basins to the south. They reported a loss of genetic diversity within the hatchery stock.

Category

The hatchery was determined to belong to case 2 (SSHAG 2003; Appendix B, Table B-3). Broodstock are taken from the source population, but the small population could easily lead to significant genetic bottlenecks.

23. Southern California Steelhead ESU

Summary of Previous BRT Conclusions

The geographic range of the Southern California steelhead ESU extends from the Santa Maria River basin near the town of Santa Maria, south to the U.S. border with Mexico. *O. mykiss* populations are reported in Baja California del Norte (Ruiz-Campos and Pister 1995); these populations are thought to be resident trout, but could be found to have an anadromous component with further study (note that they do not lie within the jurisdiction of the ESA). NMFS (1997b) cites reports of several other steelhead populations south of the border. The Southern California steelhead ESU is the extreme southern limit of the anadromous form of *O. mykiss*. It was separated from steelhead populations to the north on the basis of a general faunal transition (in the fauna of both freshwater and marine systems) in the vicinity of Point Conception. The genetic differentiation of steelhead populations within the ESU, and from other ESUs in northern California or the Pacific Northwest appears to be great; however, the conclusion is based on genetic data from a small number of populations.

Summary of Major Risks and Status Indicators

Risks and limiting factors

The original BRT (Busby et al. 1996) noted that there has been extensive loss of populations, especially south of Malibu Creek, due to urbanization, dewatering, channelization of creeks, man-made barriers to migration, and the introduction of exotic fish and riparian plants. Many of these southernmost populations may have originally been marginal or intermittent (i.e., exhibiting repeated local extinctions and recolonizations in bad and good years, respectively). No hatchery production exists for the ESU. The relationship between anadromous and resident *O. mykiss* is poorly understood in this region, but likely plays an important role in population dynamics and evolutionary potential of the fish.

Status indicators

Historical data on the Southern California steelhead ESU were sparse. The historical run size for the ESU (Busby et al. 1996) was roughly estimated to be at least 32,000–46,000 (estimates for the four systems comprising the Santa Ynez, Ventura, and Santa Clara rivers and Malibu Creek, which omits the Santa Maria system and points south of Malibu Creek). Recent run sizes for the same four systems were roughly estimated to be less than 500 adults total. No time-series data were found for any populations.

Previous BRT Conclusions

The original BRT concluded that the Southern California steelhead ESU was in danger of extinction, noting that populations were extirpated from much of their historical range (Busby et al. 1996). The BRT had strong concern about widespread degradation, destruction, and blockage of freshwater habitats, and concern about stocking of rainbow trout. The two major areas of uncertainty were 1) lack of data on run sizes, past and present, and 2) the relationship between resident and anadromous forms of the species in the region. A second BRT convened for an update (NMFS 1997b) found that the small amount of new data did not suggest that the situation had improved, and the majority view was that the ESU was still in danger of extinction.

The Southern California steelhead ESU was listed as endangered in 1997. The original listing defined the ESU as having its southern geographic limits in Malibu Creek. Two small populations were subsequently discovered south of this point, and in 2002 a notice was published in the *Federal Register* (Hogarth 2002), extending the range to include all steelhead found in drainages south to the U.S. border with Mexico.

Listing status: Endangered.

New Data and Updated Analyses

There are four new significant pieces of information regarding the Southern California steelhead ESU:

1. Four years of adult counts in the Santa Clara River
2. Observed recolonizations of vacant watersheds, notably Topanga Creek in Los Angeles County and San Mateo Creek in Orange County
3. A comprehensive assessment of the current distribution of *O. mykiss* within the historical range of the ESU (Boughton and Fish 2003)
4. Changes in the harvest regulations of the sport fishery

Discussion of this new information follows.

Current Distribution versus Historical Distribution

In 2002, an extensive study was made of steelhead occurrence in most of the coastal drainages within the geographic boundaries of the Southern California steelhead ESU (Boughton and Fish 2003). Steelhead were considered to be present in a basin if adult or juvenile *O. mykiss* were observed in any stream reach that had access to the ocean (i.e., no impassable barriers between the ocean and the survey site), in any of the years 2000–2002 (i.e., within one steelhead generation). Of 46 drainages in which steelhead were known to have occurred historically, *O. mykiss* still occupied between 37% and 43%. The range in the occupancy estimate occurs because a number of basins could not be surveyed due to logistical problems, pollution, or lack of permission to survey on private land. Three basins were considered vacant because they were dry, 17 were considered vacant due to impassable barriers below all spawning habitat, and 6 were considered vacant because a snorkel survey found no evidence of *O. mykiss*. The snorkel surveys consisted of spot checks in likely habitats and did not involve a comprehensive assessment of each basin.

One of the "dry" basins—the San Diego River—may have water in some tributaries; it was difficult to establish that the entire basin below the dam was completely dry. Numerous anecdotal accounts suggest that several of the basins that had complete barriers to anadromy may have landlocked populations of native steelhead and rainbow trout in the upper tributaries. These basins include the San Diego, Otay, San Gabriel, Santa Ana, and San Luis Rey rivers. Occupancy was also determined for 17 basins with no historical record of steelhead occurrence; none was found to be currently occupied.

Nehlsen et al. (1991) listed the following southern California stocks as extinct: Gaviota Creek, Rincon Creek, Los Angeles River, San Gabriel River, Santa Ana River, San Diego River, San Luis Rey River, San Mateo Creek, Santa Margarita River, Sweetwater River, and Maria Ygnacio River. The distributional study of 2002 determined that steelhead were present in two of these systems, namely Gaviota Creek (Stoecker and CCP 2002) and San Mateo Creek (a recent colonization; see below). Nevertheless, the current distribution of steelhead among the region's basins appears to be substantially less than what occurred historically. Except for the small population in San Mateo Creek in northern San Diego County, the anadromous form of the species appears to be completely extirpated from all systems between the Santa Monica Mountains and the Mexican border. Additional years of observations, either of presence or absence, would reduce the uncertainty of this conclusion.

Recent Colonization Events

Several colonization events were reported during the interval from 1996 to 2002. Steelhead colonized Topanga Creek in 1998 and San Mateo Creek in 1997.[30] As of October 2002, both colonizations persist, although the San Mateo Creek colonization appears to be declining. T. Hovey[31] used genetic analyses to establish that the colonization in San Mateo Creek was made by two spawning pairs in 1997. In the summer of 2002 a dead mature female was found in the channelized portion of the San Gabriel River in the Los Angeles area.[32] A single live adult was found trapped and oversummering in a small watered stretch of Arroyo Sequit in the Santa Monica Mountains.[33] The run sizes of these colonization attempts are of the same order as recent run sizes in the Santa Clara system—namely, less than five adults per year. Each of the four colonization events reported above occurred in a basin in which the presence of steelhead had been documented historically (Titus et al. 2002).

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[30] Tim Hovey, California Department of Fish and Game, San Diego, CA. Pers. commun., 28 March 2003.

[31] See Footnote 30.

[32] M. Larsen, California Department of Fish and Game, Los Alamitos, CA. Pers. commun., 13 October 2002.

[33] K. Pipal and D. Boughton, Southwest Fisheries Science Center, Santa Cruz, CA. Pers. commun., 9 September 2002.

Table 58. Estimates from Busby et al. (1996) for run sizes in the major river systems of the Southern California steelhead ESU.

River basin	Run-size estimate	Year	Reference
Santa Ynez	20,000–30,000	Historical	Reavis (1991)
	12,995–25,032	1940s	Shapovalov and Taft (1954)
	20,000	Historical	Titus et al. (2002)
	20,000	1952	CDFG (1982)
Ventura	4,000–6,000	Historical	AFS (1991)
	4,000–6,000	Historical	Hunt et al. (1992)
	4,000–6,000	Historical	Henke (1994)
	4,000–6,000	Historical	Titus et al. (2002)
Matilija Creek	2,000–2,500	Historical	Clanton and Jarvis (1946)
Santa Clara	7,000–9,000	Historical	Moore (1980)
	9,000	Historical	Comstock (1992)
	9,000	Historical	Henke (1994)

Two significant analyses exist: 1) a critical review of the historical run sizes cited in the previous status review (Busby et al. 1996), and 2) a few new data on run size and population distribution in three of the larger basins.

Review of Historical Run Sizes

Few quantitative data exist on historical run sizes of southern California steelhead. Based on the available information at the time, the previous status review made rough estimates for three of the large river systems (Table 58), and a few of the smaller ones (Busby et al. 1996).

The Santa Ynez River

The run size in the Santa Ynez system—probably the largest run historically—was estimated to originally lie between 20,000 and 30,000 spawners (Busby et al. 1996). This estimate was based primarily on four references cited in the status review: Reavis (1991), 20,000–30,000 spawners; Titus et al. (2002), 20,000 spawners; Shapovalov and Taft (1954), 12,995–25,032 spawners; and CDFG (1982), 20,000 spawners. Examination of these references revealed the following: Reavis (1991) asserted a run size of 20,000–30,000, but provided no supporting evidence. Titus et al. (2002) reviewed evidence described by Shapovalov (1944), described below. Shapovalov and Taft (1954) did not address run sizes in this geographic region; the citation is probably a miscitation for Shapovalov (1944). CDFG (1982) makes no reference to salmonid fishes in southern California.

Entrix Environmental Consultants (1995) argued that the estimate of 20,000–30,000 is too large. They argued that the only direct observations of run size are from Shapovalov (1944), an assertion that appears to be correct. These data are based on a CDFG employee's visual estimate that the 1944 run was "at least as large" as runs in the Eel River (northern California), which the employee had observed in previous years. Estimated run sizes for the Eel River ranged between 12,995 and 25,032 during the years 1939 to 1944 (Shapovalov 1944), and this has thus been reported as the estimated run size of the Santa Ynez. Entrix (1995) observed, however, that the employee who made the comparison was only present at the Eel River during two seasons, 1938–1939 and 1939–1940. The estimates for run sizes in those years were 12,995 and 14,476, respectively, which suggests that a more realistic estimate for the Santa Ynez run of 1944 would be 13,000–14,500. Taking this chain of reasoning to its logical conclusion, the range 13,000–14,500 should be regarded as a minimum run size for the year in question, since the employee used the phrase "at least as large."

It is perhaps useful to place the year 1944 in context, since expert opinion about run size is based solely on observations made in that year. Entrix (1995) reports that 1944 occurred toward the end of a wet period, which may have provided especially favorable spawning and rearing conditions for steelhead. Rainfall data from Santa Barbara County historical records give a different picture from Entrix (1995): only 2 of the preceding 8 years (1940 and 1943) were wetter than the 107-year average for the area,[34] 1944 was near average; and otherwise, rainfall was below average.

In addition, 1944 occurred toward the end of a period in which it seems extensive rescues of juvenile steelhead were made during low-flow years (Shapovalov 1944, Titus et al. 2002). Over the interval 1939–1946, a total of 4.3 million juveniles were rescued from drying portions of the main stem, and they were usually replanted elsewhere in the system. This process averages to about 61,400 juveniles rescued per year. Assuming that rescue operations lowered the mean mortality rate, as intended, during the 1939–1946 interval, the Santa Ynez population may have increased somewhat (or failed to undergo a decline) due to the rescue operations. A rough estimate of magnitude can be made: Assuming deterministic population growth (as opposed to stochastic), and a survival to spawning of about 1%, the rescues would have increased the run size by about 4% per generation. High environmental stochasticity in survival of the rescued fish and in the overall population growth—which almost certainly was the case—would have reduced the size to much lower than 4%.

The counterargument to the argument that the 1944 estimate is too high is that it is too low. The estimate was not made until 24 years after a significant proportion of spawning and rearing habitat had been blocked behind dams. The Santa Ynez system currently has three major mainstem dams, which block portions of spawning and rearing habitat. The middle dam (Gibraltar), built in 1920, blocked access to 721 km of stream, much of which was widely regarded to be high-quality spawning and rearing habitat (Appendix B, Table B-1; Titus et al. 2002). At that time, no estimates of run size had been made for the Santa Ynez. An upper dam (Juncal) was constructed in 1930 and may have had a negative effect on run size through reduction of flows to the lower main stem. Only the lower dam (Cachuma or Bradbury) was built late enough (1953) to not cause the 1944 estimate to be a biased estimate of historical run size.

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[34] M. Capelli, Southwest Regional Office, Santa Barbara, CA. Pers. commun., 29 May 2003.

Ventura River

According to Titus et al. (2002), the Ventura River was estimated to have a run size of 4,000–5,000 adults during a normal water year. This estimate was made in 1946, although it is likely that the estimate is an expert opinion based on numerous years of observation. The system had received numerous plantings of juveniles in the preceding period (27,200 in 1943, 20,800 in 1944, and 45,440 in 1945, as well as 40,000 in 1930, 34,000 in 1931, and 15,000 in 1938). These rescues probably had small effect, for reasons similar to those cited above for the Santa Ynez. As in the Santa Ynez, anecdotal accounts suggest that run sizes declined precipitously during the late 1940s and 1950s, due possibly to both drought and to anthropogenic changes to the river system such as dam construction. Similar considerations apply to the estimate made by Clanton and Jarvis (1946), of 2,000–2,500 adults in the Matilija Basin, a major tributary of the Ventura River.

Santa Clara River

Moore's (1980) estimate of 9,000 spawners in the Santa Clara Basin is an extrapolation of the estimate of Clanton and Jarvis's (1946) estimate for Matilija Creek. Moore assumed similar levels of production per stream mile in the two systems, and noted that at least five times more spawning and rearing habitat exists in the Santa Clara. Moore (1980) regarded his estimate as biased downward because, although it included the major spawning areas (Santa Paula, Sespe, and Piru creeks), it omitted numerous small side tributaries.

Ed Henke (cited in NMFS 1997b, p. 9) stated that abundance of steelhead in the Southern California steelhead ESU was probably about 250,000 adults prior to European settlement of the region. His argument is based on historical methods of research involving interviews of older residents of the area as well as written records. The original analysis producing the cited estimate is part of ongoing research and was not made available for review at the time of this writing.[35]

In summary, the estimates of historical run sizes for the Southern California steelhead ESU are based on very sparse data and long chains of assumptions that are plausible but have not been adequately tested. It seems reasonable to say that the existing estimates are biased upward or downward by some unknown amount. It is certainly clear from the historical record that adult run sizes of the past could be two or three orders of magnitude greater in size than those of recent years, but the long-term mean or variance in run size is not known with any reasonable precision. Assuming that spawning and rearing success are related to rainfall, the variance between years was likely high due to climatic variability in southern California; and variance among decades high due to the Pacific Decadal Oscillation. In addition, long-term climate change in the region likely causes the running mean of run size (whatever it may be) to exhibit drift over time. If one were interested in the true potential productivity of these systems, much could be learned by targeted field studies on the current habitat-productivity relationships for the fish, and by studies

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[35] E. Henke, Historical Research, Ashland, OR. Pers. commun., 28 January 2003.

of the influence of climate, water management practices, and their interaction. It does not seem likely that further historical research will turn up information useful for making more refined estimates, despite the fact that it is useful for determining where exactly the fish occurred.

Recent Run Sizes of Large River Systems

It seems likely that the larger river systems were originally the mainstay of the Southern California steelhead ESU. Large river systems that harbored steelhead populations in the past are (from north to south) the Santa Maria, Santa Ynez, Ventura, Santa Clara, Los Angeles, San Gabriel, Santa Ana, and possibly the San Diego. Of these eight systems, the data suggest that steelhead currently occur in only four—the Santa Maria, Santa Ynez, Ventura, and Santa Clara.

Santa Maria River

There do not appear to be any estimates for recent run sizes in the Santa Maria system. Twitchell Dam blocks access to a significant proportion of historical spawning habitat, the Cuyama River, one of the two major branches of the Santa Maria. The other major branch, the Sisquoc River, appears to still have substantial spawning and rearing habitat that is accessible from the ocean; juvenile steelhead have recently been observed in these areas (Cardenas 1996, Stoecker and Stoecker 2003).

Santa Ynez River

Most of the historical spawning habitat is blocked by Cachuma and Gibraltar dams. However, extensive documentation exists for steelhead and rainbow trout populations in a number of ocean-accessible sites below Cachuma Dam (Table 59): Salsipuedes/El Jaro, Hilton, Alisal, Quiota, San Miguelito creeks, and three reaches in the main stem (Hanson et al. 1996 and Engblom 1997, 1999, 2001). Various life stages of steelhead, including upstream migrants and smolts, have been consistently observed at some of these sites (Table 59), suggesting the occurrence of persistent populations. Run sizes are unknown, but likely small (<100 adults total), implying the populations are not viable over the long term. A third dam, Juncal Dam, occurs above the other two dams in the watershed, and is reported to support a small population of landlocked steelhead that annually enter the reservoirs' tributaries to spawn.[36]

Ventura River

There are no estimates of recent run sizes in the Ventura River. Casitas Dam on Coyote Creek and Matilija Dam on Matilija Creek block access to significant portions of the historical spawning habitat. There are recent individual reports of sightings of steelhead in the Ventura River and San Antonio Creek (Capelli 1997), but no quantitative estimates.

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[36] See Footnote 34.

Table 59. Presence of steelhead in the lower Santa Ynez River system.

Tributary	Redds	<6”	>6”	Smolts	Adults	Year (spring)	Source
Salsipuedes/	–	Y	Y	Y	Y[a]	1994	Hanson et al. (1996)
El Jaro	–	–	–	Y	Y[a]	1995	Hanson et al. (1996)
	Y	Y	Y	Y	Y[a]	1996	Hanson et al. (1996), Engblom (1997)
	Y	Y	Y	Y	Y[a]	1997	Engblom (1997)
	Y	Y	Y	–	Y[a]	1998	Engblom (1999)
	Y	Y	Y	–	Y[a]	1999	Engblom (1999)
	–	–	–	–	Y[a]	2000	Engblom (2001)
	–	Y	Y	Y	Y[a]	2001	Engblom (2001)
Hilton Creek	–	N	N	–	Y[a]	1994	Hanson et al. (1996)
	–	Y	Y[b]	Y	Y[a]	1995	Hanson et al. (1996)
	–	–	–	N	Y[a]	1996	Hanson et al. (1996), Engblom (1997)
	N	Y	Y	N	Y[a]	1997	Engblom (1997)
	Y	Y	–	–	Y[a]	1998	Engblom (1999)
	–	–	–	–	N[a]	1999	Engblom (1999)
	–	Y	Y	–	Y[a]	2001	Engblom (2001)
Alisal Creek	–	Y	Y	–	Y[a]	1995	Hanson et al. (1996)
Nojoqui	–	N	N	–	N[a]	1994	Hanson et al. (1996)
Creek	–	–	–	N	N[a]	1995	Hanson et al. (1996)
	–	–	–	N	–	1997	Engblom (1997)
	–	N	Y	–	Y[a]	1998	Engblom (1999)
	–	–	–	–	N[a]	1999	Engblom (1999)
Quiota Creek	Y	–	Y	–	N[a]	1995	Hanson et al. (1996)
(and	–	Y	Y	–	–	1994	Hanson et al. (1996)
tributaries)	–	Y	–	–	–	1998	Engblom (1999)
	–	Y	Y	–	–	2001	Engblom (2001)
San	–	Y	Y	–	–	1996	Hanson et al. (1996)
Miguelito	Y	–	–	Y	–	1997	Engblom (1997)
Creek	–	Y	–	N	N[a]	1998	Engblom (1999)
	Y	–	–	N	N[a]	1999	Engblom (1999)
Main stem/	–	Y	Y	–	–	1995	Hanson et al. (1996)
Hwy 154	–	Y	Y	–	–	1996	Hanson et al. (1996)
	–	–	–	–	Y	1994	Hanson et al. (1996)
	–	Y	Y	–	–	1998	Engblom (1999)
	Y	–	–	–	–	1999	Engblom (1999)
	–	Y	Y	–	–	2001	Engblom (2001)
Main stem/	–	Y	Y	–	–	1995	Hanson et al. (1996)
Refugio	–	N	Y	–	–	1996	Hanson et al. (1996)
	–	Y	Y	–	–	1998	Engblom (1999)
	Y	N	Y	–	–	1999	Engblom (1999)
	–	Y	Y	–	–	2001	Engblom (2001)
Main stem/	–	Y	Y	–	–	1995	Hanson et al. (1996)
Alisal reach	–	N	Y	–	–	1996	Hanson et al. (1996)
	–	Y	Y	–	–	1998	Engblom (1999)
	–	Y	Y	–	–	1999	Engblom (1999)
	–	Y	Y	–	–	2001	Engblom (2001)
Main stem/	–	N	N	–	–	1995	Hanson et al. (1996)
Cargasachi	–	N	N	–	–	1996	Hanson et al. (1996)

[a] Caught in upstream migrant trap.

[b] Actual lengths 5″ < x < 6″ but assumed to be 1+ fish.

Santa Clara River

A few estimates of recent run sizes exist for the Santa Clara system, due to the presence of a fish ladder and counting trap at the Vern Freeman Diversion Dam on the main stem. This diversion dam lies between the ocean and what is widely believed to be one of the largest extant populations of steelhead in the Southern California steelhead ESU (the Sespe Canyon population). The run size of upstream migrants in each was one adult in 1994 and 1995, two adults in 1996, and no adults in 1997. No data have been collected since that date, and the fish ladder is thought to be dysfunctional.

Harvest Impacts

Since the original status review of Busby et al. (1996), regulations concerning sport fishing have been changed in a way that may potentially reduce extinction risk for the Southern California steelhead ESU.

The CDFG currently prohibits sport harvest of steelhead in the ocean (CDFG 2002a), and ocean harvest is a rare event.[37] For freshwaters (CDFG 2002b), summer/fall catch-and-release angling is allowed in Piru Creek below the dam, San Juan Creek (Orange County), San Mateo Creek (one section), Santa Margarita River and tributaries, and Topanga Creek. Year-round catch and release is allowed in the San Gabriel River (below Cogswell Dam) and Sespe Creek and tributaries. All of the above are historical steelhead streams, and many of the stretches open to fishing are potentially used both by anadromous runs and resident populations.

Year-round trout fisheries are allowed in Calleguas Creek and tributaries (limit 5), Piru Creek above the dam (limit 2), San Luis Rey River (limit 5), Santa Paula Creek above the falls (limit 5), the Santa Ynez River above Gibraltar Dam (limit 2), Sisquoc River (limit 5), and Sweetwater River (limit 5). With the exception of the Sisquoc River, these take-fisheries appear to be isolated from the ocean by natural or man-made barriers. Except for Calleguas Creek and possibly the Sweetwater, the above drainages are listed as historical steelhead streams by Titus et al. (2002). It is certainly possible, and indeed likely, that some currently harbor native trout with the potential to exhibit anadromy.

At catch-and-release streams, all wild steelhead must be released unharmed. There are significant restrictions on gear used for angling. The CDFG monitors angling effort and catch-per-unit effort in selected basins by way of a “report card” system in which sport anglers self-report their catch, gear used, and so forth, and in selected other basins by way of creel censuses.

Although the closure of many areas and institution of catch-and-release elsewhere is expected to reduce extinction risk for the ESU, this risk reduction cannot be estimated quantitatively from the existing data sets (due to the fact that natural abundance is not being estimated). After the federal listing decisions, NMFS requested that CDFG prepare a Fishery Management and Evaluation Plan (FMEP) for the listed steelhead ESUs in California. This plan

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[37] See Footnote 25.

has not yet been done for the Southern California steelhead ESU, so the rationale for the set of regulations summarized above is not transparent.

Resident *O. mykiss* Considerations

Resident (nonanadromous) populations of *O. mykiss* were assigned to one of three categories for the purpose of provisionally determining ESU membership (see subsection, Resident Fish, in Section 1 for a description of the three categories and default assumptions about ESU membership). The third category consists of resident populations that are separated from anadromous conspecifics by recent man-made barriers such as dams without fish ladders. No default assumption about ESU membership was possible for case 3 populations, so here they are considered case by case according to available information.

As of this writing we have few data on occurrence of resident populations and even fewer on genetic relationships. A provisional survey of the occurrence of case 3 populations in the ESU (see Appendix B, Table B-1) revealed the following: Numerous case 3 populations occur within the original geographic range of the Southern California steelhead ESU. All of the larger watersheds originally inhabited by the ESU now have major barriers completely blocking substantial portions of habitat (Table B-1; a major barrier is defined as a complete barrier to migration that has greater than 260 sq. km of watershed area lying above it). In the watershed of the Santa Maria River, 71% of total stream kilometers are above Twitchell Dam. The Santa Clara watershed has 99% of stream kilometers above Vern Freeman diversion dam. This facility has a fish ladder, but the ladder is currently dysfunctional due to channel migration, which has disconnected the ladder intake from the river's thalweg, combined with deficient quantities and configurations of water releases through the facility.[38] The Santa Ynez watershed, which probably originally harbored the strongest run of steelhead in the Southern California steelhead ESU, has 58% of its stream kilometers above Cachuma Dam. In each case the historical record has reports of steelhead ascending to and spawning in areas that are now blocked behind the above-mentioned dams (Titus et al. 2002). In the case of the Santa Ynez, adult *O. mykiss* have been observed to make "steelhead-like" runs from the uppermost reservoir (behind Juncal Dam) into the North Fork Juncal and the upper Santa Ynez for at least the past 7 years.[39]

All the large watersheds farther south have major barriers blocking substantial portions of stream habitat. Consequently, in the set of major watersheds originally inhabited by the ESU, at least 48% of stream kilometers are now behind barriers impassable to anadromous fish (the value is probably somewhat higher due to minor barriers not considered in Appendix B, Table B-1). At least 11 of these 15 major watersheds are known to have resident populations above the barriers (Table B-1).

We do not know much about the genetic relationships of these resident populations. One study of genetic relationships among hatchery stocks, anadromous fish, and resident populations above barriers (Nielsen 2003) used selectively neutral genetic markers to assess genetic distances among the various categories of fish (anadromous, residualized, hatchery, etc.), but the results were inconclusive. However, according to the provisional survey described in Appendix B,

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[38] M. Whitman, California Department of Fish and Game, Sacramento, CA 95814. Pers. commun., 29 May 2003.

[39] M. Capelli, Southwest Regional Office, Santa Barbara, CA 93101. Pers. commun., 21 May 2003.

Table B-1, at least 7 of the 11 watersheds with resident populations above major barriers are currently stocked with hatchery fish. It is not clear whether the stocked fish have successfully interbred with native fish, whether such interbreeding would have led to significant gene flow between the introduced and native fish, or to what extent local adaptations of the native fish would have been maintained by selection even if gene flow occurred.

24. California Central Valley Steelhead ESU

Summary of Previous BRT Conclusions

Major Risk Factors and Status Indicators

Steelhead were once widespread throughout the Central Valley (CACSS 1988, Reynolds et al. 1993). Steelhead require cool water in which to oversummer, and much of this habitat is now above impassable dams. Where steelhead are still extant, natural populations are subject to habitat degradation, including various effects of water development and land use practices. The BRT's concerns include extirpation from most of the historical range, a monotonic decline in the single available time series of abundance (Table 60, Figure 190), declining proportion of wild fish in spawning runs, substantial opportunity for deleterious interactions with hatchery fish (including out-of-basin-origin stocks), various habitat problems, and lack of ongoing population assessments. Compared to most Chinook salmon populations in the Central Valley, steelhead spawning above Red Bluff Diversion Dam (RBDD) had a fairly strong negative population growth rate and small population size at the time of last census (1993) (Figure 191).

Previous BRT Conclusions

The BRT previously concluded that the California Central Valley steelhead ESU was in danger of extinction (Busby et al. 1996), and this opinion did not change in two status review updates (NMFS 1997b, 1998b). The Nimbus Hatchery and Mokelumne River Hatchery

Table 60. Summary statistics for California Central Valley steelhead ESU trend analyses (are 90% confidence intervals in parentheses).

Population[a]	**5-year mean**[b]	**5-year min.**	**5-year max.**	**λ**	**μ**	**Long-term trend**	**Short-term trend**
Sacramento River steelhead	1,952	1,425	12,320	0.95 (0.90, 1.02)	–0.07 (–0.13, 0.00)	–0.09 (–0.13, –0.06)	NA
Sacramento River winter-run Chinook	2,191	364	65,683	0.97 (0.87, 1.09)	–0.10 (–0.21, 0.01)	–0.14 (–0.19, –0.09)	0.26 (0.04, 0.48)
Butte Creek spring-run Chinook	4,513	67	4,513	1.30 (1.09, 1.60)	0.11 (–0.05, 0.28)	0.11 (0.03, 0.19)	0.36 (0.03, 0.70)
Deer Creek spring-run Chinook	1,076	243	1,076	1.17 (1.04, 1.35)	0.12 (–0.02, 0.25)	0.11 (0.02, 0.21)	0.16 (–0.01, 0.33)
Mill Creek spring-run Chinook	491	203	491	1.19 (1.00, 1.47)	0.09 (–0.07, 0.26)	0.06 (–0.04, 0.16)	0.13 (–0.07, 0.34)

[a] Threatened and endangered Chinook salmon populations are shown for comparison.

[b] Note that for steelhead, the 5-year geometric mean refers to the period ending in 1993. There is insufficient recent data to calculate a short-term trend in abundance.

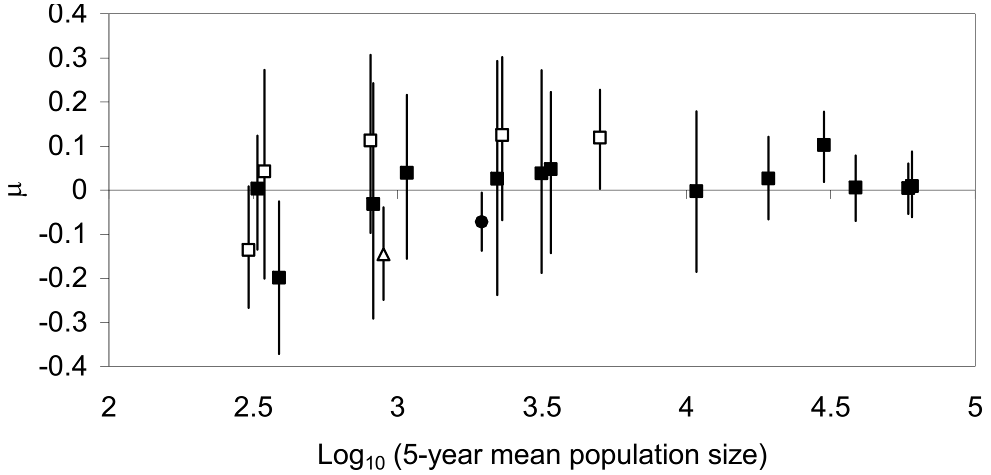

Figure 190. Abundance and growth rate of Central Valley salmonid populations. ● = steelhead (above Red Bluff Diversion Dam); □ = spring-run Chinook; △ = winter-run Chinook; ■ = other Chinook stocks (mostly fall runs). Error bars represent central 0.90 probability intervals for μ estimates. Note: as defined in other sections of the status reviews, μ ≈ log (λ).

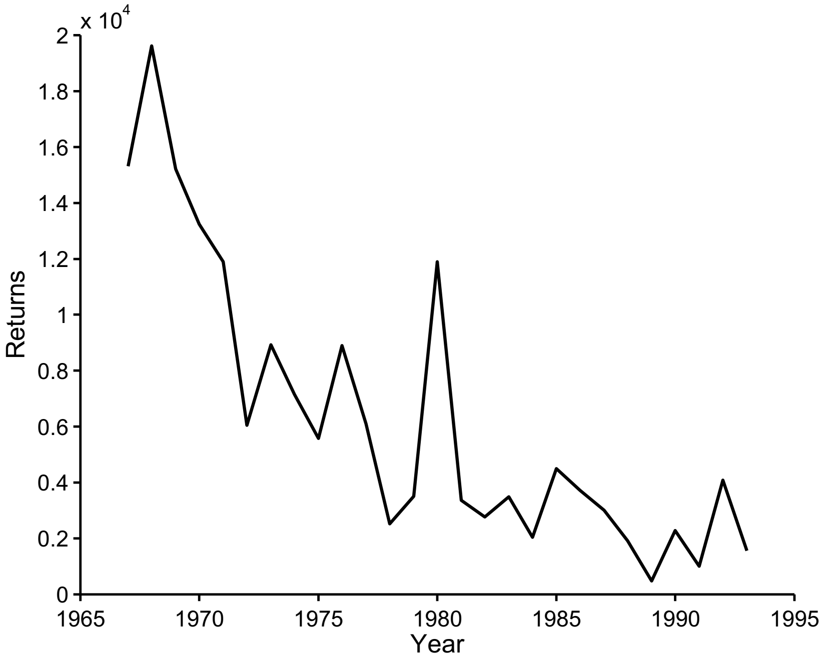

Figure 191. Returns of steelhead passing the Red Bluff Diversion Dam fish ladders, 1966–1994. These fish include hatchery fish from Coleman National Fish Hatchery.

steelhead stocks were excluded from the California Central Valley steelhead ESU (NMFS 1998c).

Listing status: Threatened.

New Data and Updated Analyses

Historical Distribution and Abundance

McEwan (2001a) reviewed the status of Central Valley steelhead. Steelhead probably occurred from the McCloud River and other northern tributaries to Tulare Lake and the Kings River in the southern San Joaquin Valley. McEwan also guessed that more than 95% of historical spawning habitat is now inaccessible. He did not hazard a guess about current abundance. He guessed, on the basis of the fairly uncertain historical abundance estimates of Central Valley Chinook salmon reported by Yoshiyama et al. (1998), that between 1 million and 2 million steelhead may have once spawned in the Central Valley. McEwan's estimate is based on the observation that, presently, steelhead are found in almost all systems where spring-run Chinook salmon occur and can use elevations and gradients even more extreme than those spring-run Chinook use, as well as mid-elevation areas not used by spring-run Chinook. Steelhead should therefore have had more freshwater habitat than spring-run Chinook, and the sizes of steelhead populations should therefore have been roughly comparable those of spring-run Chinook.

Current Abundance

One source of new abundance information since the last status review comes from midwater trawling below the confluence of the Sacramento and San Joaquin Rivers at Chipps Island. This trawling targets juvenile Chinook salmon; catches of steelhead are incidental. In a trawling season, over 2,000 20-minute tows are made. Trawling occurred from the beginning of August through the end of June in 1997–1998 and 1998–1999, after which trawling has occurred year round. Usually, 10 tows are made per day, and trawling occurs several days per week.

Since the 1998 broodyear, all hatchery steelhead have been ad-clipped. Trawl catches of steelhead provide an estimate of the proportion of wild to hatchery fish, which, combined with estimates of basinwide hatchery releases, provide an estimator for wild steelhead production:

$$N_w = \frac{C_w}{C_h} N_h \tag{24}$$

where N_w is the number of wild steelhead, C_w and C_h are the total catches of wild and hatchery steelhead, and N_h is the number of hatchery fish released. The accuracy of the estimate depends on the assumption that hatchery and natural steelhead are equally vulnerable to the trawl gear. In particular, if hatchery fish are more vulnerable to the gear, natural production is underestimated.

Table 61. Estimated natural production of steelhead juveniles from the Central Valley.

				Wild female spawners		
Year	**C_w/C_h**[a]	**N_r (millions)**[b]	**N_w (thousands)**[c]	**ESS[d] = 1%**	**ESS[d] = 5%**	**ESS[d] = 10%**
1998	0.300	1.12	336	6,720	1,344	672
1999	0.062	1.51	94	1,872	374	187
2000	0.083	1.38	115	2,291	458	229
Average	0.148	1.34	181	3,628	726	363

[a] C_w/C_h = ratio of unclipped to clipped steelhead.
[b] N_r = total hatchery releases.
[c] N_w = estimated natural production.
[d] ESS = egg-to-smolt survival.

Catches of steelhead are sporadic—most sets catch no steelhead, but a few sets catch up to four steelhead. To estimate the mean and variance of C_w/C_h, the trawl data sets were resampled with replacement 1,000 times. The mean C_w/C_h ranged from 0.06 to 0.30, and coefficients of variation ranged from 16% to 37% of the means.

From such calculations, it appears that about 100,000–300,000 steelhead juveniles (roughly, smolts) are produced naturally each year in the Central Valley (Table 61). If we make the fairly generous assumptions (in the sense of generating large estimates of spawners) that average fecundity is 5,000 eggs per female, 1% of eggs survive to reach Chipps Island, and 181,000 smolts are produced (the 1998–2000 average); about 3,628 female steelhead spawn naturally in the entire Central Valley. This can be compared with McEwan's (2001a) estimate of 1 million to 2 million spawners before 1850 and 40,000 spawners in the 1960s. Table 61 shows the effects of different assumptions about survival on estimates of female spawner abundance.

Another source of information comes from screw trap operations at Knights Landing on the lower Sacramento River, just above the confluence with the Feather River (Snider and Titus 2000a, 2000b, 2000c). Over the period 1995–1999, estimates of the natural production for the areas above Knights Landing averaged 9,800 yearling steelhead outmigrants (a range of 7,260–11,700). This level of production is about 5% of the total production as estimated above, and may be a substantial underestimate due to the application of trap efficiency estimates generated from recaptures of marked Chinook juveniles, which probably are less able to avoid traps.

Nobriga and Cadrett (2001) analyzed captures of steelhead in trawls at Chipps Island and in fish salvage facilities associated with water diversions in the southern delta. They computed average daily catch of hatchery and wild steelhead per unit effort and used these numbers to estimate the percentage of hatchery fish. They found that hatchery steelhead comprised 63–77% of the trawl catch of steelhead at Chipps Island (compared to 77–92% estimated from the resampling method described above) and generally lower percentages in the south delta, which is not surprising because the bulk of hatchery production comes out of the Sacramento River basin. This alternative analysis of the Chipps Island trawl data suggests that wild steelhead are roughly threefold more abundant than the resampling analysis discussed above.

Current Distribution

Recent spawner surveys of small Sacramento River tributaries (Mill, Deer, Antelope, Clear, and Beegum creeks; Moore 2001) and incidental captures of juvenile steelhead during Chinook salmon monitoring (Calaveras, Cosumnes, Stanislaus, Tuolumne, and Merced rivers) confirmed that steelhead are widespread, if not abundant, throughout accessible streams and rivers. McEwan (2001a) reviews much of this information. Figure 192 cartographically summarizes the information on steelhead distribution in Central Valley streams; details are listed in Table 62.

CDFG (2003a) reported trawl captures of *O. mykiss* at Mossdale on the lower San Joaquin River (below the confluence of the Tuolumne, Stanislaus, and Merced rivers). Because the Mossdale area is not suitable habitat for resident *O. mykiss*, these fish are assumed to be steelhead smolts. Between 2 and 30 fish per year were captured from 1988 to 2002. Rotary screw trap data suggests that the bulk of this production comes from the Stanislaus River, although some smolts were captured in the Merced and Tuolumne rivers as well.

Resident *O. mykiss* Considerations

Coastal *O. mykiss* is widely distributed in the Central Valley Basin. Roughly half of the trout habitat (by area) in the Central Valley is above dams that are impassable to fish; higher elevation habitats appear to support quite high densities of trout, ranging from a few hundred to a few thousand 4″–6″ fish per kilometer (see Appendix B, Table B-2).

Several areas of substantial uncertainty make interpreting this information difficult. First, it is not clear how anadromous and nonanadromous coastal *O. mykiss* interacted in the Central Valley before the dam-building era. In other systems, anadromous and nonanadromous *O. mykiss* forms can exist within populations, while in other systems these groups can be reproductively isolated despite nearly sympatric distributions within rivers (Zimmerman and Reeves 2000). Second, hatchery produced *O. mykiss* have been widely stocked throughout the Central Valley, Sierra Nevada, and southern Cascades. It is possible that this stocking has had deleterious effects on native wild trout populations, although limited information indicates that native trout populations remain in some areas that have received stocked fish (Nielsen et al. 2000).

We suspect that some coastal *O. mykiss* populations that are above man-made barriers could be part of the California Central Valley steelhead ESU, because these populations were probably exhibiting some degree of anadromy and interacting with each other on evolutionary time scales prior to barrier construction. Due to a lack of data, we cannot, however, identify any particular resident populations as part of the California Central Valley steelhead ESU.

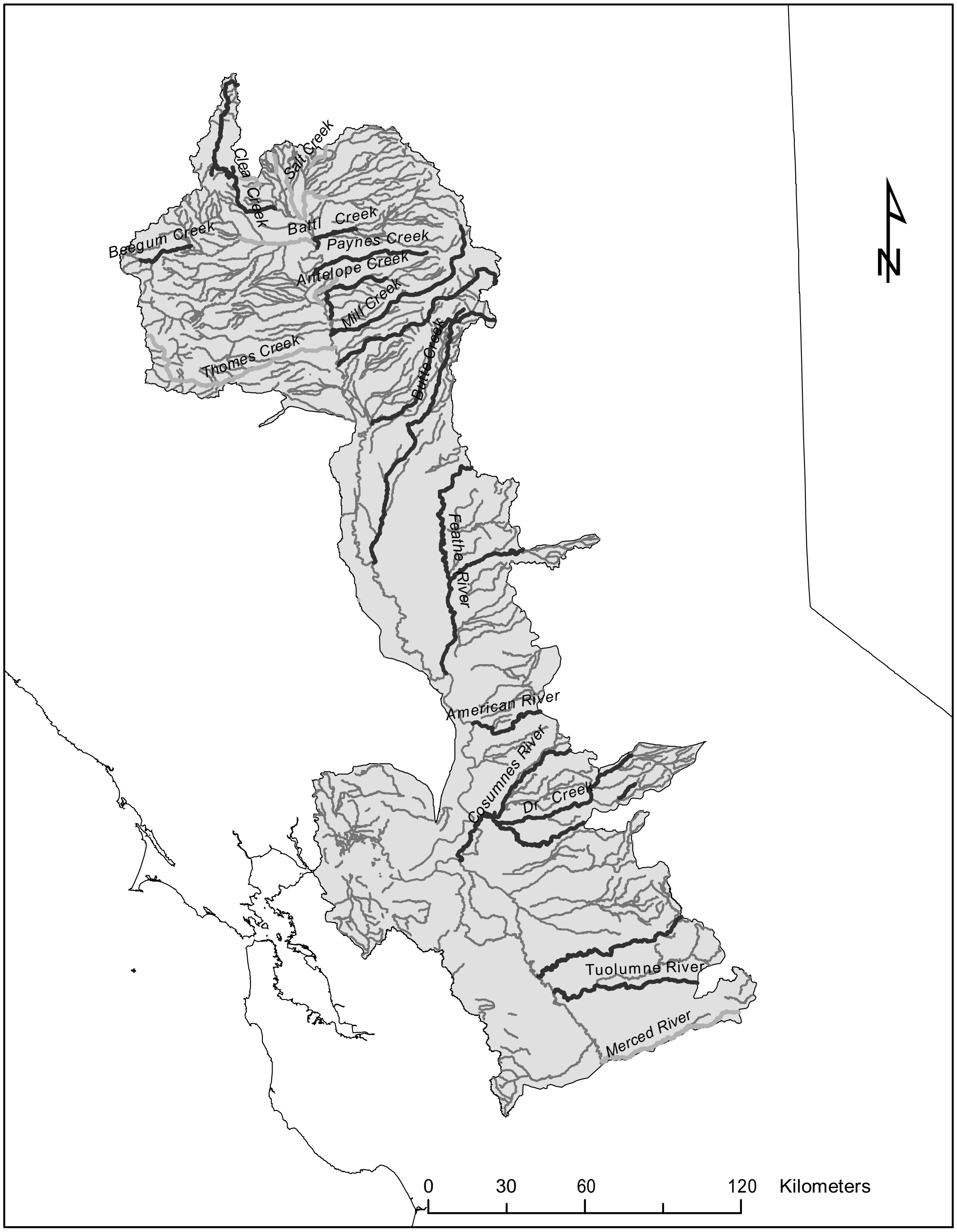

Figure 192. Central Valley tributaries known (dark gray lines) or suspected (medium gray lines) to be used by steelhead adults. Source: Kerrie Pipal (National Marine Fisheries Service, Santa Cruz Laboratory) assembled this information from agency and consultant reports and discussions with California Department of Fish and Game field biologists.

Table 62. Summary of distribution information for steelhead in the California Central Valley steelhead ESU.

System /tributary	Current presence	Most recent documented date of presence	Count/ life stage	Comments	Source
Sacramento River					
Clear Creek	Yes	2001	Adults/ juveniles	Snorkel surveys and redd counts, rotary screw traps	J. Newton[a]
Rock Creek	Probable	2001	Adults/ juveniles	Creek used for spawning	M. Berry[b]
Salt Creek	Probable	2001	Adults/ juveniles	Possible spawning; non-natal rearing	M. Berry[b]
Sulphur Creek	Probable	2001	Adults/ juveniles	Creek used for spawning	M. Berry[b]
Olney Creek	Probable	2001	Adults/ juveniles	Spawning, nonnatal rearing	M. Berry[b]
Stillwater Creek	Probable	–	–	Nonnatal rearing	M. Berry[b] ; Maslin et al. (1998)
Cow Creek + tributaries	Probable	1992	–	Suitable habitat, access problems	CDFG (1993)
Cottonwood Creek	Probable	–	–		CDFG (1993)
Beegum Creek	Yes	2001	Adults		Moore (2001)
South Fork Cottonwood Creek	Possible	–	–	Large populations of “rainbow trout”	M. Berry[b]
Bear Creek	Possible	–	–		CDFG (1993)
Battle Creek	Yes	2002	–		Kier & Associates (2001); J. Newton[a]
Paynes Creek	Yes	2002	Adults	Self-sustaining population unlikely	M. Berry[b]
Antelope Creek	Yes	2001	Adults + redds		Moore (2001)
Mill Creek	Yes	2001	Adults + redds	Small numbers counted.	Moore (2001)
Elder Creek	Possible	No recent surveys	–	Resident trout present	CDFG (1993)
Thomes Creek	Probable	1969 and 2002	–	Used by Chinook salmon, “trout” observed	Puckett (1969), Killam (2002), M. Berry[b]

Table 62 continued. Summary of distribution information for steelhead in the California Central Valley steelhead ESU.

System /tributary	**Current presence**	**Most recent documented date of presence**	**Count/ life stage**	**Comments**	**Source**
Deer Creek	Yes	2001	Adults + redds		Moore (2001)
Rice Creek	Yes	1998	Juveniles		Maslin et al. (1998)
Big Chico Creek	Yes	–	–		CDFG (1993)
Butte Creek	Yes	2000	–	Report confirms steelhead presence, no details	USFWS (2000)
Feather River	Yes	1998	Young of year + Juveniles	Screw trap captures	CDWR (1999)
Yuba River	Yes	1998	–	Report confirms steelhead presence, no details	IEP (1998)
Deer Creek (Yuba tributary)	Yes	1993	Adults	Dive survey	StreamNet (http://www.streamnet.org)
Dry Creek	Yes	–	–	Secret and Miners Ravines	CDWR (2002)
American River	Yes	2002	Adults + redds	Counted redds, estimated number of adults based on redd counts	Hannon and Healey (2002)
Putah Creek	Yes	2000	–	Very small numbers of adult steelhead make their way to the base of Monticello Dam	Moore (2001)
San Joaquin River					
Cosumnes River	Yes	1995	–	Smolts salvaged from drying pools	Nobriga (1995)
Mokelumne River	Yes	2001	Adults + juveniles		Workman (2001)
Calaveras River	Yes	2001	Adults + juveniles	Several reports list presence, but do not give any details; angler reports/photos.	G. Castillo[c]
Stanislaus River	Yes	2001	Young of year and age-1+		Kennedy (2002)
Tuolumne River	Yes	2001	Juveniles	Incidental rotary screw trap captures	J. Newton[a]
Merced River	Possible	2002	Juveniles	Incidental rotary screw trap captures, large trout caught by anglers, enter hatchery	D. Vogel[d] and M. Cozart[e]

Table 62 continued. Summary of distribution information for steelhead in the California Central Valley steelhead ESU.

[a] J. Newton, USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, CA. Pers. commun., 27August 2002.

[b] M. Berry, California Department of Fish and Game, Redding, CA. Pers. commun., 8 October 2002.

[c] G. Castillo, USFWS, Stockton, CA. Pers. commun., 3 Mar 2004.

[d] D. Vogel, NRC, Red Bluff, CA. Pers. commun., 7 June 2002.

[e] M. Cozart, Merced River Hatchery, Snelling, CA. Pers. commun., 5 September 2002.

Harvest Impacts

Steelhead are caught in freshwater recreational fisheries, and CDFG estimates the number of fish caught. Because the sizes of Central Valley steelhead populations are unknown, however, the impact of these fisheries is unknown. According to a CDFG creel census, the great majority (93%) of steelhead catches occur on the American and Feather rivers, sites of steelhead hatcheries (CDFG 2001d). In 2000, 1,800 steelhead were retained, and 14,300 were caught and released. The total number of steelhead contacted might be a significant fraction of basinwide escapement, so even low catch-and-release mortality may pose a problem for wild populations. Additionally, steelhead trout fisheries on some tributaries and the mainstem Sacramento River may affect some steelhead juveniles.

The State of California's proposed Fishery Management and Evaluation Plan (part of the requirements to obtain ESA coverage for in-river sport fisheries) was recently rejected by NOAA Fisheries, mostly because of the inadequacy of existing and proposed monitoring of fisheries impacts.

New Hatchery Information

There is little new information pertaining to hatchery stocks of steelhead in the Central Valley. Figures 193 and 194 show the releases and returns of steelhead to and from Central Valley hatcheries. As discussed in the subsection, Current Abundance, hatchery steelhead juveniles dominate catches in the Chipps Island trawl, suggesting that hatchery production is large relative to natural production. Note that Mokelumne River Hatchery and Nimbus Hatchery stocks are not part of the California Central Valley steelhead ESU due to broodstock source and genetic, behavioral, and morphological similarity to Eel River stocks. Categorization of Central Valley steelhead hatchery stocks (SSHAG 2003) can be found in Appendix B, Table B-3.

Comparison with Previous Data

The few new pieces of information do not indicate a dramatic change in the status of the California Central Valley steelhead ESU. The Chipps Island trawl data suggest that the population decline evident in the Red Bluff Diversion Dam counts, and the previously noted decline in the proportion of wild fish, is continuing. The fundamental habitat problems are little changed, with the exception of some significant restoration actions on Butte Creek. There is still a nearly complete lack of steelhead monitoring in the Central Valley.

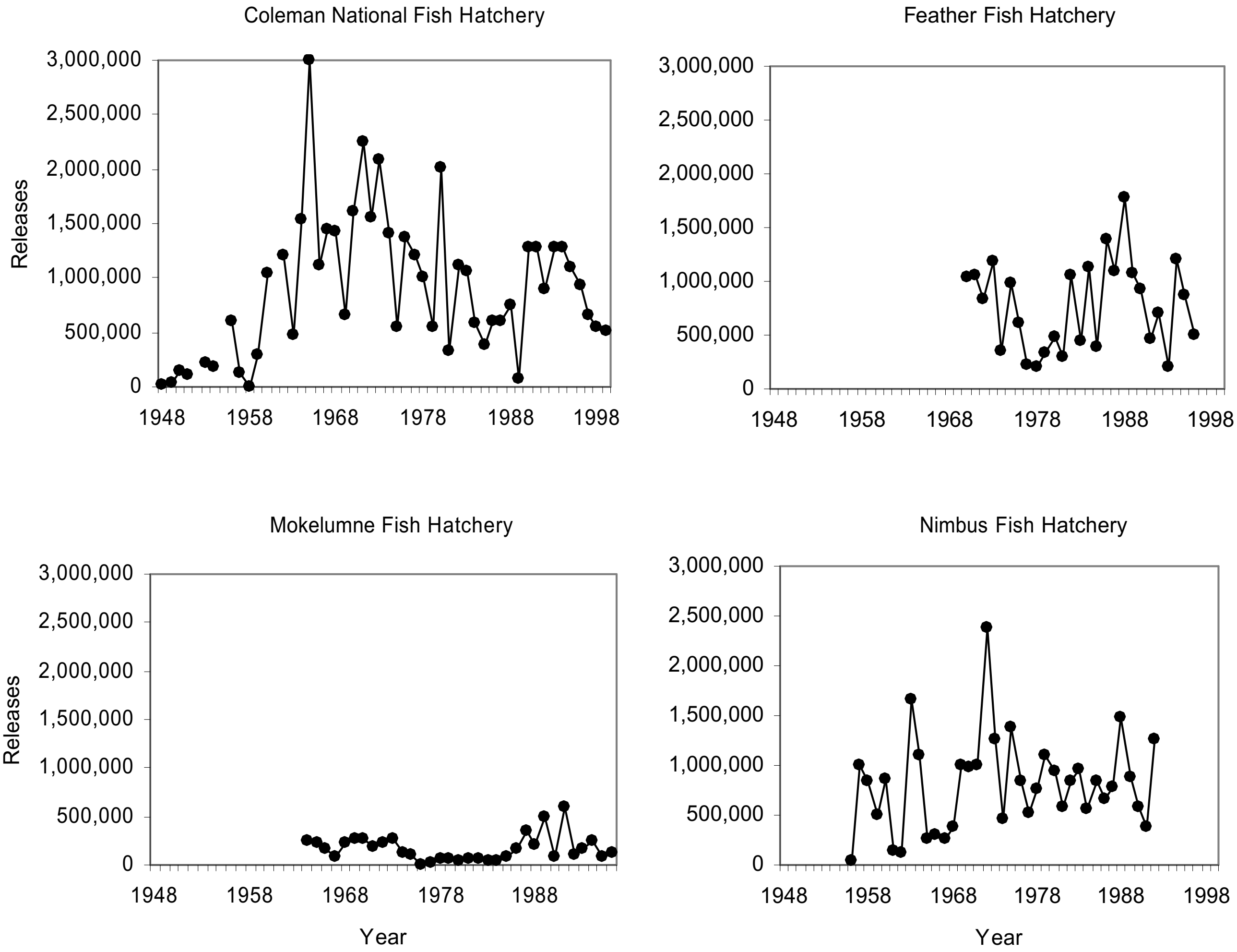

Figure 193. Releases of steelhead from Central Valley hatcheries.

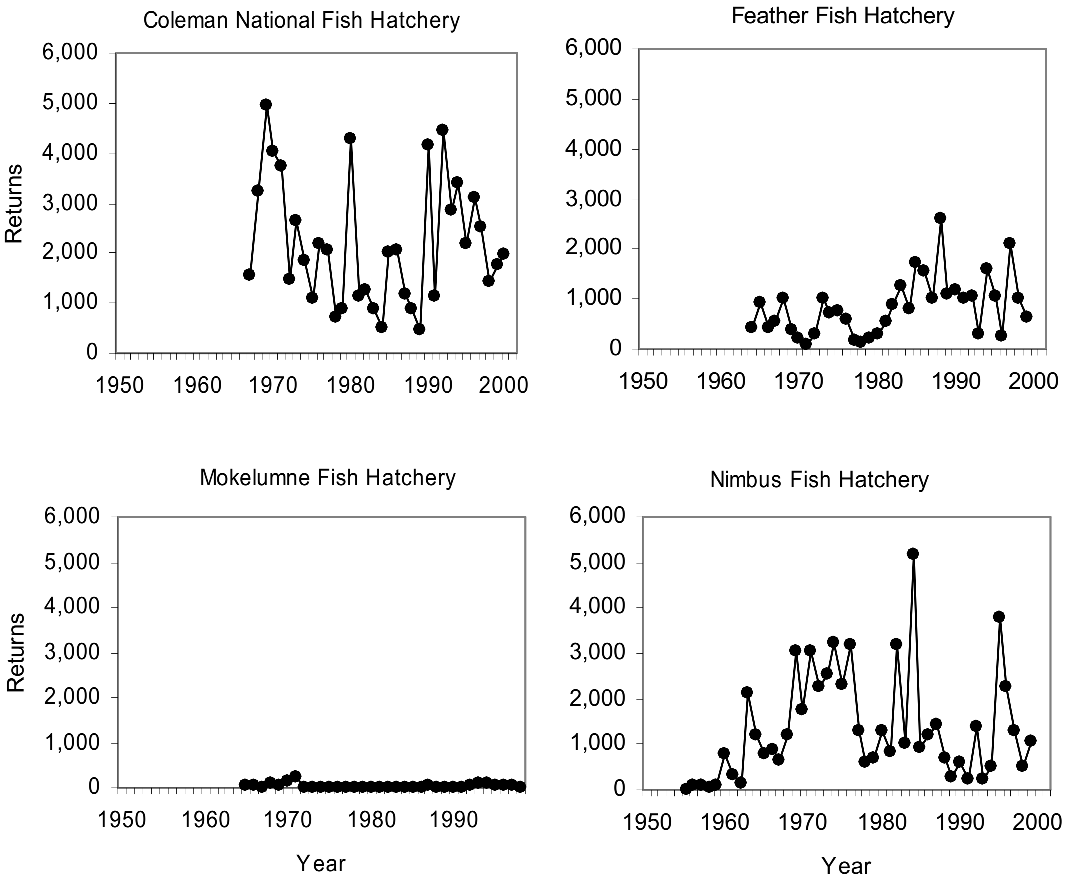

Figure 194. Returns of steelhead to Central Valley hatcheries.

25. Steelhead BRT Conclusions

Section 3 of the ESA allows listing of "species, subspecies, and distinct population segments." The option to list subspecies is not available for Pacific salmon, since no formally recognized subspecies exist. However, a number of subspecies have been identified for *O. mykiss*, including two that occur in North America and have anadromous populations. According to Behnke (1992), *O. mykiss irideus* (the "coastal" subspecies) includes coastal populations from Alaska to California (including the Sacramento River), while *O. mykiss gairdneri* (the "inland" subspecies) includes populations from the interior Columbia, Snake, and Fraser rivers. Both subspecies thus include populations within the geographic range of this updated status review, but both also include northern populations outside the geographic range considered here. The BRT did not attempt to evaluate extinction risk to *O. mykiss* at the species or subspecies level; instead, we evaluated risk at the distinct population segment or ESU level, as for the other species considered in this report.

Snake River Basin Steelhead ESU

A majority (over 70%) 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 (Table 63). The BRT did not identify any extreme risks for this ESU but found moderate risks in all the VSP categories (mean risk matrix scores ranged from 2.5 for spatial structure to 3.2 for growth rate/productivity) (Table 64). The continuing depressed status of B-run populations was a particular concern. Paucity of information on adult spawning escapements to specific tributary production areas makes a quantitative assessment of viability for this ESU difficult. As indicated in previous status reviews, the BRT remained

Table 63. Tally of FEMAT vote distribution regarding the status of 10 steelhead ESUs reviewed. Each of 16 BRT members allocated 10 points among the three status categories.

ESU	**Danger of extinction**	**Likely to become endangered**	**Not likely to become endangered**
Snake River[a]	14	103	23
Upper Columbia[a]	75	62	3
Middle Columbia[a]	1	71	68
Lower Columbia[b]	10	110	30
Upper Willamette[b]	7	106	37
Northern California	18	119	23
Central California Coast	40	111	9
South-Central California	40	109	11
Southern California	129	31	0
Central Valley	106	54	0

[a] Votes tallied for 14 BRT members.

[b] Votes tallied for 15 BRT members.

Table 64. Summary of risk scores (1 = low to 5 = high) for four VSP categories (see subsection, Factors Considered in Status Assessments, for a description of the risk categories) for the 10 steelhead ESUs reviewed. Data presented are means (range).

ESU	Abundance	Growth rate/productivity	Spatial structure and connectivity	Diversity
Snake River	3.1 (2–4)	3.2 (2–4)	2.5 (1–4)	3.1 (2–4)
Upper Columbia	3.5 (2–4)	4.3 (3–5)	3.1 (2–4)	3.6 (2–5)
Middle Columbia	2.7 (2–4)	2.6 (2–3)	2.6 (2–4)	2.5 (2–4)
Lower Columbia	3.3 (2–5)	3.3 (3–4)	2.7 (2–4)	3.0 (2–4)
Upper Willamette	2.8 (2–4)	2.9 (2–4)	2.9 (2–4)	2.6 (2–3)
Northern California	3.7 (3–5)	3.3 (2–4)	2.2 (1–4)	2.5 (1–4)
Central California Coast	3.9 (3–5)	3.9 (3–5)	3.6 (2–5)	2.8 (2–4)
South-Central California	3.7 (2–5)	3.3 (2–4)	3.9 (3–5)	2.9 (2–4)
Southern California	4.8 (4–5)	4.3 (3–5)	4.8 (4–5)	3.6 (2–5)
Central Valley	4.4 (4–5)	4.3 (4–3)	4.2 (2–5)	3.6 (2–5)

concerned about the replacement of naturally produced fish by hatchery fish in this ESU; naturally produced fish now make up only a small fraction of the total adult run. Again, lack of key information considerably complicates the risk analysis. Although several large production hatcheries for steelhead exist throughout this ESU, relatively few data exist regarding the numbers and relative distribution of hatchery fish that spawn naturally, or the consequences of such spawnings when they do occur.

On a more positive note, sharp upturns in 2000 and 2001 in adult returns in some populations and evidence for high smolt-adult survival indicate that populations in this ESU are still capable of responding to favorable environmental conditions. In spite of the recent increases, however, abundance in most populations for which there are adequate data are well below interim recovery targets (NMFS 2002b).

Based on the provisional framework discussed in the general Introduction to this report, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of this ESU, while those above long-standing natural barriers (e.g., in the Palouse and Malad rivers) are not. Recent genetic data suggest that native resident *O. mykiss* above Dworshak Dam on the North Fork Clearwater River should be considered part of this ESU, but hatchery rainbow trout that have been introduced to that and other areas would not. The BRT did not attempt to resolve the ESU status of resident fish residing above the Hells Canyon Dam complex, as little new information is available relevant to this issue. However, Kostow (2003) suggested that, based on substantial ecological differences in habitat, the anadromous *O. mykiss* that historically occupied basins upstream of Hells Canyon (e.g., Powder, Burnt, Malheur, Owhyee rivers) may have been in a separate ESU. For many BRT members, the presence of relatively numerous resident fish mitigated the assessment of extinction risk for the ESU as a whole.

Upper Columbia River Steelhead ESU

A slight majority (54%) of the BRT votes for this ESU fell in the “danger of extinction” category, with most of the rest falling in the “likely to become endangered” category (Table 63).

The most serious risk identified for this ESU was growth rate/productivity (mean score 4.3); scores for the other VSP factors were also relatively high, ranging from 3.1 (spatial structure) to 3.6 (diversity) (Table 64). The last 2 to 3 years have seen an encouraging increase in the number of naturally produced fish in this ESU. However, the recent mean abundance in the major basins is still only a fraction of interim recovery targets (NMFS 2002b). Furthermore, overall adult returns are still dominated by hatchery fish, and detailed information is lacking regarding productivity of natural populations. The ratio of naturally produced adults to the number of parental spawners (including hatchery fish) remains low for upper Columbia steelhead. The BRT did not find data to suggest that the extremely low replacement rate of naturally spawning fish (estimated adult:adult ratio was only 0.25–0.3 at the time of the last status review update) has improved substantially.

Based on the provisional framework discussed in Section 1, Introduction, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of this ESU, while those above long-standing natural barriers (e.g., in the Entiat, Methow, and perhaps Okanogan basins) are not. Resident fish potentially occur in all areas in the ESU used by steelhead. Case 3 resident fish above Conconully Dam are of uncertain ESU affinity. The BRT did not attempt to resolve the ESU status of resident fish residing above Grand Coulee Dam, because little new information is available relevant to this issue. Possible ESU scenarios for these fish include 1) they were historically part of the ESU and many of the remnant resident populations still are part of this ESU; 2) they were historically part of the ESU but no longer are, due to either introductions of hatchery rainbow trout or rapid evolution in a novel environment; or 3) they were historically part of a separate ESU. For many BRT members, the presence of relatively numerous resident fish mitigated the assessment of extinction risk for the ESU as a whole.

Middle Columbia River Steelhead ESU

A slight majority (51%) of the BRT votes for this ESU fell in the “likely to become endangered” category, with a substantial minority (49%) falling in the “not likely to become endangered” category (Table 63). The BRT did not identify any extreme risks for this ESU but found moderate risks in all the VSP categories (mean risk matrix scores ranged from 2.5 for diversity to 2.7 for abundance) (Table 64).

This ESU proved difficult to evaluate for two reasons. First, the status of different populations within the ESU varies greatly. On the one hand, abundance in two major basins, the Deschutes and John Day, is relatively high and over the last 5 years is close to or slightly over the interim recovery targets (NMFS 2002b). On the other hand, steelhead in the Yakima Basin, once a large producer of steelhead, remain severely depressed (10% of the interim recovery target), in spite of increases in the last 2 years. Furthermore, in recent years escapement to spawning grounds in the Deschutes River has been dominated by stray, out-of-basin (and largely out-of-ESU) fish—which raises substantial questions about genetic integrity and productivity of the Deschutes population. The John Day is the only basin of substantial size in which production is clearly driven by natural spawners. For the other major basin in the ESU (the Klickitat), no quantitative abundance information is available. The other difficult issue centered on how to evaluate contribution of resident fish, which according to Kostow (2003) and other sources are very common in this ESU and may greatly outnumber anadromous fish. The BRT concluded that the relatively abundant and widely distributed resident fish mitigated extinction risk in this ESU somewhat. However, due to significant threats to the anadromous component the majority of BRT members concluded the ESU was likely to become endangered.

Historically, resident fish are believed to have occurred in all areas in the ESU used by steelhead, although current distribution is more restricted. Based on the provisional framework discussed in Section 1, Introduction, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of this ESU, while those above long-standing natural barriers (e.g., in Deschutes and John Day basins) are not. Case 3 resident fish above Condit Dam in the Little White Salmon, above Pelton and Round Butte dams (but below natural barriers) in the Deschutes, and above irrigation dams in the Umatilla rivers are of uncertain ESU status.

Lower Columbia River Steelhead ESU

A large majority (over 73%) of the BRT votes for this ESU fell in the “likely to become endangered” category, with small minorities falling in the “danger of extinction” and “not likely to become endangered” categories (Table 63). The BRT found moderate risks in all the VSP categories, with mean risk matrix scores ranging from 2.7 for spatial structure to 3.3 for both abundance and growth rate/productivity) (Table 64). All of the major risk factors identified by previous BRTs still remain. Most populations are at relatively low abundance, and those with adequate data for modeling are estimated to have a relatively high extinction probability. Some populations, particularly summer run, have shown higher returns in the last 2 to 3 years. The WLC-TRT (Myers et al. 2002) has estimated that at least four historical populations are now extinct. The hatchery contribution to natural spawning remains high in many populations.

Based on the provisional framework discussed in the general introduction to this report, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of this ESU, while those above long-standing natural barriers (e.g., in upper Clackamas, Sandy, and some of the small tributaries of the Columbia River gorge) are not. Case 3 resident fish above dams on the Cowlitz, Lewis, and Sandy rivers are of uncertain ESU status.

Upper Willamette River Steelhead ESU

The majority (over 71%) of the BRT votes for this ESU fell in the “likely to become endangered” category, with small minorities falling in the “danger of extinction” and “not likely to become endangered” categories (Table 63). The BRT did not identify any extreme risks for this ESU but found moderate risks in all the VSP categories (mean risk matrix scores ranged from 2.6 for diversity to 2.9 for both spatial structure and growth rate/productivity) (Table 64). On a positive note, 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 is small for an entire ESU, resulting in a number of populations that are each at relatively low abundance. The recent increases are encouraging, but whether they can be sustained is uncertain. The BRT considered it a positive sign that releases of the “early” winter-run hatchery population have been discontinued, but remained concerned that releases of nonnative summer-run steelhead continue.

Because coastal cutthroat trout is a dominant species in the basin, resident *O. mykiss* are not as widespread here as in areas east of the Cascades. Resident fish below barriers are found in the Pudding/Molalla, Lower Santiam, Calapooia, and Tualatin drainages, and these would be considered part of the steelhead ESU based on the provisional framework discussed in the Introduction (page 1). Resident fish above Big Cliff and Detroit Dams on the North Fork Santiam and above Green Peter Dam on the South Fork Santiam are of uncertain ESU affinity. Although no obvious physical barrier separates populations upstream of the Calapooia from those lower in the basin, resident *O. mykiss* in these upper reaches of the Willamette Basin are quite distinctive both phenotypically and genetically and are not considered part of the Upper Willamette River steelhead ESU.

Northern California Steelhead ESU

The majority (74%) of BRT votes were for "likely to become endangered," with the remaining votes split about equally between "in danger of extinction" and "not warranted" (Table 63). Abundance and productivity were of some concern (scores of 3.7 and 3.3 in the risk matrix); spatial structure and diversity were of lower concern (scores of 2.2 and 2.5); although at least one BRT member gave scores as high as 4 for each of these risk metrics (Table 64).

The BRT considered the lack of data for this ESU to be a source of risk due to uncertainty. The lack of recent data is particularly acute for winter runs. Although there are older data for several of the larger river systems that imply run sizes became much reduced since the early 20th century, there are no recent data suggesting much of an improvement.

Based on the provisional framework discussed in Section 1, Introduction, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of the Northern California Coast steelhead ESU, while those above long-standing natural barriers are not. Historically, resident fish are believed to have occurred in all areas in the ESU steelhead use, although current distribution is more restricted. Resident fish above recent (usually man-made) barriers—including Robert W. Matthews Dam on the Mad River and Scott Dam on the Eel River—but below natural barriers are of uncertain ESU affinity. In this ESU, the inclusion of resident fish would not greatly increase the total numbers of fish, and the resident fish have not been exposed to large amounts of hatchery stocking.

Central California Coast Steelhead ESU

The majority (69%) of BRT votes were for "likely to become endangered," and another 25% were for "in danger of extinction" (Table 63). Abundance and productivity were of relatively high concern (mean score of 3.9 for each, with a range of 3 to 5 for each), and spatial structure was also of concern (score 3.6) (Table 64). Predation by pinnipeds at river mouths and during the ocean phase was noted as a recent development posing significant risk.

There were no time-series data for the Central California Coast steelhead ESU. A variety of evidence suggested the ESU's largest run (the Russian River winter steelhead run) has been, and continues to be, reduced in size. Concern was also expressed about populations in the southern part of the ESU's range—notably those in Santa Cruz County and the South Bay area.

Based on the provisional framework discussed in Section 1, Introduction, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of the Central California Coast steelhead ESU, while those above long-standing natural barriers are not. Historically, resident fish are believed to have occurred in all areas in the ESU used by steelhead, although current distribution is more restricted. Resident fish above recent (usually man-made) barriers—including Warm Springs Dam on Dry Creek, Russian River; Coyote Dam on the East Fork Russian River; Seeger Dam on Lagunitas Creek; Peters Dam on Nicasio Creek, Lagunitas Creek; and Standish Dam on Coyote Creek—but below natural barriers are of uncertain ESU affinity. In this ESU, an estimated 22% of historical habitat is behind recent barriers. The only relevant biological information about the populations above these barriers pertains to Alameda Creek, and suggests that some but not all populations above dam 1 are genetically similar to populations within the ESU. For some BRT members, the presence of resident fish mitigated the assessment of extinction risk for the ESU as a whole.

South-Central California Coast Steelhead ESU

The majority (68%) of BRT votes were for "likely to become endangered," and another 25% were for "in danger of extinction" (Table 63). The strongest concern was for spatial structure (score 3.9; range 3–5), but abundance and productivity were also a concern (Table 64). The cessation of plants to the South-Central California Coast steelhead ESU from the Big Creek Hatchery (Central California Coast steelhead ESU) was noted as a positive development, whereas continued predation from sport fishers was considered negative.

New data suggest that steelhead populations exist in most streams within the geographic boundaries of the ESU; however, the BRT was concerned that the two largest river systems—the Pajaro and Salinas basins—are much degraded and have steelhead runs much reduced in size. The BRT also expressed concern that these two large systems are ecologically distinct from the populations in the Big Sur area and San Luis Obispo County; thus their degradation affects the ESU's spatial structure and diversity. Much discussion centered on the Carmel River data set, including the effects of drought in the 1980s, the population's current dependence on intensive management of the river system, and the population's vulnerability to future droughts.

Based on the provisional framework discussed in Section 1, Introduction, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of the South-Central California Coast steelhead ESU, while those above long-standing natural barriers are not. Historically, resident fish are believed to have occurred in all areas in the ESU steelhead use, although current distribution is more restricted. Resident fish above recent (usually man-made) barriers—including San Antonia, Nacimiento, and Salinas dams on the Salinas River; Los Padres Dam on the Carmel River; Whale Rock Dam on Old Creek; and Lopez Dam on Arroyo Grande Creek—but below natural barriers are of uncertain ESU affinity. In this ESU, little of the historical habitat is behind recent barriers, and most of that is on the Salinas River. For some BRT members, the presence of resident fish mitigated the assessment of extinction risk for the ESU as a whole.

Southern California Steelhead ESU

The majority (81%) of BRT votes were for "in danger of extinction," with the remaining 19% of votes for "likely to become endangered" (Table 63). Extremely strong concern was expressed for abundance, productivity, and spatial structure (mean scores of 4.8, 4.3, and 4.8, respectively, in the risk matrix); diversity was also of concern (mean score of 3.6) (Table 64).

The BRT expressed concern about the lack of data on the Southern California steelhead ESU, about uncertainty as to the metapopulation dynamics in the southern part of the ESU's range, and about the fish's nearly complete extirpation from the southern part of the range. Several members were concerned and uncertain about the relationship between the population in Sespe Canyon, which is supposedly a sizeable population, and the small run size passing through the Santa Clara River, which connects the Sespe to the ocean. There was some skepticism that flows in the Santa Maria River were sufficient to allow fish passage from the ocean to the Sisquoc River, another "stronghold" of *O. mykiss* in the ESU.

Based on the provisional framework discussed in Section 1, Introduction, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of the Southern California steelhead ESU, while those above long-standing natural barriers are not. Historically, resident fish are believed to have occurred in all areas in the ESU steelhead use, although current distribution is more restricted. Resident fish above recent (usually man-made) barriers—including Twitchell Dam on the Cuyama River, Bradbury Dam on the Santa Ynez River, Casitas Dam on Coyote Creek and Ventura River, Matilija Dam on Matilija Creek and Ventura River, Santa Felicia Dam on Piru Creek and Santa Clara River, and Casitac Dam on Casitac Creek and Santa Clara River—but below natural barriers are of uncertain ESU affinity. In this ESU, a large portion of the original area is behind barriers, and the few density estimates that are available from this ESU indicate that the inclusion of area above recent barriers would substantially increase the number of fish in the ESU. Due to the extremely low numbers of anadromous fish in this ESU, it is possible that above-barrier populations contribute a significant number of fish to the below-barrier population by spill over. For some BRT members, the presence of resident fish mitigated the assessment of extinction risk for the ESU as a whole.

California Central Valley Steelhead ESU

The majority (66%) of BRT votes were for "in danger of extinction," and the remainder was for "likely to become endangered" (Table 63). Abundance, productivity, and spatial structure were of highest concern (4.2–4.4), although diversity considerations were of significant concern (3.6) (Table 64). All categories received a 5 from at least one BRT member.

The BRT was highly concerned that what little new information was available indicated that the monotonic decline in total abundance and in the proportion of wild fish in the California Central Valley steelhead ESU was continuing. Other major concerns included the loss of the vast majority of historical spawning areas above impassable dams, the lack of any steelhead-specific status monitoring, and the significant production of out-of-ESU steelhead by the Nimbus and Mokelumne river fish hatcheries. The BRT viewed the anadromous life history form as a critical component of diversity within the ESU and did not place much importance on sparse information suggesting widespread and abundant *O. mykiss* populations in areas above impassable dams. Dams both reduce the scope for expression of the anadromous life history form, thereby greatly reducing the abundance of anadromous *O. mykiss*, and prevent exchange of migrants among resident populations, a process presumably mediated by anadromous fish.

Based on the provisional framework discussed in the general Introduction to this report, the BRT assumed as a working hypothesis that resident fish below historical barriers are part of the California Central Valley steelhead ESU, while those above long-standing natural barriers are not. Historically, resident fish are believed to have occurred in all areas in the ESU steelhead use, although current distribution is more restricted. Resident fish above recent (usually man-made) barriers—including Shasta Dam on the Upper Sacramento River, Whiskeytown Dam on Clear Creek, Black Butte Dam on Stony Creek, Oroville Dam on the Feather River, Englebright Dam on the Yuba River, Camp Far West Dam on the Bear River, Nimbus Dam on the American River, Commanche Dam on the Mokelumne River, New Hogan Dam on the Calaveras River, Goodwin Dam on the Stanislaus River, La Grange Dam on the Tuolumne River, and Crocker Diversion Dam on the Merced River—but below natural barriers are of uncertain ESU affinity. As noted above, collectively these dams have isolated a large fraction of historical steelhead habitat, and resident fish above the dams may outnumber ESU fish from below the dams.

COHO SALMON

26. Background and History of Coho Salmon Listings

Coho salmon (*Oncorhynchus kisutch*) is a widespread species of Pacific salmon, occurring in most major river basins around the Pacific Rim from Monterey Bay in California north to Point Hope, Alaska; through the Aleutians; and from the Anadyr River in Russia south to Korea and northern Hokkaido, Japan (Laufle et al. 1986). From central British Columbia south, the vast majority of coho salmon adults are 3-year-olds, having spent approximately 18 months in freshwater and 18 months in salt water (Gilbert 1912, Pritchard 1940, Sandercock 1991). The primary exceptions to this pattern are "jacks," sexually mature males that return to freshwater to spawn after only 5 to 7 months in the ocean. However, in southeast and central Alaska, the majority of coho salmon adults are 4-year-olds, having spent an additional year in freshwater before going to sea (Godfrey et al. 1975, Crone and Bond 1976). The transition zone between predominantly 3- and 4-year-old adults occurs somewhere between central British Columbia and southeast Alaska.

With the exception of spawning habitat, which consists of small streams with stable gravels, summer and winter freshwater habitats most preferred by coho salmon consist of quiet areas with low flow, such as backwater pools, beaver ponds, dam pools, and side channels (Reeves et al. 1989). Habitats used during winter generally have greater water depth than those used in summer and also have greater amounts of large woody debris. West Coast coho smolts typically leave freshwater in the spring (April to June) and when sexually mature re-enter freshwater from September to November and spawn from November to December and occasionally into January (Sandercock 1991). Stocks from British Columbia, Washington, and the Columbia River often have very early runs (entering rivers in July or August) or late runs (spawning into March), in addition to normally timed runs.

For purposes of ESA listings, the status of coho salmon has been reviewed many times, beginning in 1990. The first two reviews occurred in response to petitions to list coho salmon in the lower Columbia River and Scott and Waddell creeks in central California. These reviews concluded that NMFS could not identify any populations that warranted protection under the ESA in the lower Columbia River (Johnson et al. 1991, NMFS 1991d), and that the Scott and Waddell Creek populations were part of a larger, undescribed ESU (Bryant 1994, NMFS 1994b).

A review of West Coast (Washington, Oregon, and California) coho salmon populations began in 1993 in response to several petitions to list numerous coho salmon populations and NMFS's own initiative to conduct a coastwide status review of the species. This coastwide review identified six coho salmon ESUs: the three southernmost ESUs were proposed for listing, two were candidates for listing, and one was deemed "not warranted" for listing (NMFS 1995a, Weitkamp et al. 1995). In October 1996, the BRT updated the status review for the Central California coho ESU and concluded that it was at risk of extinction (NMFS 1996c): NMFS listed this ESU as threatened in October 1996 (NMFS 1996c).

In December 1996, the BRT updated the status review for both proposed and candidate coho salmon ESUs (NMFS 1996b). However, because of the scale of the review, requests from comanagers for additional time to comment on the preliminary conclusions, and the legal obligations of the NMFS, the status review was finalized for proposed coho salmon ESUs in 1997 (NMFS 1997c) but not for candidate ESUs. In May 1997, NMFS listed the Southern Oregon/Northern California Coast (SONCC) coho salmon ESU as threatened, while it announced that listing of the Oregon Coast coho salmon ESU was not warranted due to measures in the Oregon Coastal Salmon Restoration Initiative (OCSRI) plan (NMFS 1997d). This finding for Oregon coast coho salmon was overturned in August 1998, and the ESU was listed as threatened (NMFS 1998e).

The process of updating the coho salmon status review began again in October 1998 for coho salmon in Washington and the lower Columbia River. However, due to competing activities with higher priorities, this effort was terminated before the BRT could meet.

In response to a petition by Oregon Trout et al. (2000), the BRT revisited the status of lower Columbia River coho salmon in 2000, with BRT meetings held in March and May 2001 (NMFS 2001a). The BRT concluded that splitting the Lower Columbia River/Southwest Washington coho salmon ESU to form separate Lower Columbia River and Southwest Washington coast coho salmon ESUs was most consistent with available information, and that the Lower Columbia River coho salmon ESU was at risk of extinction. Like the 1996 status review update, these results were never finalized.

The coho salmon BRT[40] met in January, March, and April 2003 to discuss new data and determine whether conclusions of the original BRTs should be modified as the result of the new information. This report summarizes new information and the preliminary BRT conclusions on the following ESUs, Oregon Coast, Southern Oregon/Northern California Coast, Central California Coast, and Lower Columbia River.

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[40] The BRT for the updated status review for West Coast coho salmon included Dr. Robert Iwamoto, Dr. Orlay Johnson, Dr. Pete Lawson, Gene Matthews, Dr. Paul McElhany, Dr. Thomas Wainwright, Dr. Robin Waples, Laurie Weitkamp, and Dr. John Williams from the Northwest Fisheries Science Center (NWFSC); Dr. Peter Adams, Dr. Eric Bjorkstedt, and Dr. Brian Spence from the Southwest Fisheries Science Center (SWFSC); and Dr. Reginald Reisenbichler from the Northwest Biological Science Center, USGS Biological Resources Division, Seattle.

27. Oregon Coast Coho Salmon ESU

Summary of Previous BRT Conclusions

Major Risk Factors and Status Indicators

The Oregon Coast coho salmon ESU was assessed in two previous status reviews—one in 1995 (Weitkamp et al. 1995) and another in 1997 (NMFS 1997c). In the 1995 status review (Weitkamp et al. 1995), the BRT considered evidence from many sources to identify ESU boundaries in coho populations from Washington to California. For the most part, the most informative evidence for the ESU delineation process was that from the physical environment, ocean conditions and upwelling patterns, marine and coded-wire-tag recovery patterns, coho salmon river entry and spawn timing, and estuarine and freshwater fish and terrestrial vegetation distribution. Genetic information was used to indicate reproductive isolation between populations and groups of populations. Based on this assessment, six ESUs were identified, including the Oregon Coast coho salmon ESU, which includes naturally spawning populations in Oregon coastal streams north of Cape Blanco to south of the Columbia River.

Evaluation of ESU under Conditions in 1997

In 1997, extensive survey data were available for coho salmon in the Oregon coast region. Overall, spawning escapements had declined substantially during the 20th century and may have been at less than 5% of their abundance of the early 1900s. Average spawner abundance had been relatively constant since the late 1970s, but preharvest abundance had declined. Average recruits per spawner may also have declined. Coho salmon populations in most major rivers appear to have been heavily influenced by hatchery stocks, but some tributaries may have sustained native stocks.

For this ESU, information on trends and abundance was better than for the more southerly ESUs. Main uncertainties in the assessment included the extent of straying of hatchery fish, the influence of such straying on natural population trends and sustainability, the condition of freshwater habitat, and the influence of ocean conditions on population sustainability. In 1996, total average (5-year geometric mean) spawner abundance for this ESU was estimated at about 52,000. Corresponding ocean run size for that year was estimated to be about 72,000—which corresponds to less than one-tenth of ocean run sizes estimated in the late 1800s and early 1900s, and only about one-third of 1950s ocean run sizes (ODFW 1995a). Total freshwater habitat production capacity for this ESU was estimated to correspond to ocean run sizes between 141,000 under poor ocean conditions and 924,000 under good ocean conditions (OCSRI Science Team 1996). Abundance was unevenly distributed within the ESU through the early to mid-1990s, with the largest total escapement in the relatively small mid- to south-coast gene conservation group (GCG) and lower numbers in the north to mid-coast and Umpqua GCGs.

Trend estimates using data through 1996 showed that for all three measures (escapement, run size, and recruits per spawner), long-term trend estimates were negative. More recent escapement trend estimates were positive for the Umpqua River and mid- to south coast monitoring areas, but negative in the north to mid-coast. Recent trend estimates for recruitment and recruits per spawner were negative in all three areas and exceeded 12% annual decline in the two northern areas. Six years of stratified random survey (SRS) population estimates showed an increase in escapement and decrease in recruitment.

To put these data in a longer-term perspective, ESU-wide averages in 1996, which were based on peak index and area under the curve (AUC) escapement indices, showed an increase in spawners up to levels of the mid- to late 1980s but much more moderate increases in recruitment. Recruitment remained only a small fraction of average levels in the 1970s. An examination of return ratios showed that spawner:spawner ratios had remained above replacement since the 1990 broodyear, as a result of higher productivity of the 1990 broodyear and sharp reductions in harvest for subsequent broodyears. As of 1996, recruit:spawner ratios for 1991–1994 broodyears were the lowest on record, except for 1988 and, possibly, 1984. The 1997 BRT considered risk of extinction for this ESU under two scenarios: first, if present conditions and existing management continued into the foreseeable future; and second, if certain aspects of the Oregon OCSRI Draft Conservation Plan (Oregon Plan 1997, Governor's Natural Resources Office 1997) relating to harvest and hatchery production were implemented. As of 2003, the OCSRI is called The Oregon Plan for Salmon and Watersheds.

Population Abundance

Between the 1995 and 1997 status reviews, escapement increased for the Oregon Coast coho salmon ESU as a whole, but recruitment and recruits per spawner remained a small fraction of historical abundance. Spawning was distributed over a relatively large number of basins, both large and small. Natural escapement from 1990 to 1996 was estimated to be on the order of 50,000 fish per year in this ESU, reaching nearly 80,000 fish in 1996 coincident with drastic reductions in harvest. Prefishery recruitment was higher in 1996 than in either 1994 or 1995, but exhibited a fairly flat trend after 1990. The 1996 estimate of ESU-wide escapement indicated an approximately fourfold increase since 1990. When looked at on a finer geographic scale, as of 1996 the northern Oregon coast still had very poor escapement, the north/central coast showed mixed escapement with strong increases in some streams but continued very poor escapement in others, and the south/central coast continued to have increasing escapement.

Both recruitment and recruits per spawner declined rapidly (12% to 20% annual declines from 1986 to 1996) in two of the three Oregon Department of Fish and Wildlife GCGs in this ESU. These declines were steeper and more widespread in this ESU than in any other coho salmon ESU for which data were available, and recruits per spawner continued to decline after this ESU was reviewed in 1994. The new data, from 1994 to 1996, did not change the overall pattern of decline coupled with peaks in recruits per spawner every 4 to 5 years, with the height of the peaks declining over time.

Risks that this decline in recruits per spawner posed to sustainability of natural populations, in combination with strong sensitivity to unpredictable ocean conditions, were the most serious concern the BRT identified in 1997 for this ESU. Examining the results of the viability models addressed some aspects of this concern, although none of the models incorporated declining recruits per spawner, except as a consequence of changing ocean conditions. Preliminary results of viability models provided a wide range of results, with one model suggesting that most Oregon coast stocks could not sustain themselves at ocean survivals observed in the last 5 years, even in the absence of harvest, and another suggesting that stocks are highly resilient and would be at significant risk of extinction only if habitat degradation continues into the future. Consequently, a major question in evaluating extinction risk for this ESU was whether recent ocean and freshwater conditions would continue into the future.

Population Trends and Production

For this ESU, fishery recruitment forecasts for 1997 were slightly below the actual 1996 recruitment (PFMC 1997a), and actual returns were drastically lower, about 25% of 1996 recruitment and the second lowest on record after 1977. Stream production studies conducted by ODFW (Solazzi and Johnson 1996) indicated that 1996 smolt production in four central coast study streams was lower than recent averages, with overwinter survival the lowest or second-lowest on record for the two streams for which estimates were made, and that age-0 fish production was also low. They concluded that the “most significant impact was on juvenile coho salmon eggs that were in the gravel at the time of the [1995–1996] flood.” Although these results were based on a small sample of streams and may not reflect average effects of the flood, they suggested that 1997 and 1998 adult returns to some coastal basins would be reduced by the floods. Longer-term effects of the floods can also be expected to vary among basins, but most reports available to the BRT suggest that long-term effects should generally be neutral or slightly beneficial (e.g., from sediment removal and increased off-channel habitat) to coho salmon.

Hatchery Production and Genetic Risks

Widespread spawning by hatchery fish, as indicated by scale data, was also a major concern to the BRT. Scale analysis to determine hatchery:wild ratios of naturally spawning fish indicate moderate to high levels of hatchery fish spawning naturally in many basins on the Oregon coast, and at least a few hatchery fish were identified in almost every basin examined. Although it is possible that these data do not provide a representative picture of the extent of this problem, they represented the best information available at the time. In addition to concerns for genetic and ecological interactions with wild fish, these data also suggest ODFW may have overestimated natural spawner abundance and that the declines in recruits per spawner in many areas may have been even more alarming than current estimates indicate. However, by 1997 Oregon had made some significant changes in its hatchery practices, such as substantially reducing coho production levels in some basins, switching to on-station smolt releases, and minimizing fry releases. Uncertainty regarding the true extent of hatchery influence on natural populations, however, was a strong concern.

Another concern the BRT discussed in 1997 was asymmetry in the distribution of natural spawning in this ESU; a large fraction of the fish occurred in the southern portion and relatively few in northern drainages. Northern populations were also relatively worse off by almost every other measure: steeper declines in abundance and recruits per spawner, higher proportion of naturally spawning hatchery fish, and more extensive habitat degradation.

Habitat Conditions

With respect to habitat, the BRT had two primary concerns: 1) that the habitat capacity for coho salmon within this ESU has significantly decreased from historical levels; and 2) that the Nickelson and Lawson (1998) model predicted that, during poor ocean survival, only high-quality habitat is capable of sustaining coho populations, and subpopulations dependent on medium- and low-quality habitats would likely become extinct. Both of these concerns caused the BRT to consider risks from habitat loss and degradation to be relatively high for this ESU.

Influence of OCSRI

The 1997 BRT considered only two sets of measures from the OCSRI: 1) harvest management reforms and 2) hatchery management reforms. The BRT did not consider the likelihood that these measures would be implemented; rather, it only considered the implications for ESU status if these measures were fully implemented as described. In order to carry out these evaluations, the BRT made the following assumptions:

- The ocean harvest management regime would be continued as proposed into the foreseeable future, not revised in 2000 as stated in the plan. Without this assumption, effects of the plan beyond 2000 could not be evaluated.
- Hatchery releases would continue at or below 1997 release levels (including approximately 1 million annual fry releases) into the foreseeable future.
- The goals of maintaining naturally spawning hatchery fish at less than 10% or 50% of natural escapement (depending on genetic similarity with natural fish) would be achieved and demonstrated by effective monitoring.

Some members were very concerned that not enough is known about the causes of declines in run size and recruits per spawner to be able to directly assess the effectiveness of specific management measures.

Harvest Measures

Some BRT members felt that the harvest measures were the most encouraging part of the plan, representing a major change from previous management. However, some members were concerned that the harvest plan might be seriously weakened when it was reevaluated in 2000 and were concerned that combining the Umpqua and south-central coast GCGs into a larger aggregate (as would occur in the proposed harvest plan) might not adequately protect genetic diversity. In addition, concern was expressed about our ability to effectively monitor nontarget harvest mortality and to control overall harvest impacts.

Hatchery Measures

Of the proposed hatchery measures, the BRT thought substantial reductions in smolt releases would have the most predictable benefit for natural populations; all else being equal, fewer fish released should result in fewer genetic and ecological interactions with natural fish. Marking all hatchery fish should also help to resolve present uncertainties about the magnitude of these interactions. However, the BRT expressed concerns regarding some aspects of the proposed hatchery measures. The plan was vague on several key areas, including plans for incorporation of wild broodstock and how production would be distributed among facilities after 1997. One concern was that the recent and proposed reductions appear to be largely motivated by economic constraints and the present inability to harvest fish if they were produced rather than by recognition of negative effects of stray hatchery fish on wild populations. The BRT expressed other concerns, including no reductions in fry releases in many basins, substantially higher releases of smolts in the Yaquina River basin (which, by ODFW's own assessment, has more high-quality habitat than any other coastal basin), and no consideration of alternative culture methods that could be used to produce higher-quality hatchery smolts, which may have less impact on wild fish. Another concern was the plan's lack of recognition that hatchery-wild interactions reduce genetic diversity among populations.

Previous BRT Conclusions

In 1997, the BRT concluded that, assuming that 1997 conditions continued into the future (and that proposed harvest and hatchery reforms were not implemented), the Oregon Coast coho salmon ESU was not at significant short-term risk of extinction, but it was likely to become endangered in the foreseeable future. A minority felt that the ESU was not likely to become endangered. Of those members who concluded that this ESU was likely to become endangered, several expressed the opinion that it was near the border between this category and "not at risk." The BRT generally agreed that implementation of the OCSRI's harvest and hatchery proposals would have a positive effect on the ESU's status, but the panel was about evenly split as to whether the effects would be substantial enough to move the ESU out of the "likely to become endangered" category. Some members felt that, in addition to the extinction buffer provided by the estimated 80,000 naturally produced spawners in 1996, the proposed reforms would promote higher escapements and alleviate genetic concerns so that the ESU would not be at significant risk of extinction or endangerment. Other members saw little reason to expect that the hatchery and harvest reforms by themselves would be effective in reducing what they viewed as the most serious threat to this ESU—declining recruits per spawner. If the severe declines in recruits per spawner of natural populations in this ESU were partly a reflection of continuing habitat degradation, then risks to this ESU might remain high even with full implementation of the hatchery and harvest reforms. Although harvest and hatchery reforms may substantially reduce short-term risk of extinction, habitat protection and restoration were viewed as key to ensuring long-term survival of the ESU, especially under variable and unpredictable future climate conditions. The BRT therefore concluded that these measures would not be sufficient to alter the previous conclusion, that the ESU is likely to become endangered in the foreseeable future.

The Oregon Coast coho salmon ESU was listed as a threatened species on 10 August 1998. The ESU includes all naturally spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco (Figure 195).

Listing status: Proposed Threatened.

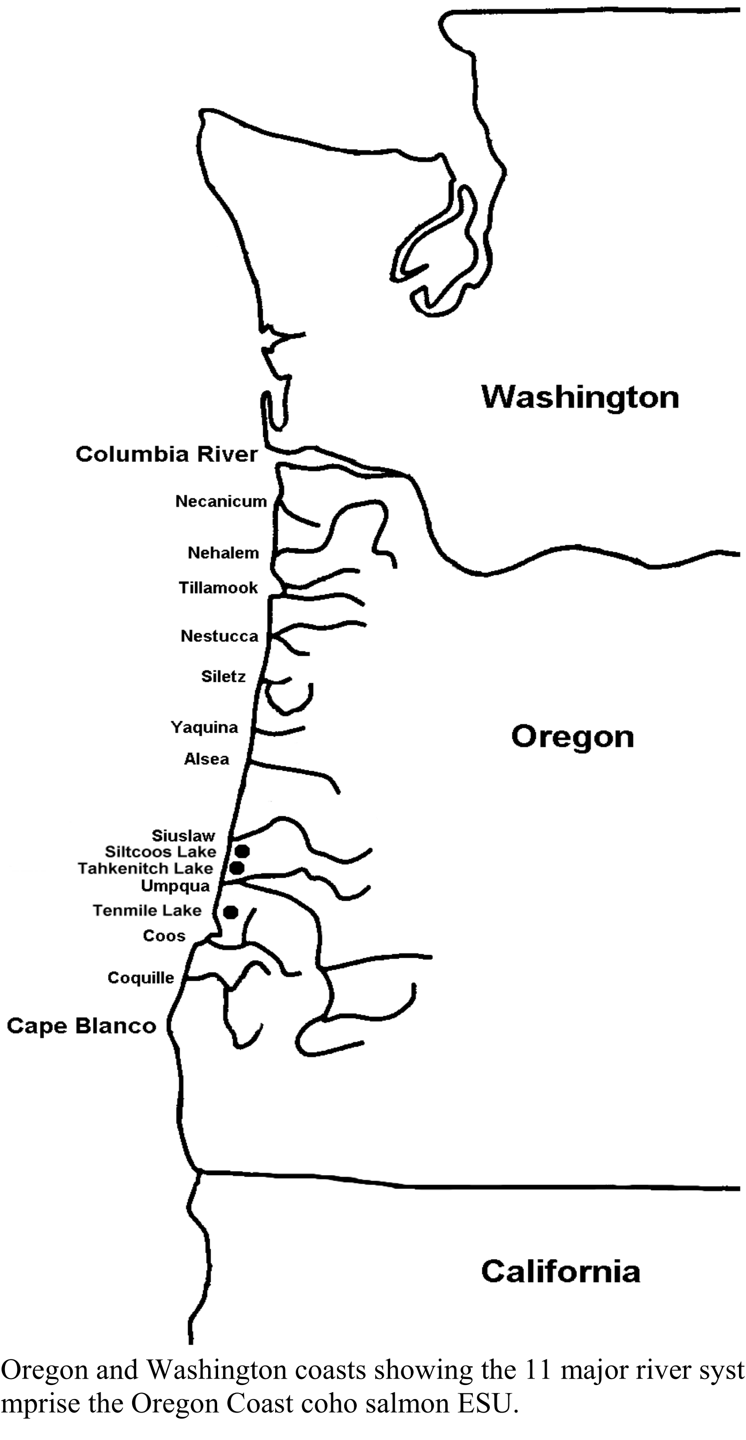

Figure 195. Map of Oregon and Washington coasts showing the 11 major river systems and three coastal lakes that comprise the Oregon Coast coho salmon ESU.

New Comments

Alsea Valley Alliance v. Evans

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

The effect of the ruling was to delist the Oregon Coast coho salmon ESU. The ruling was appealed by the appellant interveners to the U.S. Court of Appeals for the Ninth Circuit. On 14 December 2001 the Court stayed the District Court ruling pending final disposition of the appeal (*Alsea Valley Alliance v. Evans*, Ninth Circuit appeal, No. 01-36071, 14 December 2001). This returned the status of the Oregon Coast ESU to threatened under the ESA. NMFS is currently reviewing its listing policy with regard to hatchery and wild salmon.

Petition for Listing

On 25 April 2002, NMFS Regional Administrator D. Robert Lohn received a petition to define and list the wild stocks of coho salmon along the Oregon coast as a threatened species, pursuant to the ESA. The petitioners presented recent scientific reports relating to the "behavioral, physiological, ecological, reproductive and evolutionary differences between the hatchery and wild stocks" of Oregon coast coho salmon. The petition was in response to the findings of *Alsea Valley Alliance v. Evans.* The petitioners were Trout Unlimited, Oregon Council of Trout Unlimited, Washington Council of Trout Unlimited, Oregon Trout, Washington Trout, Native Fish Society, Oregon Council of Fly Fishers, Pacific Coast Federation of Fisherman's Associations and the Institute for Fisheries Resources, Oregon Natural Resources Council, Save Our Wild Salmon, Orange Ribbon Foundation, American Rivers, Audubon Society of Portland, National Wildlife Federation, and the Siskiyou Regional Education Project. The petitioners stated:

> NMFS has previously made findings of the detrimental impact that the artificial production of localized, but rather widespread in every basin in the Oregon coast where wild coho are present, based on the presence of hatchery coho in every stream system (ODFW 1995b; Jacobs et al. 2001). Additionally, the fluctuations in the ocean conditions, and the changes in the ocean carrying capacity, may exacerbate the impacts in certain years (NWPPC 1999). Additional reports suggest that the impact of these hatchery programs is resulting in at least phenotypic differences (genetic and environmental) between coho, and is not limited to hatchery management practices alone, but due to other direct biological and environmental effects (IMST 2001; Flagg et al. 2000; Chilcote 2002).

The petitioners cited substantial updated information on current abundance, historical abundance and carrying capacity, trends in abundance, natural and human-influenced factors that cause variability in survival and abundance, possible threats to genetic integrity, and recent events such as the extended period of El Niño–like conditions prior to 1997, significant flood events in 1995–1996 and 1998, and recently improved ocean conditions (Trout Unlimited 2002).

Independent Multidisciplinary Science Team

Since the 1997 status review, the Oregon Plan for Salmon and Watersheds (formerly Oregon Coastal Salmon Restoration Initiative Conservation Plan) has developed into an extensive effort to recover threatened or endangered salmonid populations through a combination of grassroots actions using watershed councils, refocusing effort and resources of fisheries and other state agencies, and convening a group of scientists to "advise the state on matters of science related to the Oregon Plan for Salmon and Watersheds" (IMST 2002b). This group of scientists consists of a seven-member team with "recognized expertise in fisheries artificial propagation, stream ecology, forestry, range, watershed and agricultural management"; it is known as the Independent Multidisciplinary Science Team (IMST). The IMST has been responsible for a series of review documents on the science relating to recovery of Oregon coastal coho salmon stocks. The first of these efforts was a workshop of agency and university fisheries professionals convened to help in the "Defining and Evaluating Recovery of OCN [Oregon Coast Natural] Coho Salmon Stocks: Implications for Rebuilding Stocks under the Oregon Plan for Salmon and Watersheds" (IMST 1999). Alternative recovery definitions are proposed and criteria for evaluating recovery are discussed.

Additional reports issued by this team germane to the deliberations of the Oregon coastal coho salmon BRT include "Conservation Hatcheries and Supplementation Strategies for Recovery of Wild Stocks of Salmonids: Report of a Workshop" (IMST 2000) and "The Scientific basis for Artificial Propagation in the Recovery of Wild anadromous Salmonids in Oregon" (IMST 2001), which analyzes the hatchery programs of ODFW, presents 3 substantial conclusions, and puts forth a series of 10 recommendations based on these conclusions. In addition, a comprehensive look at the "Recovery of Wild Salmonids in Western Oregon Lowlands" (IMST 2002a) provides an extensive analysis of 5 science questions relating to the importance of lowlands to the recovery of salmonids, with 21 recommendations relating to recommended actions by state agencies to contribute to the recovery of salmonids in lowland areas. They do not, however, present substantially new information that can shed light on the evaluation of risk to the Oregon Coast coho salmon ESU.

Douglas County Board of Commissioners

The Douglas County Board of Commissioners submitted a report titled "Viability of Coho Salmon Populations on the Oregon and Northern California Coasts," to NMFS Protected Resources Division on 12 April 2002 (Cramer and Ackerman 2002). This report analyzes information available for both the Oregon Coast coho salmon ESU and the Southern Oregon/Northern California Coast coho salmon ESU in several areas: trends in abundance and distribution, trends in survival, freshwater habitat condition, potential hatchery-wild interactions, changes in harvest regulation, and extinction risk modeling. Few data presented in the report are new, but independent analyses focus on unique aspects of the data: changes in fishery management, increasing spawning escapements, reduced hatchery releases, habitat restoration, and evidence of successful rearing of fry outmigrants throughout the Oregon coast. Although the report reached no conclusions regarding the ESU's overall status, the Douglas County Board of Commissioners cites the report in concluding that coho salmon populations in this ESU are "strongly viable."

New Data and Updated Analyses

Population Abundance

For the Oregon Coast coho salmon ESU, the BRT received updated estimates of total natural spawner abundance based on stratified random survey (SRS) techniques, broken down by ODFW's monitoring areas (MAs), for 11 major river basins and for the coastal lakes system.[41] (ODFW's monitoring areas are similar, but not identical to, the GCGs that were the population units in the 1997 update.) These data are for the return years 1990–2002 and are presented in Table 65 (for consistency with the previous status review for this ESU, abundance and trend analysis in this update are expressed in terms of naturally produced fish, rather than the standard of naturally spawning fish used in other status review updates). Total recent average (3-year geometric mean) spawner abundance for this ESU is estimated at about 140,600, up from the 5-year geometric mean of 52,000 in the 1997 update and higher than the estimate at the time of the status review. In 2001, the ocean run size was estimated to be about 178,000; this corresponds to one-tenth of ocean run sizes estimated in the late 1800s and early 1900s, and only about one-third of those in the 1950s (ODFW 1995a). In 2002, the ocean run size increased to 304,500, fourth highest since 1970 and perhaps 25% of historical abundance. Present abundance is more evenly distributed within the ESU than it was in 1997. Escapement in the relatively small mid/south coast monitoring area was the strongest in the ESU until 2001. In 2002, escapements in the mid/south were down about 25%, while the north and mid-coast monitoring areas showed strong gains. The Umpqua monitoring area is up by a factor of 4 since 1996 (Table 65).

We have updated ocean exploitation estimates based on Oregon Productivity Index (OPI) estimated catch and escapement, which is based on SRS methods (OPI-SRS) for 1970–1993; postseason results of the coho FRAM for 1994–2001; and the preseason FRAM estimate for 2002 (OPI-SRS and FRAM from PFMC 2002b). The ODFW Standard Index spawner escapement estimates were discontinued in 1999 and data from 1970 to 1989 were standardized to the SRS data. All analyses were done using this updated time series. Exploitation rates are based on ocean catch and incidental mortality plus escapement. Recruits are calculated as spawners divided by 1 minus the ocean exploitation rate. A major assumption is that progeny of natural spawners are affected by fishing gear the same as hatchery fish, so that ocean mortalities are in the same proportion as escapement. Freshwater harvest and mortality is not directly assessed, but is conventionally considered to be 10% of ocean escapement for retention fisheries and 1% for catch-and-release fisheries. The BRT also did not attempt to adjust trends for the contribution of stray hatchery fish; sufficient data for such an adjustment are not available for these populations.

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[41] S. Jacobs, Oregon Department of Fish and Wildlife, Corvallis, OR. Pers. commun., 14 November 2002.

Table 65. Numbers of natural-origin spawners in the Oregon Coast coho salmon ESU, 1990–2002, subtotaled by ODFW monitoring area, rivers, lakes, and coastwide. Source: Estimated from Oregon Department of Fish and Wildlife stratified random surveys, 1990–2002 return years.

ODFW monitoring area/location	**Return year**												
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
North coast													
Necanicum and Elk creeks	191	1,135	185	941	408	211	768	253	946	728	474	5,247	2,710
Nehalem	1,552	3,975	1,268	2,265	2,007	1,463	1,057	1,173	1,190	3,713	14,285	22,310	20,654
Tillamook Bay	265	3,000	261	860	652	289	661	388	271	2,175	1,983	1,883	16,488
Nestucca	189	728	684	401	313	1,811	519	271	169	2,201	1,171	3,940	12,334
Sand Lake and Neskowin Creek	0	240	24	41	77	108	275	61	0	47	0	71	16
Miscellaneous	0	204	0	0	0	0	0	0	0	0	0	0	0
North coast total*	2,197	9,282	2,422	4,508	3,457	3,882	3,280	2,148	2,576	8,864	17,913	33,451	52,202
Mid-north													
Salmon	385	39	28	364	107	212	271	237	8	175	0	310	1,237
Siletz	441	984	2,447	400	1,200	607	763	336	394	706	3,553	1,437	2,369
Yaquina	381	380	633	549	2,448	5,668	5,127	384	365	2,588	647	3,039	25,039
Beaver Creek	23	0	756	500	1,259	0	1,340	425	1,041	3,366	738	5,274	7,596
Alsea	1,189	1,561	7,029	1,071	1,279	681	1,637	680	213	2,050	2,465	3,339	5,767
Yachats	280	28	337	287	67	117	176	99	102	150	79	52	1,661
Siuslaw	2,685	3,740	3,440	4,428	3,205	6,089	7,625	668	1,089	2,724	6,767	11,024	57,125
Miscellaneous	207	0	700	180	251	231	1,188	13	71	0	12	764	3,315
Mid-north total*	5,591	6,732	15,372	7,779	9,816	13,605	18,127	2,842	3,283	11,759	14,261	25,239	104,109
Umpqua													
Lower Umpqua and Smith	589	1,316	1,759	4,804	1,689	6,803	4,904	935	5,118	2,323	3,696	8,850	25,939
Umpqua	455	0	192	1,431	1,240	352	339	397	444	1,289	2,774	8,177	7,972
Elk and Calapooya creeks	185	0	0	0	708	2,315	1,709	196	379	434	1,864	2,581	1,477
South Umpqua	2,508	2,284	0	2,415	579	755	1,685	512	678	1,219	479	6,482	1,419
Cow Creek	0	0	201	661	269	1,124	1,112	193	1,807	1,234	1,582	6,661	5,608
Umpqua total*	3,737	3,600	2,152	9,311	4,485	11,349	9,749	2,233	8,426	6,499	10,395	32,751	42,415

Table 65 continued. Numbers of natural-origin spawners in the Oregon Coast coho salmon ESU, 1990–2002, subtotaled by ODFW monitoring a, rivers, lakes, and coastwide. Source: Estimated from Oregon Department of Fish and Wildlife stratified random surveys, 1990–2002 return years.

ODFW monitoring area/location	**Return year**												
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Mid-south													
Coos Bay and Big Creek	2,273	3,813	16,545	15,284	14,685	10,351	12,128	1,127	3,167	4,945	5,386	43,301	35,005
Coquille	2,712	5,651	2,115	7,384	5,035	2,116	16,169	5,720	2,466	3,001	6,130	13,310	8,488
Miscellaneous	0	1	2	3	4	5	6	7	8	9	10	11	11
Mid-south total*	4,985	9,465	18,662	22,671	19,724	12,472	28,303	6,854	5,641	7,946	11,516	56,611	43,512
Coastwide rivers	16,512	29,078	38,607	44,270	37,481	41,306	59,459	14,076	19,926	34,696	54,063	149,847	242,238
Lakes	4,394	7,251	1,986	10,145	5,842	11,216	13,494	8,603	11,108	12,711	12,747	19,669	22,097
Coastwide total*	20,906	36,329	40,593	54,415	43,323	52,522	72,953	22,679	31,034	47,407	66,810	169,516	264,335

[*] Monitoring area totals from 1999 to 2002 are estimated by monitoring area and may differ from the sums of the individual rivers.

The BRT determined that the coded-wire-tag-based index (CWT) became less useful after the implementation of coho nonretention fisheries in 1994. The CWT index depends on ocean recoveries of coded-wire tags, and there are no tag recoveries in nonretention fisheries. Noncatch mortalities (hook-and-release, drop-off, illegal retention) are either estimated in the coho FRAM or estimated externally and input directly in the model.

The BRT used escapement estimates provided by ODFW (Table 65).[42] The SRS escapement data indicate that, ESU-wide, spawning escapement reached a 30-year high in 2001 and continued to climb in 2002 (Figures 196 and 197). This high escapement is due to a combination of improved marine survival and sharply curtailed ocean fisheries. When viewed on a finer geographic scale, the north coast has responded well after a very weak period through 1999. The mid-coast was mixed in 2001, with strong increases in some streams but continued very poor escapement in others. Substantial increases in 2002 made it the strongest area on the coast. The mid/south coast rebounded in 2002 after a 4-year drop (Table 65).

Three-year statistics (geometric mean, arithmetic mean, minimum and maximum spawners, and recruits) in individual river basins are strongly affected by the recent 2 years of high marine survival (Table 66). Abundance grew exponentially in the past 3 years, so arithmetic means are uniformly higher than geometric means. The minimum and maximum abundances show that, with a few exceptions, abundances in individual basins have increased about tenfold in the past 3 years. Abundance in the Nehalem River ranged only from 14,285 to 22,310, indicating that this system may have been near capacity before survival improved. On the other hand, the Yaquina River grew from 647 to 25,039—nearly a fortyfold increase. Statistics for the combined systems (Table 67) are more stable, but they indicate an overall fourfold increase in spawners over the past 3 years.

In the return years 1997–1999 (broodyears 1994–1996), and for the first time on record (since 1950), recruits failed to replace the parental spawners: a recruitment failure occurred in all three brood cycles, even before accounting for harvest-related mortalities (Figure 196). Since 1999, improving marine survival and higher rainfall are thought to be the factors contributing to an upswing in wild recruitment. Fishery recruitment for 2002 was up over fourfold from 2000, with about 304,000 recruits, but below the 30-year high of 450,000 observed in 1973. Given current habitat conditions, OCN coho are thought to require an overall marine survival rate of 0.03 to achieve a spawner:recruit ratio of 1:1 in the best quality habitat (Nickelson and Lawson 1998). Less productive habitats require higher marine survivals to sustain populations. Based on OPI hatchery survival rates, marine survival after exploitation exceeded 0.03 only in 2001. Assuming natural spawners survive at twice the hatchery rate, in 7 out of 13 years since 1990 marine survivals after exploitation were high enough to sustain the strongest populations. Increases in recruits and spawners (Figures 196 and 197) reflect improved marine survival for the 2000 and 2001 smolt years. It is far from certain that these favorable marine conditions will continue and, with the current freshwater habitat conditions, the ability of OCN coho to survive another prolonged period of poor marine survival remains in doubt.

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[42] See Footnote 41.

Table 66. Three-year statistics and 13-year trends for 11 major river basins in the Oregon Coast coho salmon ESU.

	Spawners[a]						Recruits[b]					
	3-year mean		3-year range		13 year		3-year mean		3-year range		13 year	
Basin	**Geometric**	**Arithmetic**	**Minimum**	**Maximum**	**Trend**	**SE**	**Geometric**	**Arithmetic**	**Minimum**	**Maximum**	**Trend**	**SE**
Necanicum	1,889	2,810	474	5,247	1.169	0.860	2,096	3,101	522	5,667	1.076	0.941
Nehalem	18,741	19,083	14,285	22,310	1.206	0.889	20,799	21,188	15,728	24,097	1.110	1.042
Tillamook	3,949	6,785	1,883	16,488	1.191	1.084	4,382	7,723	2,034	18,952	1.096	1.191
Nestucca	3,846	5,815	1,171	12,334	1.230	1.015	4,269	6,574	1,289	14,177	1.132	1.133
Siletz	2,295	2,453	1,437	3,553	1.070	0.760	2,547	2,729	1,552	3,912	0.985	0.847
Yaquina	3,665	9,575	647	25,039	1.204	1.205	4,067	10,925	712	28,780	1.108	1.204
Alsea	3,621	3,857	2,465	5,767	1.042	0.960	4,018	4,316	2,714	6,629	0.959	1.089
Siuslaw	16,213	24,972	6,767	57,125	1.120	1.037	17,993	28,339	7,450	65,661	1.031	1.150
Umpqua	24,351	28,520	10,395	42,415	1.182	0.662	27,025	31,857	11,445	48,753	1.088	0.764
Coos	20,136	27,897	5,386	43,301	1.088	1.066	22,346	30,978	5,930	46,769	1.002	1.098
Coquille	8,847	9,309	6,130	13,310	1.070	0.649	9,819	10,294	6,749	14,376	0.984	0.684

[a] Spawners are natural-origin spawners only.

[b] Recruits are natural-origin adults before ocean harvest.

Table 67. Three-year statistics and 33-year trends for Oregon Coast coho salmon ESU rivers, lakes, and combined rivers and lakes.

	Spawners[a]						Recruits[b]					
	3-year mean		3-year range		33 year		3-year mean		3-year range		33 year	
	Geometric	**Arithmetic**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Geometric**	**Arithmetic**	**Minimum**	**Maximum**	**Trend**	**SE**
Rivers	122,718	147,933	50,500	242,200	1.017	0.600	136,291	165,933	55,600	279,000	0.950	0.575
Lakes	16,189	16,635	12,747	22,097	1.013	0.735	17,966	18,567	14,034	25,399	0.946	0.592
Combined	140,568	164,569	63,247	264,297	1.016	0.566	156,105	184,500	69,634	304,399	0.949	0.520

[a] Spawners are natural-origin spawners only.

[b] Recruits are natural-origin adults before ocean harvest.

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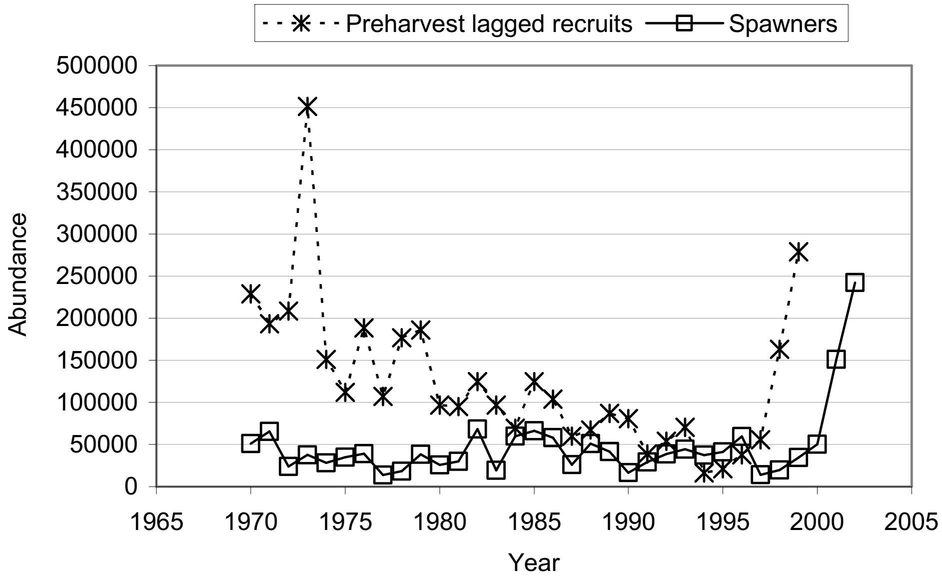

Figure 196. Time series of spawners and preharvest recruits, by broodyear, for rivers in the Oregon Coast coho salmon ESU, 1970–2002.

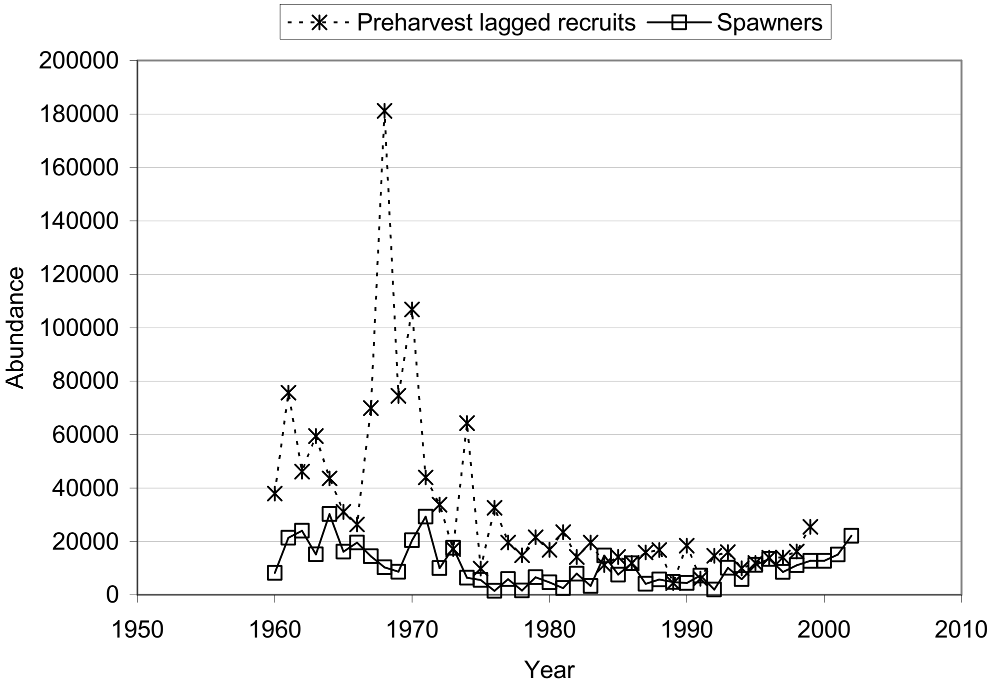

Figure 197. Time series of spawners and preharvest recruits, by broodyear, for lakes in the Oregon Coast coho salmon ESU, 1960–2002.

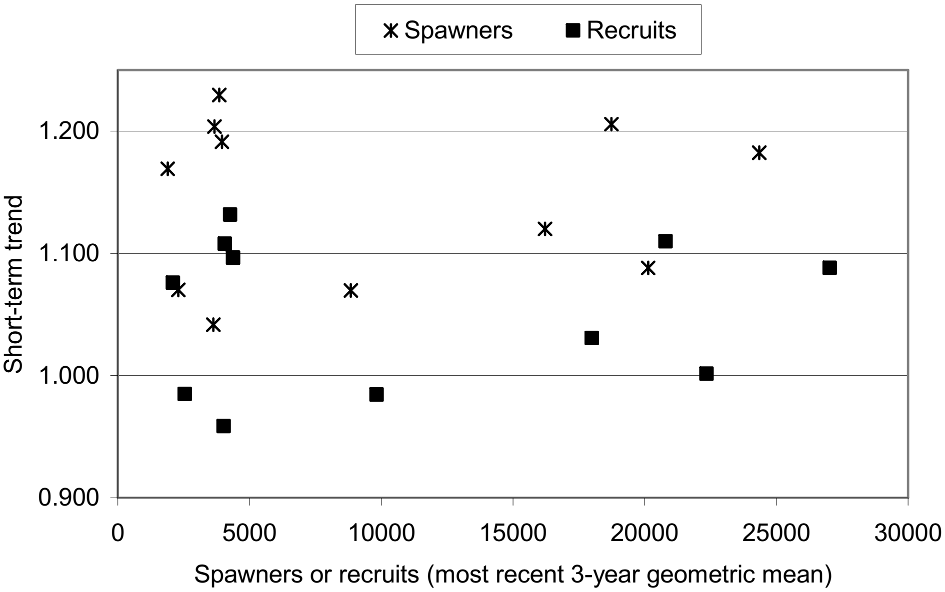

Figure 198. Short-term (13-year, 1990–2002) trends in spawners and recruits versus the recent 3-year geometric mean abundance plotted for 11 major river populations in the Oregon Coast coho salmon ESU.

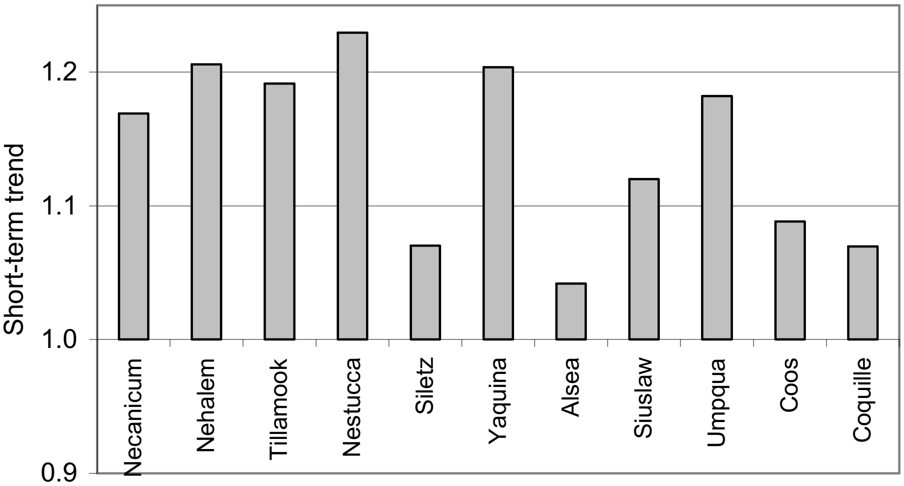

Figure 199. Short-term (13-year, 1990–2002) trends in spawner abundance for 11 major river basins in the Oregon Coast coho salmon ESU. Basins are ordered from north to south.

Growth Rates and Productivity

Trend analyses were performed on short- and long-term time series of spawner abundance and preharvest recruit abundance calculated as described above. Short-term trends were based on SRS estimates of abundance in 11 major river basins considered to be the principal populations in this ESU. Short-term trends used data from 1990 to 2002 return years. Long-term trends were estimated separately for the aggregated coastal rivers (including several small systems outside the 11 major river basins) and for the coastal lakes. The river trends were based on data calibrated to the SRS time series from 1970 to 2002. The lake trends were based on the historical time series of lakes abundance from 1970 to 2002.

Thirteen-year trends of spawner abundance for 11 major river systems are presented in Table 65 and illustrated in Figures 198 and 199. Spawner trends were positive in all 11 basins, with the biggest increases (>10% per year) on the north coast (Necanicum, Nehalem, Tillamook, Nestucca), mid coast (Yaquina, Siuslaw), and the Umpqua, and with smaller increases on the central (Siletz, Siuslaw) and south (Coos, Coquille) coasts. The Alsea showed the weakest trend; it was greater than 1 as of the 2002 spawning returns (Figure 199).

Thirteen-year trends in preharvest recruits (Figures 198 and 200) show a less favorable picture. Necanicum, Nehalem, Tillamook, Nestucca, Yaquina, and Umpqua all showed positive trends of about 8% to 13% per year. Siletz, Alsea, and Coquille showed declines ranging from 1% to 4% per year. Upward trends in the Tillamook, Siuslaw, and Coos hinge on the high 2002 escapements. The most recent 3-year geometric mean abundance showed little relationship to trend (Figure 198).

Long-term (33-year) trends in spawner abundance for both the lakes and rivers have been relatively flat (Table 66, Figure 201), with lakes increasing about 2% per year and rivers increasing about 1% per year. In both the lakes and rivers, long-term trends in recruits have declined about 5% per year since 1970. For the ESU as a whole, spawners and recruits have declined at a 5% rate over the past 33 years.

Population Spatial Structure

We have very limited direct information about the spatial structure of the Oregon Coast coho salmon populations. Recent analyses (Nickelson and Lawson 1998, Nickelson 2001) assumed that spawners from major river basins are largely isolated, and that each basin comprises at least one population. The Umpqua River is large and diverse enough to hold several populations, but for the purposes of this analysis it was considered as one. The three coastal lakes, Siltcoos, Tahkenitch, and Tenmile, are considered to be a single population, but may actually be separate. Genetic analyses are being conducted to resolve these questions, but results were not available at the time of this review. This is a change from the status review update in 1997 (Schiewe 1997), when the Oregon coast was considered to consist of four populations, called gene conservation groups. Three of these groups (north/mid coast, mid/south coast, and Umpqua) were in the Oregon Coast coho salmon ESU and the fourth (south coast) was in the Southern Oregon/Northern California Coast coho salmon ESU.

Population Diversity

New information on population diversity is anecdotal. With extremely low escapements in recent years, many small systems have shown local extirpations. For example, Cummins

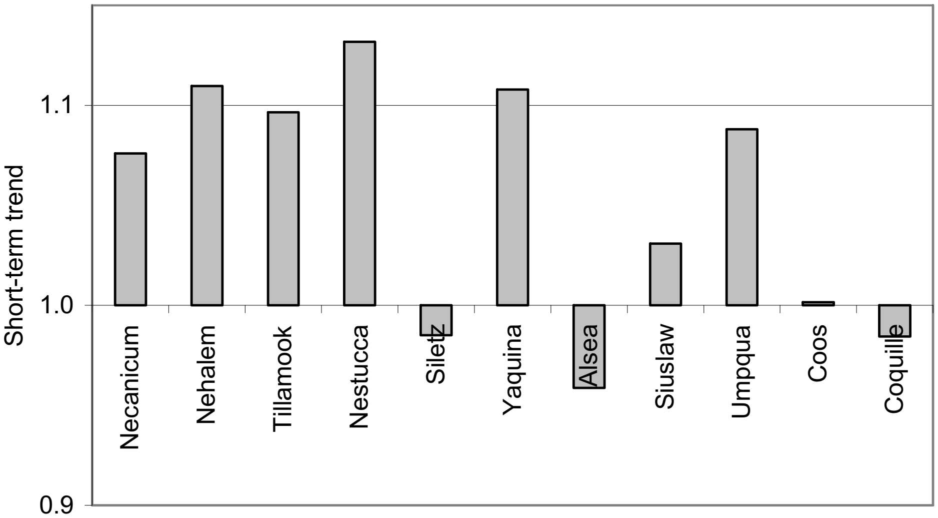

Figure 200. Short-term (13-years, 1990–2002) trends in recruit abundance for 11 major river basins in the Oregon Coast coho salmon ESU. Basins are in order from north to south.

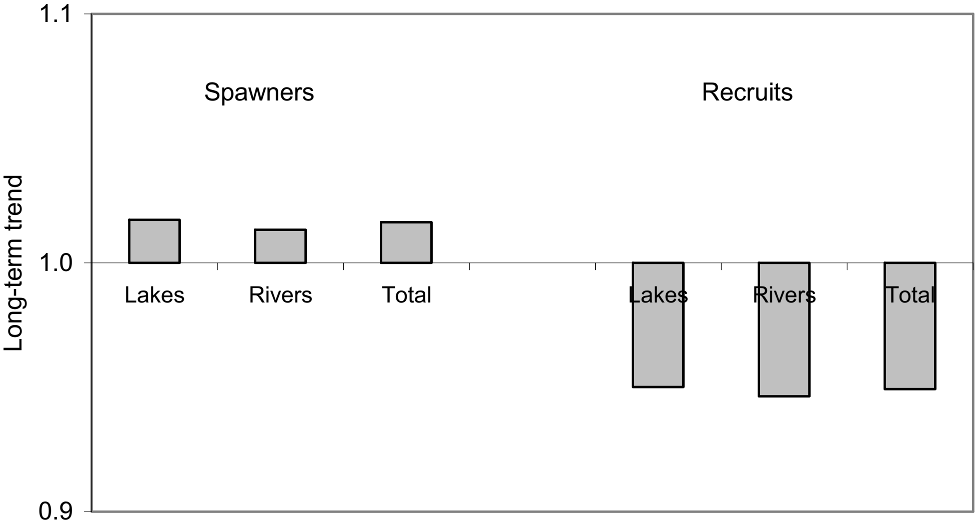

Figure 201. Long-term trends (33 years, 1970–2002) for spawners and recruits in coastal lakes (lakes), river basins (rivers), and total in the Oregon Coast coho salmon ESU.

Creek, on the central coast, had zero spawners in 1998,[43] indicating the loss of a brood cycle. These systems are apt to be repopulated by stray spawners if abundances increase. Whether these events represent loss of genetic diversity, or are indications of normal metapopulation function, is not known.

Harvest Impacts

Historical harvest rates on OPI area coho salmon were in the range of 60% to 90% from the 1960s into the 1980s. Modest harvest reductions were achieved in the late 1980s, but rates remained high until a crisis was perceived, and most directed coho salmon harvest was prohibited in 1994. Subsequent fisheries have been severely restricted, and most reported

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[43] S. Johnson, Oregon Department of Fish and Wildlife, Newport, OR. Pers. commun., 15 January 2003.

mortalities are estimates of indirect (noncatch) mortality in Chinook fisheries and selective fisheries for marked (hatchery) coho. Estimates of these indirect mortalities are somewhat speculative, and there is a risk of substantial underestimation.

Amendment 13

The Pacific Fishery Management Council adopted Amendment 13 (PFMC 1998) to its Salmon Fishery Management Plan in 1998. This amendment was developed as part of the Oregon Plan for Salmon and Watersheds (formerly OCSRI). It specified an exploitation rate harvest management regime with rates for OCN dependent on marine survival (as indexed by hatchery jack:smolt ratios) and parental and grandparental spawning escapements. Exploitation rates ranged from 13% to a maximum of 35%. In 2000, Amendment 13 was reviewed, and the harvest rate matrix was modified to include a 0–8% category under conditions of extremely poor marine survival, as was observed in the late 1990s. At the same time, the maximum exploitation rate was increased to 45%. Exploitation rates were calculated to allow a doubling of spawners under conditions of moderate-to-good ocean survival.

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

Mark-selective fisheries

Beginning in 1998 most adult hatchery-origin coho salmon in the OPI area were marked with an adipose fin clip. This marking allowed the implementation of mark-selective fisheries, with legal retention only of marked fish. Unmarked fish were to be released unharmed. Recreational mark-selective fisheries have been conducted on the Oregon coast in each year since 1998, with quotas ranging from 13,000 to 24,000 marked fish. Commercial troll fisheries targeting Chinook salmon were also operating.

Both the mark-selective coho and commercial troll Chinook salmon fisheries catch and release coho salmon, resulting in incidental mortalities. In addition, some coho encounter the gear but escape or are eaten by predators—so-called drop-offs. Estimates of noncatch mortalities from hook and release and drop-off are difficult because they are, by their nature, unobserved. Field studies in the 1990s (NRC 1996) and a literature review and metaanalysis resulted in the adoption, by the Pacific Fishery Management Council (PFMC), of hooking mortality rates of 13% for recreational fisheries and 24% for commercial fisheries. In addition, drop-off mortalities were assumed to equal 5% of the number of fish brought to the boat. Based on these mortality rates, the PFMC uses a coho FRAM to estimate noncatch mortalities in

Table 68. Oregon Productivity Index (OPI) area hatchery marine survival, Oregon coastal hatchery adult returns per smolt, and OPI area exploitation rate on unmarked coho salmon, 1990–2002. All values are lagged to adult return year.

Year	OPI hatchery adults per smolt	Coastal hatchery adults per smolt	OPI area unmarked exploitation rate	OPI marine survival after exploitation
1990	0.020	0.003	0.72	0.006
1991	0.050	0.007	0.57	0.022
1992	0.026	0.004	0.56	0.011
1993	0.011	0.003	0.45	0.006
1994	0.018	0.005	0.03	0.017
1995	0.024	0.005	0.23	0.018
1996	0.021	0.006	0.15	0.018
1997	0.006	0.005	0.13	0.005
1998	0.008	0.005	0.07	0.007
1999	0.011	0.008	0.08	0.010
2000	0.023	0.014	0.09	0.021
2001	0.050	0.044	0.07	0.046
2002	0.026	0.033	0.12*	0.023

* Preseason estimate.

council-managed fisheries. Postseason estimates of OCN exploitation rates based on FRAM modeling have ranged from 0.07 to 0.12 since the cessation on directed coho salmon fishing in 1994 (Table 68). The BRT is concerned that these rates may be underestimates, and that actual mortalities may be greater. It is difficult to assess the risk to these stocks resulting from harvest at these levels.

Despite these uncertainties, there is no doubt that harvest-related mortalities have been reduced substantially over the past decade. This reduction is reflected in positive short-term trends in spawner escapements (Figure 199) despite continued downward trends in preharvest recruits for 6 of the 11 major river basins (Figure 200). Harvest management has succeeded in maintaining spawner abundance in the face of a continuing downward trend in productivity of these stocks. Further harvest reductions can have little effect on spawning escapements. Future remedies must be found outside of harvest management until the decline in productivity is reversed.

Habitat Condition

Freshwater

The Oregon Plan for Salmon and Watersheds (Oregon Plan 1997) is the most ambitious and far-reaching program to improve watersheds and recover salmon runs in the Pacific Northwest. It is a voluntary program focused on building community involvement, habitat restoration, and monitoring. All state agencies with activities affecting watersheds are required to evaluate their operations with respect to salmon impacts and report on actions taken to reduce these impacts to the governor on a regular basis. The original Coastal Salmon Restoration

Initiative was written in 1997, so the plan has been in operation for several years. As a result of the plan, watershed councils across the state have produced watershed assessments of limiting factors for anadromous salmonids on both public and private land. The State of Oregon has dedicated about $20 million per year to implement restoration projects and is developing a system to link project development with whole-watershed assessments. The Oregon Department of Environmental Quality and the Oregon Department of Agriculture are implementing regulatory mechanisms to reduce non-point-source pollution. If these efforts are successful, Oregon could see a widespread improvement in water quality. There is room for improvement in the reporting of watershed assessment results and limiting factors, and identification of actions to be taken or progress made in addressing these limiting factors. Although this is a significant recovery effort in the Pacific Northwest, and an extensive, coordinated monitoring program is in place, measurable results of the program will take years or decades to materialize.

Marine

The climate regime shift in 1976 was the beginning of an extended period of poor marine survival for coho salmon in Oregon. Conditions worsened in the 1990s, and OPI hatchery survival reached a low of 0.006 adults per smolt in 1997 (1996 ocean entry, Table 68). Coastal hatcheries appear to have fared even worse, although adult counts at these facilities are often incomplete, biasing these estimates low. Following an apparent shift to a more productive climate regime in 1998, marine survival started to improve, reaching 0.05 for adults returning in 2001 (Table 68). The Pacific Decadal Oscillation (PDO) had been in a cold, productive phase for about 4 years, and in August 2001 it reversed, indicating a warm, unproductive period. This reversal may be short-lived; the PDO historically has shown a 20- to 60-year cycle. However, "the rising influence of global warming should throw up a big caution sign to us when trying to use past decadal patterns as predictive models for the future."[44]

A long-term understanding of the prospects for OCN coho can be constructed from a simple conceptual model incorporating a trend in habitat quality and cyclical ocean survival (Figure 202, Lawson 1993). Short-term increases in abundance driven by marine survival cycles can mask longer-term downward trends resulting from freshwater habitat degradation (as in Figure 202) or longer-term trends in marine survival that may be a consequence of global climate change. Decreases in harvest rates (C in Figure 202) can increase escapements and delay ultimate extinction (D in Figure 202). Harvest rates have been reduced to the point where no further meaningful reductions are possible. The current upswing in marine survival is a good thing for OCN coho, but will only provide a temporary respite unless other downward trends are reversed.

New Hatchery Information

Interactions between hatchery and wild fish are generally considered to have negative outcomes for the wild fish. A growing body of literature documents reduced spawning success, freshwater survival, and production of wild fish when hatchery fish are present (NRC 1996, Flagg and Nash 1999, Flagg et al. 2000, Independent Scientific Group [ISG] 2000, IMST 2001,

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[44] N. Mantua, School of Marine Affairs/Joint Institute for the Study of Atmospheric and Oceanic Climate Impacts Group, University of Washington, Seattle. Pers. commun., 7 January 2003.

Einum and Fleming 2001, Chilcote 2002). Additional negative interactions are associated with mark-selective fisheries directed at hatchery coho salmon in the ocean. In the past 12 years there have been closures of some Oregon coastal hatchery facilities, reduction in numbers of smolts released from the remaining facilities, and efforts to include more native broodstock. In principle, these changes should somewhat reduce risks to naturally spawning coho on the Oregon coast. Starting in 1999 most adult coho salmon of hatchery origin were marked with an adipose fin clip. This marking enabled the introduction of mark-selective fisheries for hatchery (fin-clipped) coho salmon. An additional benefit is better accounting of hatchery fish spawning in the wild.

Hatchery smolts released are reported in Table 69. Numbers have dropped from a high of 6.2 million in 1992 to 0.93 million in 2001. Over that time period, several small hatcheries closed or stopped releasing coho. For 3 years (1995–1997) coho smolts were released from the acclimation facility on Yaquina Bay. In 1999, Fall Creek Hatchery on the Alsea River stopped releasing coho salmon smolts. The percentage of hatchery-origin spawners on natural spawning

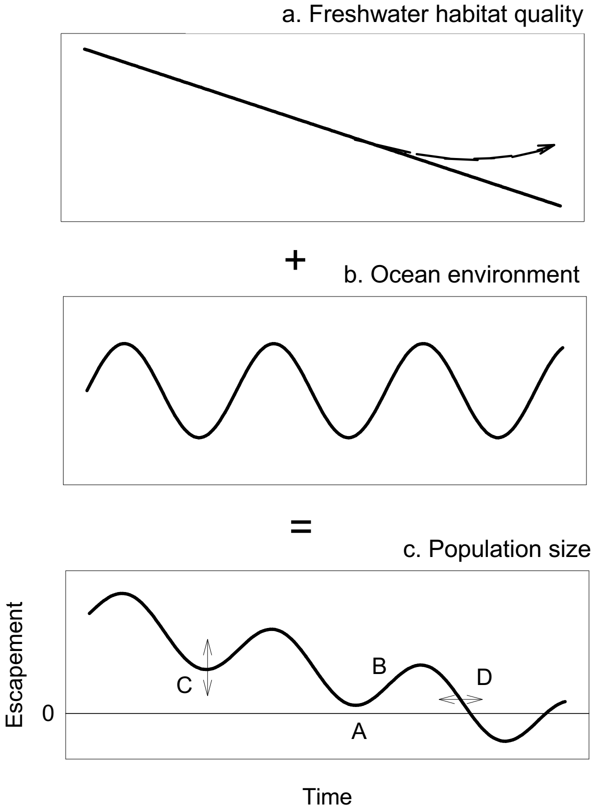

Figure 202. Conceptual model of effects of declining habitat quality and cyclic changes in ocean productivity on the abundance of Oregon's coastal natural coho salmon: a. Trajectory over time of habitat quality. The dotted line represents possible effects of habitat restoration projects. b. Generalized time series of ocean productivity. c. Sum of top two panels; labeled points are A = situation in the mid 1990s, B = current situation, C = change in escapement from increasing or decreasing harvest, and D = change in time of extinction from increasing or decreasing harvest (Lawson 1993).

grounds also decreased (Figure 203, Tables 70 and 71). Throughout most of the1990s, the percentage of natural spawners that were of hatchery origin exceeded 10% in more than half of Oregon coast basins and exceeded 70% in three. By contrast, in the most recent 3 years the proportion of hatchery-origin spawners has generally been much lower (Tables 70 and 71). The decrease is most notable in north coast systems, which had up to 70% hatchery spawners in the early 1990s and have averaged below 5% since 1999. Both the Tillamook and Umpqua basins continue to show elevated numbers of hatchery-origin spawners in most years, and the Alsea River had 7% hatchery spawners in 2001 despite the closure of the Fall Creek Hatchery in that system.

Overall, the reduction in hatchery activity is expected to benefit wild runs. However, it may take several years before these benefits become apparent, depending on the mix of demographic and genetic effects on natural production. In the meantime, the future of the hatchery program is uncertain. On one hand, public opinion and a perceived short-term benefit may create pressure to increase hatchery activity despite the likely negative effects on wild runs. On the other hand, Oregon state budget problems may force additional hatchery closures. The Trask and Salmon river hatcheries were scheduled to be closed in 2001 but were given a last-minute reprieve by the Oregon legislature.

Jacobs et al. (2000) discussed potential errors associated with the change in methodology used to determine the origin of natural spawners. Prior to 1998, hatchery or wild origin was determined primarily by scale analysis, while mass marking permitted the use of adipose fin clips beginning in 1998. In 1998 and 1999 both methods were used. Comparison of results from the two methodologies show that scales tend to indicate greater proportion of hatchery fish than fin clips, although limitations are associated with both methodologies. The primary limitation of scale analysis is availability of adequate reference scales for naturally produced fish, while marking programs may not actually mark 100% of the fish as intended.

Estimates of hatchery fish contribution rates from scale analysis are complicated by the low sample sizes collected during the extremely low coho abundances in the 1990s. ODFW determined that acceptable estimates of hatchery contribution rates could not be made in cases where fewer than 10 scales were collected in a basin in a year. These rates were reported as 0% hatchery fish even when hatchery scales were observed in the sample. Small sample zeros are not distinguishable from true zeros in Table 70, resulting in an underreporting of hatchery contributions that the BRT was unable to evaluate. Figure 203 attempts to minimize this problem by aggregating data from 1992 to 1998, and probably presents a truer overall picture for that time period of general patterns in hatchery fish distribution in the ESU.

Table 69. Millions of smolts released, adult returns, and number of operating hatcheries on the Oregon coast, 1990–2002.

Year	Smolts released (millions)	Adult returns to hatchery	Number of hatcheries[a]
1990[b]	5.70	15,489	6
1991	5.30	39,555	6
1992	6.20	23,307	6
1993	4.33	20,209	6
1994	5.02	23,435	6
1995	3.71	25,173	6
1996	3.28	23,422	7
1997	2.92	17,776	7
1998	1.66	15,287	7
1999	1.06	13,347	6
2000	0.86	14,984	5
2001	0.93	38,149	5
2002	0.98	30,862	5

[a] Excludes three small hatcheries: Elk River, Cedar Creek, and Eel Lake.

[b] An additional 5.4 million smolts were released from private facilities in 1990.

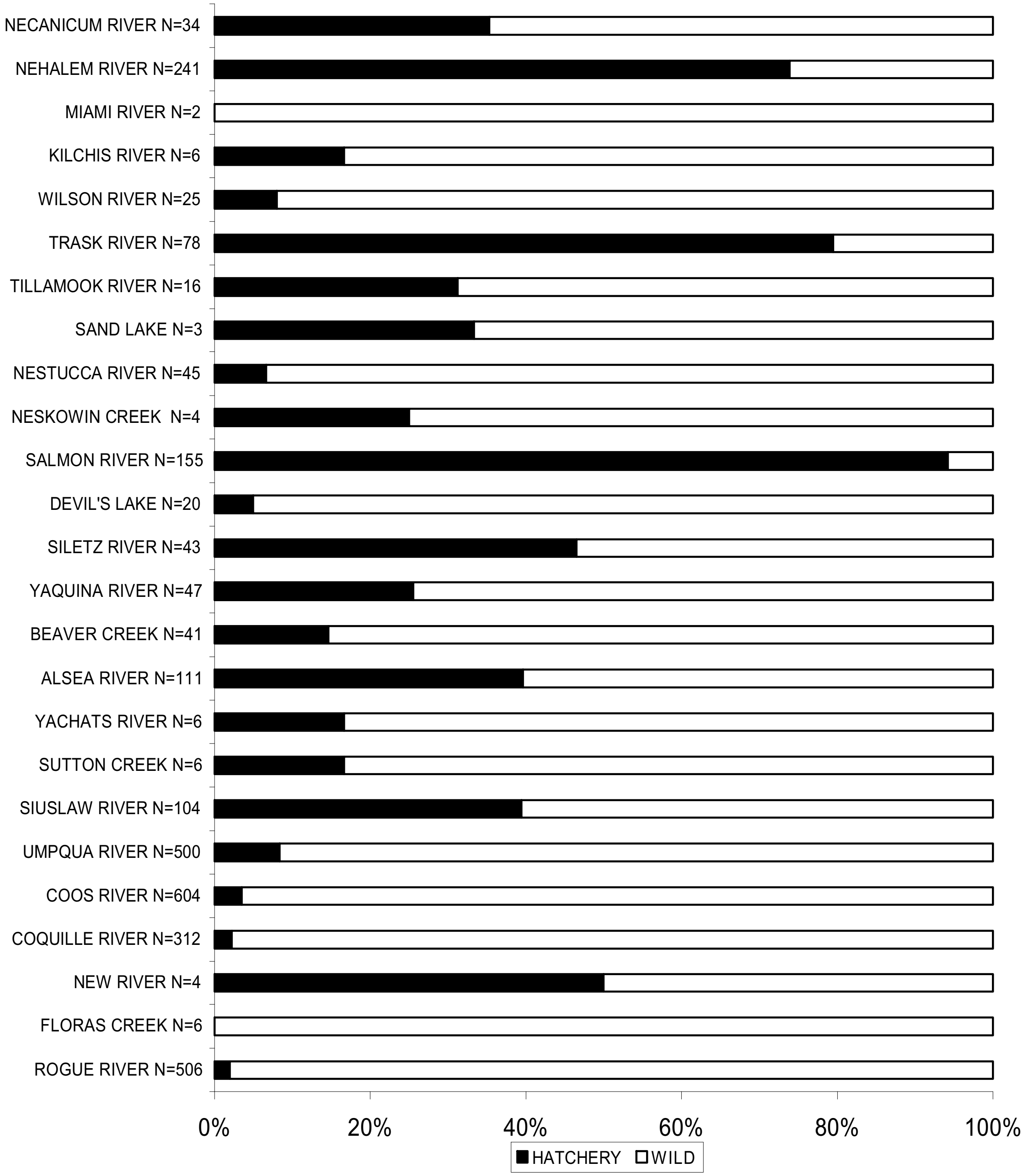

Figure 203. Rearing origin of naturally spawning adult coho salmon in major Oregon coastal river basins over the 6-year period 1992–1998. Estimates derived from analysis of scales collected on random spawning surveys. Samples from the Rogue River basin are only from the most recent 3-year period (1996–1998). Solid bars represent hatchery fish and open bars represent naturally produced fish. Source: Reproduced from Jacobs et al. (2000).

Table 70. Percent of natural spawning (n) coho salmon of hatchery origin in Oregon coastal river basins, based on fin clips from carcasses (1998, 1999) or both carcasses and live fish (2000–2002). Source: Data from Jacobs et al. (2000, 2001, 2002) and S. Jacobs.[a]

	1998		1999		2000		2001		2002	
Major basin	**n**	**%H[b]**	**n**	**%H[b]**	**n**	**%H**	**n**	**%H**	**n**	**%H**
North Coast										
Necanicum and Elk creeks	2	0.0	8	0.0			605	6.4	280	2.9
Nehalem[c]	22	26.0	14	0.0	1,995	0.5	2,735	2.0	2,535	6.2
Tillamook Bay	1	0.0	18	5.6	224	10.8	124	4.1	1,874	2.0
Nestucca	1	0.0	20	0.0	188	2.1	212	10.4	1,034	1.6
North Coast totals, average	26	22.0	60	1.7	2,407	1.6	3,676	3.3	5,723	3.8
Mid-North										
Salmon	142	98.6	6	17.5					145	34.5
Siletz[d]	2	100.0	5	41.9	185	2.7	153	12.4	171	1.8
Yaquina	16	37.5	6	0.0			239	1.7	1,579	0.3
Devil's Lake and Beaver Creek	19	21.1	13	0.0			193	1.6	527	0.8
Alsea	24	87.5	4	0.0	107	2.8	162	7.4	448	0.2
Siuslaw	9	11.1	15	6.7	351	0.9	782	1.2	3,240	0.3
Coastal lakes	647	0.0	80	1.3	54	0.0	183	0.0	3,293	0.1
Mid-North totals, average	859	20.3	129	4.0	697	1.6	1,712	2.8	9,403	0.8
Umpqua										
Smith[e]	59	0.0	25	0.0	693	0.4	1,603	2.3	2,252	1.1
Mainstem Umpqua	7	14.3	17	5.9	209	3.3	508	40.8	617	5.8
Elk and Calapooya creeks	10	10.0	13	15.4	231	3.9	158	1.3	204	2.9
South Umpqua	11	36.4	47	6.4			285	4.6	67	0.0
Cow Creek	21	14.0	34	3.0	124	21.8	498	5.1	192	1.6
Umpqua totals, average	108	8.3	136	5.2	1,257	3.7	3,052	9.3	3,332	2.1
Mid-South										
Coos Bay	53	1.9	85	0.0	376	0.0	2,569	0.8	4,145	0.3
Coquille	29	0.0	40	0.0	431	0.2	1,733	6.0	880	0.9
Tenmile Lake	51	0.0	80	0.0	65	0.0	767	0.1	341	1.5
Floras Creek and New River	10	0.0	4	0.0			217	5.1	2	0.0
Mid-South totals, average	143	0.7	209	0.0	872	0.1	5,286	2.6	5368	0.4
Coastwide totals, average	1,136	16.7	534	2.5	5,233	1.8	13,726	4.3	23,826	1.6

[a] Steve Jacobs, Oregon Department of Fish and Wildlife, Corvallis, OR. Pers. commun., 9 April 2003.

[b] Hatchery percentages from 1998 and 1999 are adjusted by marked:unmarked ratios at the nearest hatchery facility.

[c] 2002 data are missing dead fish from North Nehalem, area of high hatchery straying.

[d] In 2002, does not include recoveries from Steer Creek, located near Siletz Tribal Release Point. With Steer Creek recoveries, n = 435, %H = 49.4%.

[e] Includes lower Umpqua River in 2000, 2001, and 2002.

Table 71. Proportion of natural spawning fish of hatchery origin, 1990–2002. In some cases with insufficient data ODFW reported 0.00 hatchery spawners when, in fact, hatchery spawners may have been present.

Management area/ location	**Return year**												
	1990 [a]	**1991 [a]**	**1992 [a]**	**1993 [a]**	**1994 [a]**	**1995 [a]**	**1996 [a]**	**1997 [a]**	**1998[b]**	**1999 [b]**	**2000 [b]**	**2001 [b]**	**2002 [b]**
North coast													
Necanicum and Elk creeks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Nehalem	0.65	0.22	0.43	0.81	0.43	0.49	0.74	0.45	0.23	0.00	0.00	0.02	0.08
Tillamook Bay	0.00	0.00	0.00	0.53	0.29	0.62	0.14	0.08	0.00	0.06	0.11	0.13	0.02
Nestucca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.02
Sand Lake and Neskowin Creek	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00	0.00
North coast average	0.57	0.11	0.28	0.70	0.34	0.33	0.49	0.32	0.12	0.02	0.02	0.02	0.05
Mid-north													
Salmon	0.11	0.00	0.80	0.00	0.93	0.84	0.90	0.43	0.99	0.17	1.00	0.76	0.20
Siletz	0.00	0.71	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.30	0.45
Yaquina	0.38	0.00	0.00	0.00	0.00	0.00	0.16	0.27	0.38	0.00	0.00	0.05	0.00
Beaver Creek	0.00		0.00	0.00	0.00		0.00	0.00	0.21	0.00	0.00	0.07	0.00
Alsea	0.01	0.00	0.17	0.00	0.00	0.00	0.00	0.27	0.87	0.00	0.00	0.15	0.00
Yachats	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siuslaw	0.00	0.00	0.00	0.04	0.38	0.00	0.26	0.00	0.11	0.07	0.00	0.00	0.00
Miscellaneous	0.00	1.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00	0.00	0.00
Mid-north average	0.05	0.26	0.14	0.02	0.26	0.08	0.25	0.17	0.45	0.08	0.04	0.09	0.02
Umpqua													
Lower Umpqua and Smith	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.03	0.01	0.02
Umpqua	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.06	0.08	0.32	0.04
Elk Creek and Calapooya Creek	0.00				0.00	0.00	0.00	0.00	0.10	0.15	0.03	0.02	0.00
South Umpqua	0.00	0.00		0.00	0.00	0.08	0.77	0.21	0.05	0.04	0.00	0.08	0.00
Cow Creek			0.00	0.00	0.71	0.08	0.58	0.00	0.67	0.00	0.09	0.09	0.02
Umpqua average	0.06	0.00	0.00	0.00	0.13	0.01	0.43	0.08	0.09	0.03	0.05	0.14	0.02
Mid-south													
Coos Bay and Big Creek	0.00	0.00	0.03	0.05	0.03	0.01	0.00	0.00	0.02	0.00	0.00	0.02	0.00
Coquille	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.01
Mid-south average[c]	0.00	0.00	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Coastwide rivers	0.17	0.11	0.09	0.21	0.15	0.07	0.22	0.11	0.16	0.03	0.03	0.07	0.02
Lakes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coastwide total	0.17	0.11	0.09	0.21	0.15	0.07	0.22	0.11	0.16	0.03	0.03	0.07	0.02

[a] Data from 1990 to 1997 are based on scale analysis.

[b] Data from 1998 to 2002 are based on fin clips.

[c] Excluding Floras Creek and Sixes River.

28. Southern Oregon/Northern California Coast Coho Salmon ESU

Summary of Previous BRT Conclusions

The Southern Oregon/Northern California Coast (SONCC) coho salmon ESU extends from Cape Blanco in southern Oregon to Punta Gorda in northern California (Weitkamp et al. 1995). The status of coho salmon coastwide, including the SONCC ESU, was formally assessed in 1995 (Weitkamp et al. 1995). NMFS has published two subsequent status review updates, one addressing all West Coast coho salmon ESUs (NMFS 1996b) and a second specifically addressing the Oregon Coast coho salmon and SONCC coho salmon ESUs (NMFS 1997c). Information from those reviews regarding extinction risk, risk factors, and hatchery influences is summarized in the following subsections.

Status Indicators and Major Risk Factors

California populations

Data on population abundance and trends were limited for the California portion of the SONCC coho salmon ESU. The BRT found no regular estimates of natural spawner escapement for coho salmon in the ESU, and most information used by the BRT came from reviews by California Department of Fish and Game (CDFG 1994a) and Brown et al. (1994). Historical point estimates of coho salmon abundance for the early 1960s and mid-1980s cited in these reviews were taken from CDFG (1965), Wahle and Pearson (1987), and Sheehan (1991).[45] These estimates suggest that statewide coho spawning escapement in the 1940s ranged between 200,000 and 500,000 fish.[46] By the early to mid-1960s, statewide escapement was estimated to have declined to just under 100,000 fish (CDFG 1965), with approximately 43,000 fish (44%) originating from rivers within the SONCC ESU (Table 72). Wahle and Pearson (1987) estimated that statewide coho salmon escapement had declined to approximately 30,000 fish by the mid-1980s, with about 12,400 (41%) originating within the SONCC coho salmon ESU. For the late 1980s, Brown et al. (1994) estimated wild and naturalized coho salmon populations at 13,240 for the state, and 7,080 (53%) for the California portion of the SONCC coho salmon ESU. To derive their estimate, they employed a "20-fish rule," in which all streams known to historically support coho salmon, except those for which recent surveys indicated coho salmon

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[45] For mid-1980s estimates, Brown et al. (1994) cite Wahle and Pearson (1987), who estimate 30,480 total spawners in California, whereas CDFG (1994) cites Sheehan's (1991) estimate of 33,500 spawners. It is unclear how Sheehan's estimates were derived, and no basin-specific estimates are presented. Thus, we have included the estimates of Wahle and Pearson (1987) in Table 71, rather than the Sheehan's (1991) estimates, cited by the BRT (Weitkamp 1995).

[46] E. Gerstung, California Depart of Fish and Game, pers. commun., cited in Brown et al. (1994).

Table 72. Historical estimates of coho salmon spawner abundance for various rivers and regions within the Southern Oregon/Northern California Coast (SONCC) coho salmon ESU.

	Estimated escapement				
River/region	CDFG (1965)[a] 1965		Wahle and Pearson (1987)[b] 1984–1985		Brown et al. (1994)[c] 1987–1991
California rivers tributaries to Oregon coast streams		1,000			
Smith River		5,000		2,000	820[d]
Other Del Norte County		400			180[d]
Klamath River		15,400		3,400	1,860
Mainstem Klamath River and tributaries	8,000		1,000		
Shasta River	800		300		
Scott River	800		300		
Salmon River	800		300		
Trinity River	5,000		1,500		
Redwood Creek		2,000		500	280
Mad River		2,000		500	460
Eel River		14,000		4,400	2,040[d]
Mainstem Eel River	500		200		
Van Duzen River	500		200		
South Fork Eel River	13,000		4,000		
North Fork Eel River	0		0		
Middle Fork Eel River	0		0		
Mattole River		2,000		500	760[d]
Other Humboldt County		1,500		1,130	680[d]
ESU total		43,300		12,430	7,080
California statewide total[e]		99,400		30,480	13,240

[a] Excludes ocean catch. CDFG = California Department of Fish and Game.

[b] Estimates are for wild or naturalized fish; hatchery returns excluded.

[c] Estimates are for wild or naturalized fish; hatchery returns excluded. For streams without recent spawner estimates (or estimates lower than 20 fish), assumes 20 spawners.

[d] Indicates high probability that natural production is by wild fish rather than naturalized hatchery stocks.

[e] Estimated number of coho salmon for Central California Coast coho salmon ESU and California portion of the SONCC coho salmon ESU combined.

no longer persist (19% of the total), were assumed to still support 20 spawners. For streams where a recent estimate of spawner abundance existed, they used either that estimate or 20 fish, whichever was larger. They suggested that application of the “20-fish rule” likely overestimated total abundance. As Brown et al. (1994) pointed out, all of these historical estimates are “guesses” that fishery managers and biologists generated using a combination of limited catch statistics, hatchery records, and personal observations.

Additional information regarding the status of coho salmon in the SONCC coho salmon ESU was obtained from an analysis of recent (1987–1991) occurrence of coho salmon in streams historically known to support coho populations (Brown et al. 1994). Of 115 historical streams in the SONCC coho salmon ESU for which recent data were available, 73 (63%) were determined to still support coho salmon, whereas it was believed they had been lost from 42 (37%). The estimated percentage of streams with coho salmon still present was lower for Del Norte County (55%) than for Humboldt County (69%). NMFS (1996b) presented more recent data (1995–1996) on presence of coho salmon within the SONCC ESU, which suggested that the percentage of streams still supporting coho salmon was lower than estimated by Brown et al. (1994). Of 176 streams recently surveyed in the SONCC ESU, 92 (52%) were found to still support coho salmon (P. Adams[47]). The estimated percentage of streams still supporting coho salmon was lower (46%) in Del Norte County than in Humboldt County (55%).

The BRT also considered two recent reviews assessing the status of coho salmon stocks in California. Nehlsen et al. (1991) identified coastal populations of coho salmon north of San Francisco Bay (includes portions of the SONCC and Central California Coast coho salmon ESUs) as being at moderate risk of extinction and Klamath River coho salmon as a stock of special concern. The Humboldt chapter of the American Fisheries Society (Higgins et al. 1992), using more detailed information on individual river basins, considered three stocks of coho salmon in the SONCC coho salmon ESU as being at high risk of extinction (Scott River [Klamath], Mad River, and Mattole River), and eight more stocks as being of special concern (Wilson Creek, lower Klamath River, Trinity River, Redwood Creek, Little River, Humboldt Bay tributaries, Eel River, and Bear River).[48]

Oregon populations

For the 1997 status update (NMFS 1997c), the BRT was asked to evaluate the status of the ESU under two conditions: 1) under existing conditions; 2) assuming that hatchery and harvest reforms of the Oregon Coastal Salmon Restoration Initiative (OCSRI) were implemented.

Evaluation under existing conditions

In the Rogue River basin, natural spawner abundance in 1996 was slightly above 1994 and 1995 levels. Abundances in the most recent 3 years were all substantially higher than abundances in 1989–1993 and were comparable to counts at Gold Ray Dam (upper Rogue) in the 1940s. Estimated return ratios for 1996 were the highest on record, but this may have been influenced by an underestimate of parental spawners. The Rogue River run included an estimated 60% hatchery fish in 1996, comparable to previous years. The majority of these hatchery fish returned to Cole Rivers Hatchery, but there was no estimate of the number that strayed into natural habitat.

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[47] P. Adams, Southwest Fisheries Science Center, pers. commun., cited in NMFS (1996b).

[48] Weitkamp et al. (1995), citing Higgins et al. (1992), indicate that the numbers of stocks at “moderate risk of extinction” and “of special concern” in the SONCC Coho salmon ESU are 6 and 10, respectively. These numbers appear to be in error.

Evaluation with hatchery and harvest reforms

The BRT considered only two sets of measures from the OCSRI—harvest management reforms and hatchery management reforms. The BRT did not consider the likelihood that these measures would be implemented; rather, it only considered the implications for ESU status if these measures were fully implemented as described. The BRT expressed several concerns regarding the harvest and hatchery components of the OCSRI plan. Some BRT members were greatly concerned that we do not know enough about the causes of declines in run size and recruits per spawner to directly assess the effectiveness of specific management measures. Some members felt that harvest measures were the most encouraging part of the plan, representing a major change from previous management. However, another concern was that the harvest plan might have been seriously weakened when it was reevaluated in 2000 as well as concern about our ability to effectively monitor nontarget harvest mortality and control overall harvest impacts.

Of the proposed hatchery measures, substantial reductions in smolt releases were thought to have the most predictable benefit for natural populations; all else being equal, fewer fish released should result in fewer genetic and ecological interactions with natural fish. Marking all hatchery fish should also help to resolve present uncertainties about the magnitude of these interactions. However, the BRT expressed concerns regarding some aspects of the proposed hatchery measures. The plan was vague on several key areas, including plans for incorporation of wild broodstock and how production was to be distributed among facilities after 1997. One concern was that the recent and proposed reductions appear to be largely motivated by economic constraints and the present inability to harvest fish if they were produced rather than by recognition of negative effects of stray hatchery fish on wild populations. Other BRT concerns included no reductions in fry releases in many basins and no consideration of alternative culture methods that could be used to produce higher-quality hatchery smolts, which may have less adverse impact on wild fish. Another concern was the plan's lack of recognition that hatchery-wild interactions reduce genetic diversity among populations.

Specific risk factors BRT identified included low current abundance, severe decline from historical run size, the apparent frequency of local extinctions, long-term trends that are clearly downward, degraded freshwater habitat and associated reduction in carrying capacity, and widespread hatchery production using exotic stocks. Of particular concern to the BRT was evidence that hatchery releases of coho salmon heavily influenced several of the largest river basins in the SONCC—including the Rogue, Klamath, and Trinity rivers. Historical transfer of stocks back and forth between SONCC and Central California Coast coho salmon ESU streams was common, and SONCC streams have also received plants from stocks from hatcheries in the Lower Columbia River/Southwest Washington, Puget Sound/Strait of Georgia, and Oregon Coast coho salmon ESUs. However, the BRT considered the frequency of out-of-basin plants to be relatively low compared with other coho salmon ESUs. Recent (late 1980s and early 1990s) droughts and unfavorable ocean conditions were identified as further likely causes of decreased abundance.

Previous BRT Conclusions

In the 1995 status review, the BRT was unanimous in concluding that coho salmon in the SONCC coho salmon ESU were not in danger of extinction, but were likely to become so in the foreseeable future if present trends continued (Weitkamp et al. 1995). In the 1997 status update, estimates of natural population abundance in this ESU were based on very limited information. Favorable indicators included recent increases in abundance in the Rogue River and the presence of natural populations in both large and small basins, factors that may provide some buffer against extinction of the ESU. However, large hatchery programs in the two major basins (Rogue and Klamath/Trinity) raised serious concerns about effects on, and sustainability of, natural populations. New presence-absence data from northern California streams that historically supported coho salmon were even more disturbing than earlier results, indicating that a smaller percentage of streams in this ESU contained coho salmon compared to the percentage presence in an earlier study. However, it was unclear whether these new data represented actual trends in local extinctions, or were biased by sampling effort. This new information did not change the BRT's conclusion regarding the status of the SONCC coho salmon ESU. Although the OCSRI proposals were directed specifically at the Oregon portion of this ESU, the harvest proposal would affect ocean harvest of fish in the California portion as well. The proposed hatchery reforms can be expected to have a positive effect on the status of populations in the Rogue River basin. However, the BRT concluded that these measures would not be sufficient to alter the previous conclusion that the ESU is likely to become endangered in the foreseeable future.

Coho salmon in the SONCC ESU were listed as threatened in May 1997 (NMFS 1997e). On 18 July 1997, NMFS published an interim rule (NMFS 1997c) that identified several exceptions to the ESA's Section 9 take prohibitions.

Listing status: Threatened.

New Data and Updated Analyses

Because data types and sources differ substantially between the California and Oregon portions of the ESU, we present information separately for each area.

California Populations

Since the status review for West Coast coho salmon (Weitkamp et al. 1995) and subsequent updates (NMFS 1996b, and NMFS 1997c) were completed, new data and analyses related to the status of coho salmon in the California portion of the SONCC ESU have become available. Most data are of two types: 1) compilations of presence-absence information for coho streams from the period 1987 to 2000, and 2) new data on densities of juvenile coho salmon in index reaches surveyed by private timber companies. We found no time series of adult counts (excepting those substantially influenced by hatchery production), and only five time series of adult spawner indices (maximum live/dead counts) for tributaries of the Eel River (Sprowl Creek), the Mad River (Canon Creek), and the Smith River (West Branch of Mill Creek [two data sets] and East Branch of Mill Creek) that span a period of 8 years or more, none of which are considered reliable indicators of population trends. Limitations of these data sets are discussed in detail below.

Two independent analyses of presence-absence and limited time-series data for the SONCC have been published recently. CDFG (2002a) analyzed coho salmon presence-absence data for SONCC streams spanning broodyears 1986–2000. NMFS (2001b) published an updated status review for coho salmon in the California portion of the SONCC, which also included analysis of presence-absence information. Since then, scientists at the Southwest Fisheries Science Center have continued compiling data on coho salmon distribution and abundance and reanalyzed the updated data, inclusive of data used in the CDFG (2002c) analysis. Thus, results presented in this report supercede those presented in NMFS (2001b).

CDFG Presence-Absence Analysis

Methods

Staff at the CDFG North Coast Region attempted to gather all published and unpublished data collected for 392 streams identified by Brown and Moyle (1991) as historical coho salmon streams.[49] Sources of data included field notes, planting records, and fish surveys from federal, state, and tribal agencies; private landowners; and academic institutions, as well as summaries contained in several recently published status reviews (Ellis 1997, Brownell et al. 1999, and NMFS 2001b). For each stream and year in which surveys were conducted, observations of coho salmon presence or absence were assigned to the appropriate broodyear. If more than one life stage was observed during a survey, then presence was assigned to more than one broodyear. Streams that were not surveyed during a particular year were assigned a "presence" value if fish were documented in an upstream tributary during that year. Overall, the CDFG data set encompasses records from broodyears 1986 to 2000, or five complete brood cycles. Additionally, CDFG (2002c) presented results of an extensive field study conducted in the summer of 2001 in which 287 of the 392 Brown and Moyle (1991) streams were surveyed for juvenile coho salmon presence-absence.[50]

For their broodyear analysis, CDFG (2002c) compared the percentage of streams for which coho salmon were detected at any time during two time periods: broodyears 1986–1991 and 1996–2000. The first period was designed to coincide with the period encompassed by the Brown and Moyle (1991) study. Statistics were generated based on data from all streams within the SONCC on the original Brown and Moyle list, as well as the subset of these streams that were sampled at least once during each of the two time periods. CDFG (2002c) also calculated the percentage of streams for which coho salmon were detected in the 2001 field survey.

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[49] Brown and Moyle (1991) identified 396 streams in California as historical coho streams; however, four of those streams were dropped by CDFG, either because barriers make historical occupancy highly unlikely, because the record of occurrence likely reflects a hatchery outplanting, or because streams were duplicated in the Brown and Moyle list.

[50] CDFG repeated their survey of Brown and Moyle (1991) streams in the summer of 2002; however, the Brown and Moyle data were unavailable at the time of the CDFG analysis.

Results

Including only streams on the Brown and Moyle list, CDFG (2002c) found that coho salmon were observed in 143 of 235 (61%) streams surveyed during the period covering broodyears 1986–1991 (Table 73). This number is similar to the value of 63% found by Brown and Moyle (1991) based on information on about half as many streams (115). For broodyears 1995–2000, surveys were conducted on 355 of the 392 historical coho salmon streams. Of these, coho salmon were detected in 179 (50%), suggesting a decline in occupancy. However, when the analysis was restricted to only the 223 streams for which data were available from both time periods, the percent of streams in which coho were detected went from 62% in 1986–1991 to 57% in 1995–2000, a change that was not statistically significant (Pearson chi square test, p = 0.228; Yates corrected chi square test, p = 0 .334).

For the 2001 field survey, presence was confirmed in only 121 (42%) of the 287 streams surveyed within the SONCC coho salmon ESU. CDFG (2002c) makes two cautions in interpreting their year-2001 results. First, CDFG considered sampling intensity to be sufficient to have a high likelihood of detecting fish for only 110 of the 166 streams where coho salmon were not found. Second, they note that absence of fish in a single year class does not mean that fish have been extirpated from the system.

NMFS Presence-Absence Analysis

Methods

Scientists at the NMFS Southwest Fisheries Science Center compiled a presence-absence database for the SONCC coho salmon ESU similar to that developed by CDFG. The data set includes information for coho salmon streams listed on the Brown and Moyle (1991) list, as well as other streams for which we have found historical or recent evidence of coho salmon presence. The data set is a composite of information contained in the NMFS (2001b) status review update, additional information gathered by NMFS since publication of the 2001 status review, data used in the CDFG (2002c) analysis, and additional data compiled by CDFG (Jong 2002) for streams not on the Brown and Moyle (1991) list. As such, the database combines information taken from primary sources such as stream surveys, data reports, and electronic files, as well as from secondary sources, including recent compilations of presence-absence data by Ellis (1997), Brownell et al. (1999), NMFS (2001b), CDFG (2002b), and Jong (2002). In many cases, we were unable to obtain original sources underlying the various data compilations, so we generally relied on the accuracy of these secondary sources.

There are four significant differences between the data and analytical approach used by NMFS as compared with CDFG's (2002c) status review. First, the NMFS analyzed data for all streams with some historical record of coho salmon presence, whereas CDFG restricted their analysis to those streams found on the Brown and Moyle (1991) list. Second, the NMFS database spans a slightly different time period: broodyears 1987–2001 (rather than 1986 to 2000). At the time these data were compiled, data from summer 2002 field surveys were only partially reported; thus, results from broodyear 2001 are preliminary. Third, unlike CDFG (2002c), we did not infer presence in streams on the basis of occurrence in upstream tributaries. Although there is an intuitive logic to assigning presence to streams en route to a particular

Table 73. Historical presence of coho salmon in the Southern Oregon/Northern California Coast (SONCC) ESU, as determined by Brown and Moyle (1991) and the California Department of Fish and Game's presence-by-broodyear investigation (as of February 2002). Source: Table modified from CDFG (2002c).

	Brown and Moyle (1991) calendar years 1987–1990				**CDFG (2002c) broodyears 1986–1991**				**CDFG (2002c) broodyears 1995–2000**			
County[*]/river basin	**No. of streams**	**No. of streams with information**	**Coho present**	**%**	**No. of streams**	**No. of streams with information**	**Coho present**	**%**	**No. of streams**	**No. of streams with information**	**Coho present**	**%**
Del Norte County												
Coastal	9	1	1		8	5	3		8	8	6	
Smith River	41	2	2		41	21	7		41	39	14	
Klamath River	113	41	21		112	82	48		112	89	55	
Subtotal	163	44	24	54	161	108	58	53	161	136	75	55
Humboldt County												
Coastal	34	7	7		33	16	14		33	32	18	
Redwood Creek	14	3	3		14	12	12		14	14	11	
Mad River	23	2	2		23	10	8		23	22	14	
Eel River	124	56	34		123	80	48		123	116	45	
Mattole River	38	3	3		38	9	3		38	35	16	
Subtotal	233	71	49	69	231	127	85	67	231	219	104	47
ESU total	396	115	73	63	392	235	143	61	392	355	179	50

[*] County classifications are based on the location of the mouth of the river system.

location, including these “inferred presence” values in the analysis tends to positively bias the overall estimate of percent occupancy because the same rationale for inference cannot be applied in the case of a recorded “absence.” The magnitude of this bias on estimated occupancy rates for a given year depends on several factors, including the proportion of streams sampled, the true occupancy rate for the year, and basin size, all of which affect how many inferences of presence can be made. Finally, in our analysis, we present summary information both by broodyear and by brood cycle (3-year aggregation). In contrast, the CDFG (2002c), in its broodyear analysis calculated percent occupancy for 6-year time spans (two complete brood cycles): any observation of presence during that 6-year window resulted in a value of presence for the entire period.

Concerns have been expressed (CDFG 2003b) about the validity of including certain streams cited as historical coho streams in various previously published status reviews. We have removed streams from our list that we found to be in error, including those CDFG explicitly identified as questionable. However, we retained information provided by secondary sources in the absence of contradictory information. We also compared our historical stream list with CDFG’s and found that, although the NMFS stream list includes some streams not found on CDFG’s list, most of them have limited, if any, data associated with them. We estimate that observations associated with these streams constitute only about 1% of the more than 9,000 observations in the database, and the proportion of “presence” values in this subset is comparable to those observed for the entire data set. Thus, even if some of these streams are found to be in error, including them likely has minimal effect on estimated occupancy rates for the ESU.

Results for the NMFS presence-absence analyses are presented by major watersheds or aggregations of adjacent watersheds (Table 74). In general, results from larger watersheds are presented independently, whereas data from smaller coastal streams, where data were relatively sparse, are grouped together. In a few cases, individual smaller coastal streams with only a few observations were aggregated with adjacent larger streams if there was no logical geographic grouping of smaller streams. We did not perform statistical analyses of temporal trends in estimated occupancy rates because of the substantial variation in the sampling methods and intensities represented in the data set, both at the level of individual observations (e.g., index reaches versus whole stream surveys) and among years (i.e., changes in the number of streams surveyed or the principal survey methods through time). Fitting a statistical model to these data without better understanding of the underlying error structure would be of questionable value and would give an illusion of analytical rigor that is likely not supported by the underlying data.

Results

On an annual basis, the estimated percentage of streams in the SONCC for which coho salmon presence was detected generally fluctuated between 36% and 61% between broodyears 1986 and 2000 (Figure 204). Data reported for the 2001 broodyear suggest a strong year class, as indicated by an occupancy rate of more than 75%; however, the number of streams for which data were reported is small compared to previous years. The data suggest that, for the period of record, occupancy rates in the SONCC were highest (54–61%) between broodyears 1991 and 1997, then declined between 1998 and 2000 (39–51%) before rebounding in 2001. The pattern

Table 74. Percent of surveyed streams within the Southern Oregon/Northern California Coast (SONCC) ESU for which coho salmon were detected for four time intervals: broodyears 1987–1989, 1990–1992, 1993–1995, 1996–1998, and 1999–2001. Streams include those for which historical or recent evidence of coho salmon presence exists (based on NMFS and CDFG data, excluding inferred presences in CDFG data).

County and river basins	No. of streams with historical presence	1987–1989			1990–1992			1993–1995			1996–1998			1999–2001		
		No. surveyed[a]	% Coho present[b]	% Coho absent[c]	No. surveyed[a]	% Coho present[b]	% Coho absent[c]	No. surveyed[a]	% Coho present[b]	% Coho absent[c]	No. surveyed[a]	% Coho present[b]	% Coho absent[c]	Number surveyed[a]	% Coho present[b]	% Coho absent[c]
Del Norte (includes Oregon tributaries)																
Illinois River	9	0	–	–	2	100	0	2	50	50	7	100	0	4	75	25
Smith River-Winchuck River	57	20	20	80	19	42	58	45	53	47	28	32	68	44	43	57
Klamath River - Trinity River	210	128	66	34	127	72	28	139	68	32	135	62	38	133	55	45
Humboldt																
Redwood Creek	23	10	80	20	10	100	0	19	79	21	13	92	8	19	84	16
Stone/Big lagoons	5	1	0	100	2	100	0	1	0	100	2	50	50	5	20	80
Litte River-Strawberry Creek	9	8	100	0	9	100	0	6	100	0	5	100	0	6	83	17
Mad River	23	8	100	0	7	86	14	7	86	14	9	78	22	22	64	36
Humboldt Bay tributaries	48	20	95	5	16	94	6	32	97	3	17	88	12	24	63	37
Eel River	221	109	47	53	126	59	41	132	58	42	59	31	69	151	30	70
Bear River-Guthrie Creek	5	0	–	–	0	–	–	3	0	100	2	0	100	4	0	100
Mattole River-McNutt Gulch	56	5	60	40	11	36	64	21	71	29	42	79	21	41	37	63
ESU Total	666	309	60	40	329	67	33	407	66	34	319	60	40	453	45	55

[a] Total number of steams surveyed at least once within the 3-year interval.

[b] Percentage of surveyed streams in which coho were present in one or more years during the interval.

[c] Percentage of surveyed streams in which coho were absent in all years of survey during the interval.

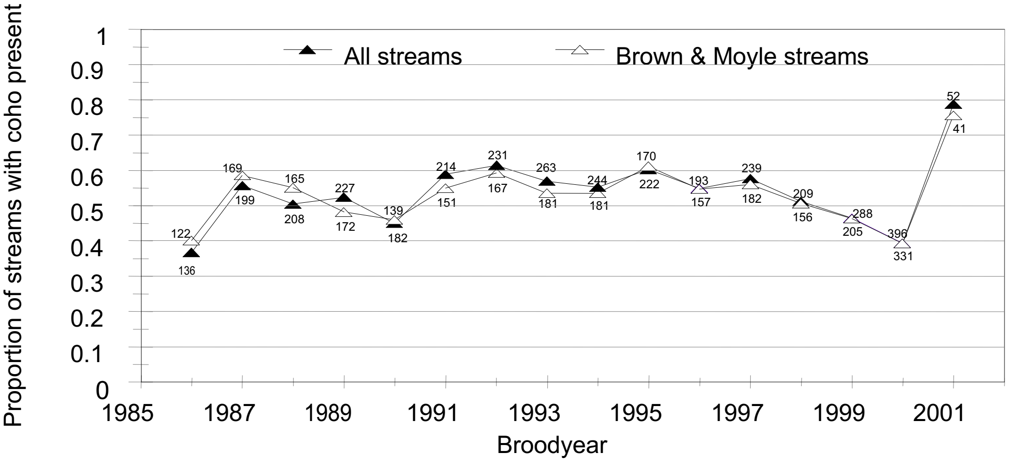

Figure 204. Proportion of streams surveyed in which coho salmon presence was detected, by broodyear, for all historical coho streams (open triangles) and coho streams identified in Brown and Moyle's (1991) historical list (closed triangles) within the Southern Oregon/Northern California Coast coho salmon ESU. Sample sizes (i.e., number of streams surveyed) are shown next to data points. Source: Spence (2001).

is similar whether all historical coho streams or just those identified in Brown and Moyle (1991) are considered (Figure 204).

When data were aggregated over complete brood cycles (3-year periods), the percentage of streams in which coho salmon presence was detected remained relatively constant (between 60% and 67%) between the 1987–1989 and 1996–1998 brood cycles (Table 74). Percent occupancy for the 1999–2001 brood cycle was lower, at 46%; however, interpretation of this apparent decline is complicated by two factors. First, the number of streams surveyed was higher than in any other period due to CDFG's intensive survey of the Brown and Moyle streams in the summer of 2001, a drought year. Second, reporting from the 2002 summer season (broodyear 2001) remains incomplete, and as noted above, preliminary data indicate that the 2001 broodyear was strong. Thus, it is likely that the percent occupancy for this period will increase after all data from CDFG's 2002 survey and other sources are analyzed. When analysis was restricted to streams on the Brown and Moyle (1991) list, the ESU-wide pattern was almost identical, with percent occupancy values being within 1% to 2% for all time periods (data not shown). Overall, it appears that, although there is considerable year-to-year variation in estimated occupancy rates, there has been no dramatic change in the percent of coho salmon streams occupied from the late 1980s and early 1990s to 2000.

In general, the proportion of streams sampled within any individual watershed (or grouping of watersheds) was sufficiently small or variable among time periods to make interpretation of local trends difficult. The most notable exception was the Eel River, which showed occupancy rates declining from between 48% and 58% in the period between 1987 and

1995 to about 30% in the past two brood cycles. Similarly, the percentage of streams with coho salmon presence in the Klamath-Trinity system appears to have declined over the five brood cycles examined, though the magnitude of the decline is smaller: from between 66% and 71% in 1987 to 1995 to 62% and 55% in the past two brood cycles. In both cases, reporting from the 2001 broodyear is incomplete, and anecdotal reports suggest that inclusion of more data from the 2002 sampling year (2001 broodyear) may increase the observed percentages because of the relatively strong adult returns in the winter of 2001–2002. Thus, these apparent declines should be interpreted with caution. Still, the relatively low percentage of streams that still support coho salmon in the Eel River and the possible downward trend in the Klamath River basin, despite continued heavy hatchery influence, are cause for concern given that these are the largest river basins in the California portion of the SONCC, and, if historical estimates are accurate (Table 72), once accounted for are well over half the coho salmon produced in the California portion of the SONCC ESU.

The results of NMFS analysis are generally consistent with those of CDFG (2002c), both suggesting a general decline in occupancy rates in from the late 1980s and early 1990s to the end of the 1990s, the significance of which remains somewhat uncertain because of nonsystematic collection of presence-absence information and variation in sampling intensity (i.e., the number of streams surveyed) through the period. NMFS (2001b) suggested that declines in percent occupancy in the SONCC from 1989 to 2000 were significant; however, the addition of new data makes us more cautious in this interpretation. Although the trend remains apparent, the magnitude of change is less than the previous data indicated. A more exhaustive examination of SONCC region stream surveys compiled by CDFG substantially increased the total number of observations in the data set (especially in the earliest years). Those additional observations were strongly weighted toward “absences.” Regardless no evidence suggests that occupancy rates have increased since the original status review for SONCC coho salmon was published in 1995.

Adult Time Series

Reliable current time series of naturally produced adult migrants or spawners are not available for SONCC ESU rivers. CDFG has conducted annual spawner surveys on 4.5 miles of Sprowl Creek, tributary to the Eel River, since 1974 (except in 1976–1977) and on 2 miles of Cannon Creek, tributary to the Mad River, since 1981 (PFMC 2002b). However, these surveys are conducted primarily to generate minimum Chinook salmon counts, and the likelihood of detecting coho salmon is influenced strongly by the frequency of sampling and environmental conditions (i.e., turbidity) during those surveys (CDFG 2003b). Spawner surveys were conducted on the West Branch Mill Creek, a tributary to the Smith River, from 1980 to 2001 (Waldvogel 2002). Peak live/dead counts fluctuated between 2 and 28 fish during this period, again making their use for trend analysis inappropriate. Surveys have also been conducted on the West Branch (4.7 miles) and East Branch (5.4 miles) of Mill Creek by Stimson Timber Company since 1993. Maximum live/dead counts recorded by Stimson on the West Branch averaged 62 fish between 1993 and 1996, declining to an average of 4 fish between 1997 and 2000. On East Branch, maximum live/dead counts averaged 32 fish between 1993 and 1996, declining to an average of 6 fish between 1997 and 2000 (Howard 1998; Albro 2002). Howard (1998) notes that the reliability of these counts varies with flow conditions.

Juvenile Time Series

Methods

Juvenile density was estimated during summer over the past 8 to 18 years at seven index sites within the Eel River basin: Upper Indian Creek, Moody Creek, Piercy Creek, Dutch Charlie Creek, and Redwood Creek in the South Fork Eel River basin (Wright and Levesque 2002), and at two sites on Hollow Tree Creek in the Middle Fork Eel basin (Harris 2002a, 20002b, and 2002c). We analyzed juvenile density to determine whether such patterns observed in juveniles are consistent with those observed in the presence-absence information analyses.

To estimate a trend, data were log-transformed, then normalized so that each data point was expressed as a deviation from the mean of that specific time series. The normalization was intended to prevent spurious trends that could arise from different methods of data collection. Following transformation, time series were aggregated, based on watershed structure, into groups thought to plausibly represent independent populations. Linear regression was used to estimate trends (i.e., slopes) for each aggregate data set. Analysis was restricted to 1) sites where a minimum of 8 years of data was available, and 2) putative populations where more than 65% of the observations were nonzero values.

Results

Aggregate trends were estimated separately for the South Fork and Middle Fork Eel river sites. In both cases, trends were positive, but not significantly different from 0 (South Fork, slope 0.053, 95% confidence interval from –074 to 0.180; Middle Fork, slope 0.016, 95% confidence interval from –0.051 to 0.180).

Oregon Populations

One effect of the OCSRI has been increased monitoring of salmon and habitats throughout the Oregon coastal region. Besides continuation of the abundance data series analyzed in the 1997 status update, Oregon has expanded its random survey monitoring to include areas south of Cape Blanco, including monitoring of spawner abundance, juvenile densities, and habitat condition.

Spawner abundance

In the Oregon portion of the ESU, spawner abundance is monitored only in the Rogue River basin. Other small coastal basins have limited coho salmon habitat, and are not thought to have sustainable local coho salmon populations (Jacobs et al. 2002). Within the Rogue Basin, two methods are used to monitor adult abundance: beach-seine surveys conducted at Huntley Park in the upper estuary and stratified-random spawning ground surveys (Jacobs et al. 2002). The Huntley Park seine estimates provide the best overall assessment of both naturally produced and hatchery coho salmon spawner abundance in the basin (Figure 206). Spawner survey–based abundance estimates are also available for the basin beginning in 1998, when the surveys were expanded south of Cape Blanco. These estimates are consistently lower than the seine-based estimates, which may be due in part to losses during upstream migration (Jacobs et al. 2002);

however, ODFW considers the seine-based estimates to be more accurate as an overall assessment of spawner abundance.[51] The spawning-ground surveys allow examination of the distribution of spawners among subbasins: in 2001, the majority of spawners were in main tributaries (Illinois and Applegate rivers and Evans and Little Butte creeks).

The occurrence of hatchery fish in natural spawning areas is also a consideration for the productivity of the natural population. Roughly half of the total spawning run in the Rogue River basin is hatchery fish; however, many of these fish return to Cole Rivers Hatchery, rather than spawning in natural habitat. Based on fin-mark observations during spawning-ground surveys, the average percent of natural spawners that are of hatchery origin has ranged from less than 2% (2000) to nearly 20% (1998) in recent years. These hatchery spawners are largely concentrated in the mainstem tributaries, with very few hatchery fish observed in major tributaries (Jacobs et al. 2002).

Results

Mean spawner abundance and trends for Rogue River coho salmon are given in Table 75. (Note that because estimates of hatchery-origin fish on the spawning ground are not available for most years, lambda (λ) was not computed for this population.) Both short- and long-term trends in naturally produced spawners are upward; however, this increasing trend in spawners results largely from reduced harvest, as trends in preharvest recruits are smaller (Figure 205, Table 75). Recruits per spawner fluctuate widely, with little apparent trend (Figure 205). Fluctuations in naturally produced spawner abundance are generally in phase with survival of hatchery fish (Figure 206), suggesting that ocean conditions play a large role in population dynamics. Note that hatchery-fish survival for the Rogue River stock is generally higher and follows a different pattern than the general OPI survival index (see Section 27, Oregon Coast Coho Salmon ESU).

Juvenile density

Regular monitoring of juvenile coho salmon in the Oregon portion of the SONCC ESU began in 1998, and 4 years of data are currently available, as reported in Rodgers (2002). Several statistics are reported, including percent occupancy and mean density. Methods differ from the California surveys reported above, so direct comparison of results is problematic. The most comparable statistic to the California presence-absence data is “percentage of sites with at least one pool containing coho,” which has been steadily increasing from about 30% in 1998 to 58% in 2001; this rate compares with a range of 52% to 80% for other parts of the Oregon coast. Percentage of pools per site containing coho salmon has also increased, reaching 41% (SE 4.9%) in 2001. Mean juvenile density has also increased over the 3 years. In 2001, overall mean density of juveniles in surveyed pools was 0.38 fish/m^2; this compares with a range of 0.27/m^2 to 0.50/m^2 for other areas of the Oregon coast.

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[51] S. Jacobs, Oregon Department of Fish and Wildlife, Corvallis, OR. Pers. commun., October 2002.

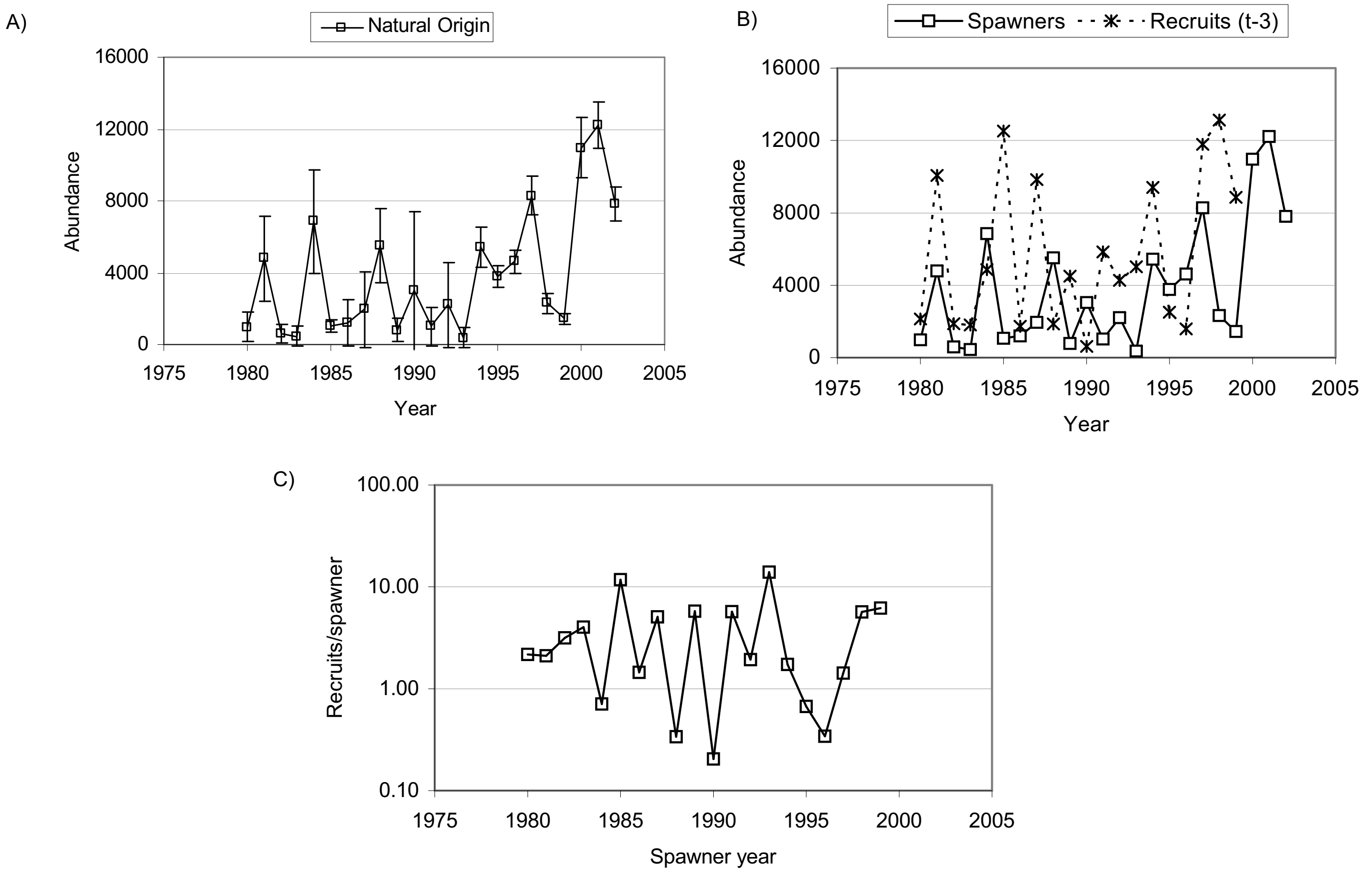

Figure 205. Trends in Rogue river coho salmon populations, based on Oregon Department of Fish and Wildlife surveys at Huntley Park (Jacobs et al. 2002. a. natural spawner abundance with 95% confidence interval.; b. preharvest recruits and spawner abundance; c. recruits (lagged 3 years) per spawner (note logarithmic scale).

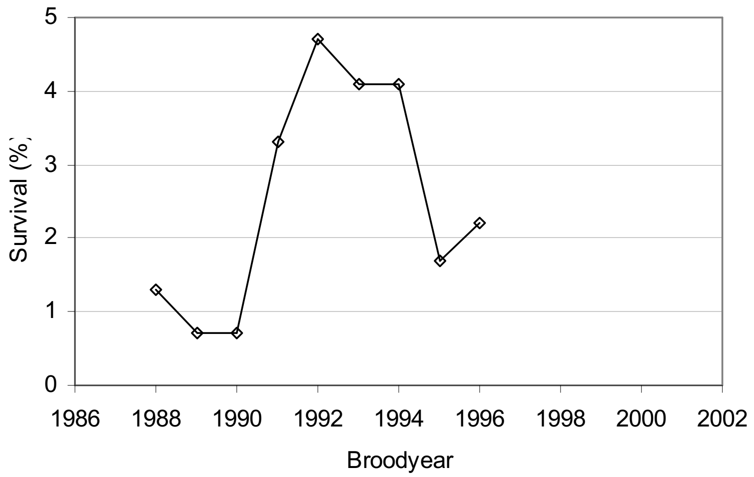

Figure 206. Percent survival of coded-wire-tag-marked coho salmon from Cole Rivers Hatchery, calculated from data in Lewis (2002).

Table 75. Abundance and trend estimates for Rogue River basin coho salmon natural spawners, estimated from Huntley Park seine data (Jacobs et al. 2002), 1980–2001. Shown are the most recent geometric mean (along with minimum and maximum values for the data series) and trend estimates for spawners and recruits, both long and short term, along with the probability that the true trend is decreasing.

Parameter	Value	95% confidence interval	P (decrease)
Recent spawner abundance			
Last 3 years geometric mean	10,147		
Last 3 years arithmetic mean	10,326		
Last 3 years range	7,800–12,213		
Spawner trend			
Short term (1990–2002)	1.16	(1.01, 1.34)	0.02
Long term (1980–2002)	1.08	(1.01, 1.15)	0.01
Preharvest recruit trend			
Short term (1990–2002)	1.08	(.94, 1.25)	0.12
Long term (1980–2001)	1.02	(0.95, 1.08)	0.27

Habitat condition

The Oregon Plan Habitat Survey (OPHS) began in 1998, as part of the ODFW Aquatic Inventories Project begun in 1990. Information here is derived from the survey's year 2000 report (Flitcroft et al. 2002). The survey selects 500-m to 1,000-m sites along streams according to a spatially balanced random selection pattern. The survey includes both summer and winter habitat sampling. In addition to characterization of the site's streamside and upland processes, specific attributes sampled are large wood, pools, riparian structure, and substrate. The program has established benchmark thresholds as indicators of habitat quality:

- Pool area greater than 35% of total habitat area,
- Fine sediments in riffle units less than 12% of all sediments,
- Volume of large woody debris greater than 20 m3 per 100-m stream length,
- Shade greater than 70%, and
- Large riparian conifers more than 150 trees per 305-m stream length.

For the combined 1998–2000 surveys in the Oregon portion of the SONCC ESU, 6% of sites surveyed met none of the benchmarks, 29% met one, 38% met two, 20% met three, 5% met four, and 2% met all five benchmarks. No trends in habitat condition can yet be assessed from these data, but it will provide a basis for future assessment of changes in habitat quality.

The Siskiyou County Farm Bureau (2002) submitted comments arguing that SONCC coho salmon should not be protected under the ESA, particularly because the relationship of Iron Gate Hatchery fish in the Klamath River to the SONCC ESU remains uncertain. Their principal argument is that widespread historical outplanting of juvenile coho salmon and incorporation of nonnative fish into hatchery broodstock make application of the ESU concept inappropriate; they argue that all West Coast coho salmon should be considered a single ESU.

The Siskiyou Project submitted comments supporting continued listing of coho salmon in the SONCC under the ESA (Siskiyou Project 2002). They argue that:

1. The status of native, naturally reproducing coho salmon in the SONCC remains unchanged since they were listed in 1997.
2. Increases in adult coho salmon observed in 2001 and 2002 are mostly due to improved ocean conditions and reduced harvest, and are not indicative of long-term trends.
3. Severe drought in the winter 2001–2002 and summer 2001 are likely to result in lower smolt production in spring 2002 and adult returns in 2003.
4. Habitat already in poor condition is likely to deteriorate with increasing human demands for natural resources and inadequate regulations.
5. Continued large releases of hatchery coho salmon pose a threat to naturally produced fish through competition, mixed-stock fishing, and reduced fitness associated with interbreeding of hatchery and wild fish.

The Siskiyou Project also included a report authored by Cindy Deacon Williams (2002), private consultant, titled "Review of the Status of Southern Oregon/Northern California Coho with Thoughts on Recovery Planning Targets." Williams' report presents basin-by-basin assessments of the status of coho salmon (using primarily previously published analyses), habitat conditions, and ongoing activities that pose risks to coho salmon. She also recommends numeric recovery criteria for SONCC coho salmon and argues that habitat targets are needed to ensure recovery.

The Douglas County Board of Commissioners submitted a report titled "Viability of Coho Salmon Populations on the Oregon and Northern California Coasts" to NMFS Protected Resources Division on 12 April 2002 (Cramer and Ackerman 2002). This report analyzes information available for the Oregon Coast Coho Salmon ESU and the SONCC ESU in several areas: trends in abundance and distribution, trends in survival, freshwater habitat condition, potential hatchery-wild interactions, changes in harvest regulation, and extinction risk modeling. Little information presented in the report is specific to the SONCC ESU. The report cites changes in fishery management, increasing spawning escapements, reduced hatchery releases, habitat restoration, and evidence of successful rearing of fry outmigrants throughout the Oregon coast, some information for the Rogue River basin, but no new information for California populations.

Daniel O'Hanlon (2002a, 2000b), attorney at law, submitted comments on two occasions on behalf of Save Our Shasta and Scott Valley Towns (SOSS), an organization of citizens concerned about the effects of ESA regulations. The latter submission includes comments submitted to the California Fish and Game Commission regarding the petition to list coho salmon in northern California under the state Endangered Species Act; the comments include, by reference, a critique of CDFG's (2002c) status review prepared by Dr. Charles Hanson. Although the critique is of the state's analysis of coho status, some of the arguments are germane to the federal status review because the underlying data are comparable. The essential arguments from this collection of documents are:

1. The limited data presented in the initial status reviews was insufficient to assess, in a scientifically rigorous way, the degree of extinction risk facing coho salmon in the SONCC.
2. There is no evidence of an immediate or near-term risk of extinction based on analysis of either presence-absence data or abundance trend data; presence-absence data have a number of weaknesses, and historical trend data (abundance and harvest) are unreliable.
3. Existing regulatory structures are adequate to protect coho salmon; new regulations would hinder, rather than help coho recovery.

The Yurok Tribal Fisheries Program (2002) submitted recent data from various sampling efforts in the lower Klamath River and its tributaries. Included were data from downstream migrant traps, adult snorkel surveys, tribal harvest, and harvest catch-per-unit effort. Data on relative contribution of naturally produced and hatchery fish to tribal harvest and to catch at the lower Klamath and lower Trinity downstream migrant trapping sites are discussed in the section below (New Hatchery Information). Other data were incorporated into NMFS presence-absence analyses discussed above. None of the time series available met the minimum criterion of 8 years, which was decided on by the BRT as the minimum needed for trend analysis.

New Hatchery Information

Weitkamp et al. (1995) identified four hatcheries that were producing and releasing coho salmon within the SONCC ESU during the mid-1990s: Mad River Hatchery, Trinity River Hatchery, Iron Gate Hatchery, and Cole Rivers Hatchery. Prairie Creek Hatchery produced coho salmon for many years, but closed in 1992 (CDFG 2002c). Rowdy Creek Hatchery is a privately owned hatchery that has produced coho salmon in the past; however, the facility did not produce coho salmon in 1999 and 2000 due to lack of adult spawners (CDFG 2002c), and no further production of coho salmon at this facility is planned.[52]

Iron Gate Hatchery

Iron Gate Hatchery (IGH), located on the Klamath River near Hornbrook, California, approximately 306 km from the ocean, was founded in 1965 and is operated by the CDFG. The hatchery was built by Pacific Power and Light Company to mitigate effects of the Iron Gate Project on wild salmonids, including coho salmon, that naturally occurred in the upper Klamath River (CDFG 2002c; SSHAG 2003). The IGH coho stock was developed initially from eggs taken from Klaskanine Hatchery in Oregon, via Trinity River Hatchery in 1966. In an effort to increase returns to Iron Gate Hatchery, coho salmon from Cascade River (Columbia River) were released in 1966, 1967, 1969, and 1970 (CDFG 2002c, 2003b). Since 1977, only Klamath Basin fish have been released from IGH (CDFG 2003b).

Annual releases of coho salmon from IGH have decreased from an average of approximately 147,000 fish from 1987 to 1991 to about 72,000 fish from 1997 to 1999 (Table 76); this reduction in releases reflects effort on CDFG’s part to more closely adhere to the IGH mitigation goal of 75,000 yearlings released per year. Adult returns averaged 1,120 fish between 1991 and 2000, and an average of 161 females have been spawned annually during this period.

The CDFG and NMFS Southwest Region Joint Hatchery Review Committee (2001) noted that no accurate estimates of the relative contribution of naturally produced versus hatchery fish are available for the Klamath River basin. Beginning in 1995, coho salmon released from IGH have been marked with left maxillary clips; however, return information was published for only a single year, 2000. These data indicate that 80% of 1,353 fish returning to IGH were marked hatchery fish, with 98% being Iron Gate releases. A few fish from the Trinity and Cole rivers (Rogue River, Oregon) hatcheries were also taken. The significance of this high percentage of hatchery fish with respect to total production in the Klamath Basin is uncertain since IGH lies near the upper end of the accessible habitat.

Additional information about the composition of Klamath Basin stocks is available from tribal harvest and downstream migrant trap data collected by the Yurok Tribal Fisheries Program (2002).

Between 1997 and 2000, tribal harvest of coho salmon ranged from 42 to 135 fish and then increased to 895 in 2001. During this 5-year period, hatchery fish constituted between 63% and 86% of the total fish harvested. Iron Gate Hatchery fish generally made up a small (8% or less) fraction of total hatchery fish captured, the exception being in 1997, when they constituted about 37% of the hatchery fish caught. In contrast, Trinity River Hatchery fish accounted for 87% to 95% of hatchery fish harvested in 1998–2001, and 40% of the hatchery fish captured in 1997.

In 1997 and 1998, Yurok Tribal Fisheries operated a downstream migrant trap in the lower Klamath River, below the confluence of the Klamath and Trinity rivers; thus the trap

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[52] A. Van Scoyk, Rowdy Creek Hatchery, Smith River, CA. Pers. commun., December 2002.

Table 76. Average annual releases of coho salmon juveniles (fry and smolts) from selected hatcheries in the Southern Oregon/Northern California Coast (SONCC) ESU during release years 1987–1991, 1992–1996, and 1997–2002. Hatchery classification assigned by the Salmon and Steelhead Hatchery Assessment Group (SSHAG 2003) is also shown.

Hatchery	SSHAG category	Average annual releases		
		1987–1991	1992–1996	1997–2002
Cochran Ponds (HFAC)		35,391[a]	NA[b]	0[b]
Mad River[c]	4	372,863	91,632	82,129[d]
Prairie Creek		89,009[e]	0[f]	0[f]
Trinity River[g]	2b	496,813	385,369	527,715
Iron Gate (Klamath)[h]	2c	147,272	92,150	71,932[i]
Rowdy Creek[j]		0	12,534[k]	10,615[l]
Cole River (Rogue)[m]	2a	271,492	239,534[n]	270,344[o]
Total		1,412,840	821,219	962,735

[a] Average from 2 years (1987—1988). Source: Weitkamp et al. 1995.

[b] Coho salmon were produced by the Humboldt Fish Action Council (HFAC) through the 1994 broodyear; release data for 1992 to 1996 are currently unavailable; no fish were released after 1996 (S. Holz, HFAC, Eureka, CA. Pers. commun., December 2002.

[c] Sources: Weitkamp et al. 1995; Gallagher 1993, 1994a, 1994b, 1995; Cartwright 1996, 1997, 1998, 1999, 2000, 2001.

[d] CDFG ceased spawning coho salmon at Mad River Hatchery in 1999; yearling were last released in 2001.

[e] Average from 4 years (1987—1988, 1990—1991). Source: Weitkamp et al. 1995.

[f] Prairie Creek Hatchery ceased producing coho salmon in 1992.

[g] Sources: Ramsden 1993, 1994a, 1994b, 1995, 1996, 1997, 1998, 2000, 2001.

[h] Sources: Hiser 1993, 1994a, 1994b, 1995; Rushton 1996, 1997, 1998, 1999, 2000, 2001.

[i] Does not include releases from year 2002 (data not available).

[j] A. Van Scoyk, Rowdy Creek Hatchery, unpublished data from Rowdy Creek Hatchery, 255 N. Fred Haight Dr., PO BOX 328, Smith River, CA 95567.

[k] Average from 2 years (1995—1996); data not available for 1992—1995.

[l] Rowdy Creek Hatchery ceased releasing coho in year 2001.

[m] Source: Waknitz 2002.

[n] Average from 1991 to 1995.

[o] Average from 1996 to 2002; includes juvenile coho salmon released to lakes.

captured fish from both the Iron Gate and Trinity hatcheries. During 2 years of sampling, Trinity hatchery fish dominated the total catch accounting for 73% and 83% of all fish caught in 1997 and 1998, respectively. Iron Gate Hatchery fish accounted for around 5% of the catch in both years. Naturally produced coho salmon made up 22% of the total catch in 1997 and 12% of the catch in 1998. In 1998, a second trap was operated on the lower Trinity River. Only 9% of the smolts captured at this trap were naturally produced. Assuming that this proportion accurately reflected the relative contributions of naturally produced and hatchery Trinity River fish to catch at the lower Klamath trap, then the percentages of naturally produced and hatchery fish exiting the Klamath River proper (above the Trinity confluence) were approximately 42% and 58%, respectively.

In previous status reviews, the BRT was uncertain whether the use of nonnative stocks to start the Iron Gate population was sufficiently important to have lasting effects on the present population. Thus, they reached no conclusion about whether the hatchery stock should be included in the ESU (NMFS 1997a). Subsequently, Iron Gate was determined to be a category 2 hatchery (SSHAG 2003). For other SSHAG hatchery stock categorizations, see Appendix C, Table C-1.

Trinity River Hatchery

Trinity River Hatchery (TRH), located below Lewiston Dam approximately 248 km from the ocean, first began releasing coho salmon in 1960. The TRH facility originally used Trinity River fish for broodstock, though coho salmon from Eel River (1965), Cascade River (1966, 1967, and 1969), Alsea River (1970), and Noyo River (1970) have also been reared and released at the hatchery as well as elsewhere in the Trinity River basin.

Trinity River Hatchery produces the largest number of coho salmon of any production facility in California. CDFG's annual production target is 500,000 yearlings. Actual production averaged 496,813 from 1987 to 1991, decreased to 385,369 from 1992 to 1996, then increased again to 527,715 fish from 1997 to 2002 (Table 76). During the period 1991–2001, an average of 3,814 adult coho were trapped and 562 females were spawned at the TRH.

It is commonly assumed that there is little production of wild coho salmon in the Trinity River system, and available data generally support this assumption. Between 1997 and 2002, hatchery fish constituted between 89% and 97% of the fish (adults plus grilse) returning to the Willow Creek weir in the lower Trinity River (Sinnen 2002). Outmigrant trapping conducted on the lower Trinity River indicates that marked TRH fish made up 91%, 97%, and 65% of the catch in years 1998, 1999, and 2000, respectively (Yurok Tribal Fisheries Program 2002). Additionally, it appears that a significant fraction of the naturally produced fish is likely the progeny of hatchery strays. By subtracting the number of hatchery and naturally produced fish returning to TRH from counts at Willow Creek weir, Sinnen (2002) estimated that hatchery fish made up between 76% and 96% of fish that spawned within the Trinity River system upstream of the weir from 1997 to 2002. A potential source of bias in these estimates is that fact that Willow Creek weir typically washes out prior to the end of the coho adult migration season. There is some suggestion that wild Trinity River coho salmon return later in the season than TRH fish, which would result in an overestimate of hatchery contribution to spawning in the wild,[53] however, there are no data by which to assess whether such bias exists. Additionally, we are aware of no information from which to assess 1) the degree to which TRH fish that pass over the weir are straying into various subbasins within the Trinity River (Hoopa Valley Tribe 2003), or 2) whether hatchery and wild fish have an equal probability of successfully spawning in the wild.

The BRT concluded that coho salmon from the Trinity River Hatchery should be considered part of the SONCC ESU since out-of-basin and out-of-ESU transfers ceased by 1970, and production since that time has been exclusively from fish within the basin. The lack of natural production within the Trinity Basin, however, remains a significant concern. The Trinity Hatchery is a category 2 hatchery (SSHAG 2003).

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[53] G. Kautsky, Hoopa Valley Tribal Fisheries, Hoopa, CA. Pers. commun., April 2003.

Mad River Hatchery

Mad River Hatchery (MRH), located approximately 20 km upriver near the town of Blue Lake, first began producing coho salmon in 1970. The original broodstock (1970) was from the Noyo River, which lies outside of the SONCC ESU, and Noyo fish were released from the hatchery during 12 additional years between 1971 and 1996. Other stocks released from the hatchery include out-of-ESU transfers from the Trask River (1972), Alsea River (1973), Klaskanine River (1973), Green River (1979), and Sandy River (1980), as well as out-of-basin, within-ESU transfers from the Trinity River (1971), Klamath River (1981, 1983, 1986–1989), and Prairie Creek (1988, 1990).

Releases of Mad River fish declined substantially during the past decade, from an average of 372,8643 fish from 1987 to 1991 to just over 82,000 in the period from 1997 to 2001 (Table 76). Production of coho salmon at MRH ceased after broodyear 1999, thus 2001 releases represent the final year of hatchery production. Adult returns were low during the 1990s, with an average of 38 adults trapped and 16 females spawned during the period between 1991 and 1999. No information was available regarding the relative contribution of naturally produced and artificially propagated fish within the Mad River basin. However, concern about both out-of-ESU and out-of-basin stock transfers, as late as 1996, was sufficiently great that the Mad River Hatchery was excluded from the SONCC ESU by NMFS (1997). The decision to cease producing coho salmon at the Mad River facility rendered this conclusion moot.

Rowdy Creek Hatchery

Rowdy Creek Hatchery is a privately owned hatchery in the Smith River basin constructed in 1977. Production emphasis has been on Chinook and steelhead, but small numbers of coho salmon were trapped and bred during the period 1990 to 1998. Only local coho salmon broodstock have been used at the Rowdy Creek facility (NMFS 1997a).

Annual releases of coho salmon yearlings averaged 12,534 between 1995 and 1996, and 15,923 from 1997 to 2000, when releases were terminated (Table 76). Adult returns to the hatchery averaged just 26 fish in the 11 years that coho salmon were trapped (A. Van Scoyk, Rowdy Creek Hatchery, unpublished data). No information was available on the relative contribution of Rowdy Creek Hatchery coho salmon to the Smith River population as a whole, but it was undoubtedly a minor component during the period of operation.

In its status review update, the BRT (NMFS 1997a) concluded that the Rowdy Creek Hatchery population should be considered part of the ESU, but that it was not essential for ESU recovery. The decision to cease producing coho salmon at the facility has rendered this conclusion moot.

Cole Rivers Hatchery

The Cole Rivers Hatchery has raised Rogue River (Oregon stock #52) coho salmon since 1973 to mitigate for lost production due to construction of Lost Creek Dam. This stock was developed from local salmon trapped in the river, and has no history of out-of-basin fish being incorporated. Recent releases (1996–2002) have averaged 270,000 per year, compared to a

1991–1995 average of 240,000 per year (Table 76); the increase is due to inclusion in the data of large-sized coho salmon released to lakes in the basin in recent years (Waknitz 2002). Spawning of hatchery fish in nature is essentially limited to mainstem tributaries and (to a lesser extent) the Applegate River, and interbreeding with natural fish is limited by separation in spawning time (Jacobs et al. 2002). The hatchery is rated as a category 1 hatchery (SSHAG 2003).

Summary

Artificial propagation of coho salmon within the SONCC has been substantially reduced in the past 8 to 10 years, with the exception of Cole Rivers Hatchery on the Rogue River and the Trinity River Hatchery. Annual releases from the Cole Rivers and Trinity hatcheries have recently averaged 270,000 and 528,000 fish, respectively. Production has ceased at one major facility (Mad River), as well as well as several minor facilities (Rowdy Creek, Eel River, and Mattole River). Production at Iron Gate Hatchery on the Klamath River has been reduced by approximately 50%. Genetic risks associated with out-of-basin and out-of-ESU stock transfers have largely been eliminated. However, two significant genetic concerns remain: 1) the potential for domestication selection in hatchery populations such as Trinity River, where there is little or no infusion of wild genes, and 2) out-of-basin straying by large numbers of hatchery coho salmon.

Harvest impacts

Historically, ocean harvest of SONCC coho salmon has occurred in coho- and Chinook-directed commercial and recreational fisheries off the coasts of California and Oregon. Significant changes in harvest management have occurred since the late 1980s, which have resulted in substantial reductions in ocean harvest of SONCC coho salmon. In establishing fishing seasons and regulations each year, the Pacific Fishery Management Council (PFMC) considers the potential impacts on various ESA-listed stocks within the region. Because there are no data on exploitation rates on wild SONCC coho salmon, Rogue and Klamath River (RK) hatchery stocks are used as a fishery surrogate stock for estimating exploitation rates on SONCC coho. The PFMC estimates that most ocean harvest of RK coho salmon (and presumably SONCC coho salmon) occurs south of Humbug Mountain, Oregon, which lies near the northern boundary of the SONCC ESU.

During the 1970s and early 1980s, commercial fishing seasons for coho salmon south of Humbug Mountain generally lasted from 4 to 5 months or more (PFMC 2003b). These seasons were substantially shortened in the late 1980s and early 1990s, particularly between Humbug Mountain and Point Arena, California, due to changes in allocation fall-run Chinook salmon to tribal and nontribal fall fisheries in the Klamath Management Zone. Retention of coho salmon in ocean commercial fisheries south of Cape Falcon, Oregon, has been prohibited since 1993 (PFMC 2002b). In 1994, retention of coho salmon in ocean recreational fisheries was prohibited from Cape Falcon south to Horse Mountain, California, and this prohibition was extended to include all California waters in 1995. The retention prohibition has remained in effect south of Humbug Mountain since that time.

Mass-marking (adipose fin clips) of hatchery coho salmon throughout much of the Oregon Production Index area led to the implementation of mark-selective recreational fisheries for hatchery fish along portions of the coast north of Humbug Mountain beginning in 1998 and continuing through 2002. Marked fish may be legally retained, while unmarked fish must be released unharmed. SONCC-origin coho salmon that migrate north of Cape Blanco experience incidental morality due to hooking and handling in this fishery; however, total incidental mortality from this fishery and Chinook-directed fisheries north of Humbug Mountain has been estimated to be less than 7% of the total mortality of RK hatchery coho salmon since 1999 (PFMC 1999, 2000, 2001a, 2002c, 2003b).

In 1999, NMFS issued a biological opinion establishing a consultation standard requiring that overall annual ocean exploitation rate not exceed 13% on RK stocks. To conform to this standard, the Pacific Fishery Management Council (PFMC) adopted fishing seasons in 1999–2002 for which the projected coastwide marine exploitation rate on RK stocks ranged between 3.0% and 7.7%. During that time, an estimated 93% to 97% of this mortality occurred in Chinook-directed fisheries south of Humbug Mountain (PFMC 1999, 2000, 2001a, 2002c, 2003b).

Estimates of ocean exploitation rates on SONCC coho salmon for years prior to their listing under ESA are not available. Harvest estimates for various landing ports in California are available dating back to the early 1950s and indicate that annual harvest in the commercial fishery ranged averaged about 163,000 between 1952 and 1991 (PFMC 2003b). Between 1962 and 1993, recreational harvest in California averaged about 34,000 fish. In both cases, these totals represent a mixture of natural- and hatchery-produced fish originating from Oregon and California. Neither escapement estimates nor estimates of the contribution of SONCC fish to total harvest, from which exploitation rates could be derived, are available. However, there is no doubt that ocean exploitation rates have dropped substantially in response to the nonretention regulations put in place in 1994 as well as general reductions in Chinook-directed effort.

Directed river harvest of coho salmon has not been allowed within the SONCC ESU since 1994, with the exception of sanctioned tribal harvest for subsistence, ceremonial, and commercial purposes by the Yurok, Hoopa Valley, and Karuk tribes (CDFG 2002c). Harvest data are only available for the Yurok Tribal Fisheries Program (2002), which reports that annual harvest of coho salmon from reservation lands on the lower Klamath River averaged 244 fish (67% marked hatchery fish) between 1997 and 2001, though this average is strongly influenced by a harvest of almost 900 fish in 2001. In the other 4 years, harvest did not exceed 135 fish. Mortality associated with incidental or illegal catch of naturally produced coho salmon in SONCC rivers is uncertain, but believed to be low (CDFG 2002c).

Comparison with Previous Data

New data for the SONCC coho salmon ESU includes expansion of presence-absence analyses; a limited analysis of juvenile abundance in the Eel River basin; a few indices of spawner abundance in the Smith, Mad, and Eel river basins; and substantially expanded monitoring of adults, juveniles, and habitat in southern Oregon. None of these data contradict conclusions the BRT reached previously. Nor do any recent data (1995 to present) suggest any marked change, either positive or negative, in the abundance or distribution of coho salmon within the SONCC ESU. Coho salmon populations continued to be depressed relative to historical numbers, and we have strong indications that breeding groups have been lost from a significant percentage of streams within their historical range. Although the 2001 broodyear appears to be the one of the strongest perhaps of the last decade, it follows a number of relatively weak years. The Rogue River stock is an exception; it had an average increase in spawners over the last several years, despite two low years (1998 and 1999).

Risk factors identified in previous status reviews, including severe declines from historical run sizes, the apparent frequency of local extinctions, long-term trends that are clearly downward, and degraded freshwater habitat and associated reduction in carrying capacity continue to be of concern to the BRT. Termination of hatchery production of coho salmon at the Mad River and Rowdy Creek facilities eliminated potential adverse risk associated with hatchery releases from these facilities. Likewise, restrictions on recreational and commercial harvest of coho salmon since 1994 undoubtedly had a substantial positive impact on coho salmon adult returns to SONCC streams. An additional risk factor identified within the SONCC ESU is predation resulting from the illegal introduction of nonnative Sacramento pikeminnow (*Ptychocheilus grandis*) to the Eel River basin (NMFS 1998f). Sacramento pikeminnow were introduced to the Eel River via Pillsbury Lake in the early 1980s and have subsequently spread to most areas within the basin. The rapid expansion of pikeminnow populations is believed to have been facilitated by alterations in habitat conditions (particularly increased water temperatures) that favor pikeminnow (Brown et al. 1994, NMFS 1998f).

29. Central California Coast Coho Salmon ESU

Summary of Previous BRT Conclusions

The Central California Coast coho salmon ESU extends from Punta Gorda in northern California south to and including the San Lorenzo River in central California (Weitkamp et al. 1995). The status of coho salmon throughout their West Coast range, including the Central California Coast coho salmon ESU, was formally assessed in 1995 (Weitkamp et al. 1995). NFMS published two subsequent status review updates with information pertaining to the Central California Coast coho salmon ESU in 1996 (NMFS 1996b, 1996d). Analyses from those reviews regarding extinction risk, risk factors, and hatchery influences are summarized in the following sections.

Status Indicators and Major Risk Factors

Data on abundance and population trends of coho salmon within the Central California Coast coho salmon ESU were limited. Historical time series of spawner abundance for individual river systems were unavailable. Brown et al. (1994) presented several historical point estimates of coho salmon spawner abundance (excluding ocean catch) for the entire state of California for 1940 and for various rivers and regions in the early 1960s and mid-1980s (Table 77). Coho salmon were estimated to number between 200,000 and 500,000 statewide in the 1940s.[54] Coho salmon spawning escapement was estimated to have declined to about 99,400 fish by the mid-1960s, with approximately 56,100 (56%) originating from streams within the Central California Coast coho salmon ESU (Table 77). In the mid-1980s, spawning escapement was estimated to have dropped to approximately 30,480 in California and 18,050 (59%) within the Central California Coast coho salmon ESU. Employing the “20-fish rule” (see status review update for Southern Oregon/Northern California Coast coho salmon ESU for details), Brown et al. (1994) estimated wild and naturalized coho salmon populations at 6,160 (47% of the statewide total) for the Central California Coast coho salmon ESU during the late 1980s (Table 77). All of these estimates are considered to be “best guesses” based on a combination of limited catch statistics, hatchery records, and personal observations of local biologists (Brown et al. 1994).

Further information regarding status was obtained from Brown et al.’s (1994) analysis of recent (1987–1991) occurrence of coho salmon in streams historically known to support populations. Of 133 historical coho salmon streams in the Central California Coast coho salmon ESU for which recent data were available, 62 (47%) were determined to still support coho runs while 71 (53%) apparently no longer support coho salmon (Table 78). A subsequent analysis of

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[54] E. Gerstung, California Department of Fish and Game, pers. commun., cited in Brown et al. 1994.

Table 77. Historical estimates of coho salmon spawner abundance for various rivers and regions within the Central California Coast ESU.

	Estimated escapement		
River/region	**CDFG (1965)[a] 1963**	**Wahle & Pearson (1987)[b] 1984–1985**	**Brown et al. (1994)[c] 1987–1991**
Ten Mile River	6,000	2,000	160[d]
Noyo River	6,000	2,000	3,740
Big River	6,000	2,000	280
Navarro River	7,000	2,000	300
Garcia River	2,000	500	
Other Mendocino County	10,000	7,000[e]	470[f]
Gualala River	4,000	1,000	200
Russian River	5,000	1,000	255
Other Sonoma County	1,000		180
Marin County	5,000		435
San Mateo and Santa Cruz counties	4,100	550	140
San Mateo County	1,000		
Santa Cruz County (excluding San Lorenzo River)	1,500	50	
San Lorenzo River	1,600	500	
ESU total	56,100	18,050	6,160
California statewide total[g]	99,400	30,480	13,240

[a] Values exclude ocean catch.

[b] Estimates are for wild or naturalized fish; hatchery returns excluded.

[c] Estimates are for wild or naturalized fish; hatchery returns excluded. For streams without recent spawner estimates (or estimates lower than 20 fish), assumes 20 spawners.

[d] Indicates high probability that natural production is by wild fish rather than naturalized hatchery stocks.

[e] Value may include Marin and Sonoma County fish.

[f] Appears to include Garcia River fish.

[g] Estimated number of coho salmon for Central California Coast ESU and California portion of the Southern Oregon/Northern California Coasts ESU combined.

surveys from 1995 to 1996 found a somewhat higher percentage (57%) of occupied streams (NMFS 1996b).[55]

Nehlsen et al. (1991) provided no specific information on individual coho salmon populations in their 1991 status review, but concluded that salmon stocks in small coastal streams north of San Francisco were at moderate risk of extinction and those in coastal streams south of San Francisco Bay were at high risk of extinction. A subsequent status review by the Humboldt Chapter of the American Fisheries Society (Higgins et al. 1992) found four populations (Pudding Creek, Garcia River, Gualala River, and Russian River) to be at high risk of extinction and five (Ten Mile, Noyo, Big, Navarro, and Albion rivers) as stocks of concern.

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[55] P. Adams, Southwest Fisheries Science Center, Seattle. Pers. commun.

Table 78. Historical presence of coho salmon in the Central California Coast ESU, as determined by Brown et al. (1994) and the CDFG's analysis of recent presence (1995–2001). Note that methods for estimating occupancy rates differed between Brown et al. (1994) and CDFG (2002c); thus, direct comparisons across time periods are inappropriate. Source: Data from CDFG (2002c).

	Brown et al. (1994) calendar years 1987–1990				**CDFG (2002c) years 1995–2001**				
County[a]/ river basin	**No. of streams**	**No. of streams with information**	**Coho present**	**%**	**No. of streams surveyed in 2001**	**No. of streams with coho present**	**No. of streams with coho assumed present**	**No. of streams with coho not detected in 2001**	**% present (1995–2001)**
Mendocino County									
Coastal	44	35	13	37	30	11	10	19	52
Ten Mile River	11	10	7	79	11	9	0	2	82
Noyo River	13	12	11	92	8	7	5	1	92
Big River	16	13	11	85	8	3	6	5	64
Navarro River	19	8	4	50	14	6	1	8	47
Subtotal	103	78	46	59	71	36	22	35	62
Sonoma County									
Coastal	10	2	1	50	4	0	0	4	0
Gualala River	11	2	1	50	10	0	0	10	0
Russian River	32	24	2	8	29	1	1	28	0
Subtotal	53	28	4	14	43	1	1	42	4
Marin County									
Coastal[b]	10	7	7	100	15	6	0	9	40
Subtotal	10	7	7	100	15	6	0	9	40
Tributaries to San Francisco Bay									
Coastal	7	7	0	0	0	0	0	0	0
Subtotal	7	7	0	0	0	0	0	0	0
South of San Francisco Bay									
Coastal	13	13	5	38					
Subtotal	13	13	5	38					
ESU total	186	133	62	47	135	43	23	92	42

[a] County classifications are based on the location of the mouth of the river system.

[b] CDFG (2002d) included five tributaries of Salmon Creek, a Sonoma County stream that empties into Tomales Bay, in their totals for Marin County.

The BRT identified risk factors that included extremely low contemporary abundance compared to historical abundance, widespread local extinctions, clear downward trends in abundance, extensive habitat degradation, and associated decreases in carrying capacity. The BRT concluded that in the Central California Coast ESU that hatcheries have heavily influenced the main stocks of coho salmon and that relatively few native coho salmon were left (Weitkamp et al. 1995). Most existing stocks have a history of hatchery planting, with many out-of-ESU stock transfers. A subsequent status review (NMFS 1996a), which focused on existing hatcheries, concluded that, despite the historical introduction of nonnative fish, the Scott Creek (Kingfisher Flat) and Noyo River broodstocks have regularly incorporated wild broodstock, and thus were unlikely to differ from naturally spawning fish within the ESU. Recent droughts and unfavorable ocean conditions were identified as natural factors contributing to reduced run size.

Previous BRT Conclusions

Based on the data presented above, the BRT concluded that all coho salmon stocks in the Central California Coast coho salmon ESU are depressed relative to historical abundance, and that most extant populations have been heavily influenced by hatchery operations. They unanimously concluded that natural populations of coho salmon in this ESU are in danger of extinction (Weitkamp et al. 1995). After considering new information on coho salmon presence within the ESU, the majority of the BRT concluded that the ESU is in danger of extinction, while a minority concluded the ESU is not presently in danger of extinction but is likely to become so in the foreseeable future (NMFS 1996b).

Listing status: Threatened.

New Data and Updated Analyses

Significant new information on recent abundance and distribution of coho salmon within the Central California Coast ESU has become available, much of which was summarized in two recent status reviews (NMFS 2001b; CDFG 2002c). Most of these data are of two types: 1) compilations of presence-absence information for coho salmon throughout the Central California Coast coho salmon ESU from 1987 to the present, and 2) new data on densities of juvenile coho salmon collected at a number of index reaches surveyed by private timber companies, the CDFG, and other researchers. Except for adult counts made at the Noyo Egg Collecting Station, which are both incomplete and strongly influenced by hatchery returns, there are no current time series of adult abundance within this ESU that span 8 years or more. Outmigrating smolts have been trapped at two trapping facilities in Caspar Creek and Little River since the mid-1980s; however, these are partial counts and only recently have mark-recapture studies been performed that allow correction for capture efficiency at these two sites. Thus, these smolt counts can only be considered indices of abundance.

Two analyses of presence-absence data were recently published. CDFG (2002c) focused on recent (1995–2001) presence of coho salmon in streams identified as historical producers of coho salmon by Brown and Moyle (1991). NMFS (2001b) published an updated status review of coho salmon presence in streams throughout the Central California Coast coho salmon ESU from 1989 to 2000. Scientists at the NMFS Southwest Fisheries Science Center continued to compile data on coho salmon presence-absence, which were incorporated into a database summarized by broodyear (rather than year of sampling) and covers broodyears 1986–2001. Data from CDFG's 2001 field survey of the Brown and Moyle (1991) streams were incorporated into this database. Analyses in this status review update supercede those in NMFS (2001b).

CDFG Presence-Absence Analysis

Methods

Methods used by CDFG (2002c) to analyze presence-absence information in the Central California Coast coho salmon ESU differed from those used for the SONCC analysis. Analysis focused on results from CDFG's 2001 summer juvenile sampling effort, in which 135 of 173 streams identified by Brown and Moyle (1991) as historical coho salmon streams within the Central California Coast coho salmon ESU were sampled. Additionally, CDFG assumed coho salmon were present in any stream where their presence was detected during any 3 consecutive years during the period 1995–2001. An estimate of percent coho salmon presence was calculated by totaling the number of streams for which presence was either observed or assumed, and dividing by the total number of streams surveyed, including those where presence was assumed. No formal statistical analysis of trends was performed because of the lack of comparable data from previous time periods.

Results

For the Central California Coast coho salmon ESU as a whole, CDFG (2002c) estimated that coho salmon were present in 42% of streams historically known to contain coho salmon. Estimated occupancy was highest in Mendocino County (62%), followed by Marin County (40%), Sonoma County (4%), and San Francisco Bay tributaries (0%) (Table 78). Because of differences in the specific streams considered and methods for estimating occupancy rates, these numbers are not directly comparable with those derived by Brown et al. (1994). Nevertheless, the regional and overall ESU patterns are generally concordant for the two studies, indicating substantial variation in occupancy rates across the ESU, with lower occupancy rates in the southern portion of the ESU (Table 78).

NMFS Presence-Absence Analysis

Methods

Scientists at NMFS's Southwest Fisheries Science Center compiled survey information from streams with historical or recent evidence of coho salmon presence within the Central California Coast coho salmon ESU. Data were provided primarily by the CDFG, private landowners, consultants, academic researchers, and others who conducted sampling within the Central California Coast coho salmon ESU from 1988 to 2002. The majority of data came from summer juvenile surveys, though information from downstream migrant trapping and adult spawner surveys was also included. Observations of presence or absence for a particular stream were assigned to the appropriate broodyear based on life stages observed (or expected, in the case of absences). The resulting data set spans broodyears 1987 to 2001, though data from the

2002 summer field season (broodyear 2001) were not fully reported when the analysis was performed.

Results for NMFS's presence-absence analysis are presented by major watersheds or aggregations of adjacent watersheds. Results from larger watersheds are typically presented independently, whereas data from contiguous smaller coastal streams, where data were relatively sparse, are grouped together. In a few cases, individual smaller coastal streams with only a few observations were aggregated with adjacent larger streams if there was no logical geographic grouping of smaller streams.

Results

The estimated percentage of streams in which coho salmon were detected shows a general downward trend from 1987 to 2000, followed by a substantial increase in 2001 (Figure 207). Several caveats, however, warrant discussion. First, the number of streams surveyed per year also shows a general increase from 1987 to 2000; thus, there may be a confounding influence of sampling size if sites surveyed in the first half of the time period are skewed disproportionately toward observations in streams where presence was more likely. Second, sample size from broodyear 2001 was relatively small and the data were weighted heavily toward certain geographic areas (Mendocino County and systems south of the Russian River). The data for broodyear 2001 included almost no observations from watersheds from the Navarro River to the Russian River, or tributaries to San Francisco Bay, areas where coho salmon have been scarce or absent in recent years. Thus, although 2001 appears to have been a relatively strong year for coho salmon in the Central California Coast ESU as a whole, the high percentage of streams where presence was detected that is shown in Figure 207 is likely inflated.

Two other patterns were noteworthy. First, compared with percent presence values for the SONCC ESU, values in the Central California Coast coho salmon ESU were more highly variable and showed a somewhat more cyclical pattern. In general, percent occupancy was relatively low in broodyears 1990, 1993, 1996, and 1999, suggesting that this brood lineage is in the poorest condition. In contrast, during the 1990s, percent occupancy tended to be high in broodyears 1992, 1995, 1998, and 2001, suggesting that this is the strongest brood lineage of the three. Second, there is a general tendency for percent occupancy to be slightly higher (2–15%) for the Brown and Moyle streams compared with the ESU as a whole. We speculate that this pattern may reflect the fact that increased concern over Central California Coast coho salmon in the mid-1990s prompted increased stream sampling, including streams other than those traditionally known to support coho salmon. Lower occupancy rates at these sites might be expected if they represent habitats that are generally less suitable for coho salmon.

When data are aggregated over brood cycles (3-year periods), the percentage of streams with coho salmon detected shows a similar downward trend, from 72% in 1987–1989, to 62% in 1990–1992, to less than 55% in the last three brood cycles (Table 79). Again there are confounding influences of increased sampling fraction through time and incomplete reporting for

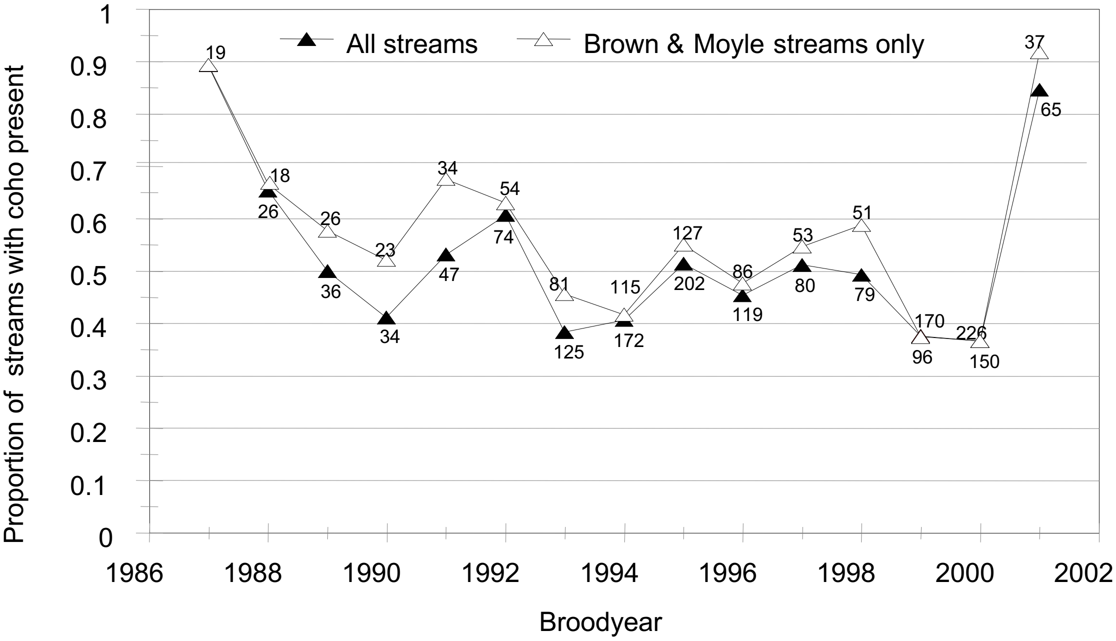

Figure 207. Proportion of streams surveyed in which coho salmon presence was detected, by broodyear, for all historical coho streams and coho streams identified in Brown and Moyle's (1991) historical list within the Central California Coast coho salmon ESU. Sample sizes (i.e., number of streams surveyed) are shown next to data points. Source: Data are from combined NMFS and CDFG data sets.

the 2001 broodyear. Nevertheless, it appears that the percent of historical streams occupied continued to decline from the late 1980s to the mid-1990s and remains below 50% for the ESU as a whole. Additionally, coho salmon appear to be extinct or nearing extinction in several geographic areas including the Garcia River, the Gualala River, the Russian River, and San Francisco Bay tributaries. There is also evidence that some populations that still persist in the southern portion of the range, including Waddell and Gazos creeks, have lost one or more brood lineages (Smith 2001a).

Results from our presence-absence analysis are generally concordant with CDFG's analysis. The two studies show consistent regional patterns suggesting that within the Central California Coast coho salmon ESU the proportion of streams occupied is highest in Mendocino County, but that populations in streams in the southern portion of the range (excluding portions of Marin County) have suffered substantial reductions in range. NMFS analysis is more suggestive of a continued decline in percent occupancy from the late 1980s to the present; however, increased sampling in recent years may be confounding any trends.

Table 79. Percent of surveyed streams within the Central California Coast ESU in which coho salmon were detected for four time intervals: broodyears 1987–1989, 1990–1992, 1993–1995, 1996–1998, and 1999–2001. Streams include those for which historical or recent evidence of coho salmon presence exists (based on combined NMFS and CDFG data).

County and river basins	No. of streams with historical presence	1987–1989			1990–1992			1993–1995			1996–1998			1999–2001		
		No. surveyed[a]	% Coho present[b]	% Coho absent[c]	No. surveyed[a]	% Coho present[b]	% Coho absent[c]	No. surveyed[a]	% Coho present[b]	% Coho absent[c]	No. surveyed[a]	% Coho present[b]	% Coho absent[c]	No. surveyed[a]	% Coho present[b]	% Coho absent[c]
Mendocino																
Coastal (Punta Gorda to Abolabodiah Creek)	24	4	75	25	6	50	50	16	50	50	11	18	82	19	32	68
Ten Mile River	25	6	50	50	15	53	47	17	65	35	14	57	43	16	94	6
Pudding Creek to Noyo River	43	4	75	25	8	88	12	35	66	34	15	80	20	38	68	32
Coastal (Hare Creek to Russian Gulch)	14	8	100	0	4	100	0	9	67	33	9	67	33	4	75	25
Big and Little rivers	28	5	20	80	7	57	43	20	75	25	16	81	19	16	38	62
Albion River	16	3	100	0	3	100	0	15	80	20	1	100	0	14	86	14
Little Salmon and Big Salmon creek	6	0	–	–	3	100	0	4	75	25	4	75	25	4	100	0
Navarro River	30	1	100	0	1	0	100	24	58	42	6	67	33	23	52	48
Coastal (Greenwood Creek to Brush Creek)	8	3	0	100	2	50	50	8	13	87	0	–	–	8	0	100
Garcia River to Digger Creek	8	3	100	0	2	0	100	8	13	87	5	20	80	7	0	100
Sonoma																
Gualala River	15	1	100	0	1	0	100	11	0	100	1	0	100	11	9	91
Fort Ross to Russian River	55	5	40	60	14	50	50	37	54	46	29	24	76	37	11	89
Marin																
Tomales Bay rivers	25	3	100	0	4	100	0	14	36	64	10	90	10	21	57	43
Coastal (Redwood Creek to Bolinas Lagoon)	6	0	–	–	1	100	0	2	50	50	4	75	25	5	100	0
San Francisco Bay																
San Francisco Bay River	6	0	–	–	4		100	6	0	100	4	0	100	0	–	–
San Mateo/Santa Cruz																
Coastal (San Francisco Bay to Aptos Creek)	17	7	100	0	7	100	0	13	69	31	14	57	43	12	67	33
Monterey																
Coastal (Carmel River to Big Sur River)	2	0	–	–	0	–	–	2	0	100	0	–	–	2	0	100
ESU Total	328	53	72	28	82	63	37	241	54	46	143	54	46	237	48	52

[a] Total number of steams surveyed at least once within the 3-year interval.

[b] Percentage of surveyed streams in which coho were present in one or more years during the interval.

[c] Percentage of surveyed streams in which coho were absent in all years of survey during the interval.

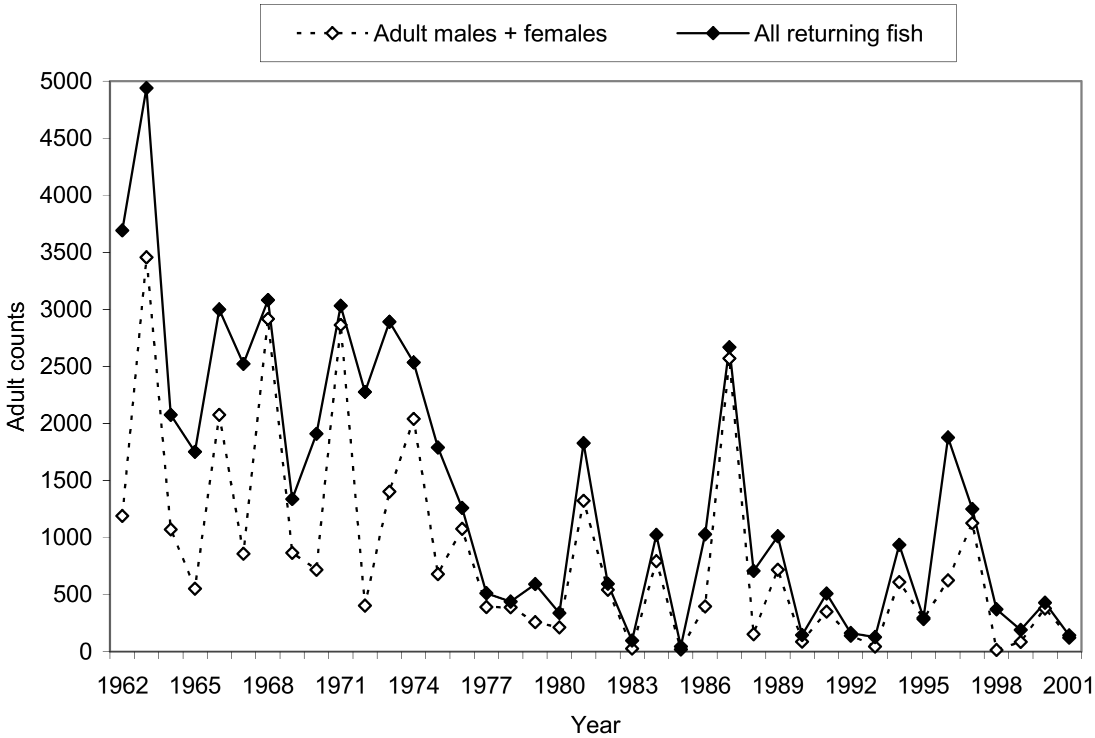

Figure 208. Counts of adult coho salmon at Noyo Egg Collecting Station, 1962–001. Solid line with closed symbol indicates total fish captured (including grilse); dashed line with open symbols indicates adult males and females only. Counts are partial counts and thus are only a crude index of adult abundance. Source: Grass (2002).

Adult Time Series

No time series of adult abundance free of hatchery influence and spanning 8 or more years are available for the Central California Coast coho salmon ESU. Adult counts from the Noyo Egg Collecting Station (ECS) dating back to 1962 represent a mixture of naturally produced and hatchery fish, and counts are incomplete most years because trap operation was sporadic during the season and typically ceased after broodstock needs were met. Thus, at best they represent an index of abundance. Assuming that these counts reflect general population trends, there appears to have been a significant decline in abundance of coho salmon in the South Fork Noyo River beginning in 1977 (Figure 208). No formal analysis of trends was conducted because of the uncertainty of the relationship between catch statistics and population size, as well as the relative contribution of hatchery fish to total numbers during the entire period of record.

Smolt Time Series

CDFG personnel have trapped outmigrating smolts at Caspar Creek and Little River since 1986. These counts are partial counts, uncorrected for capture efficiency. As such, they provide only indices of abundance. However, they likely capture gross changes in smolt abundance over the years (Figure 209). For Caspar Creek, the highest smolt counts occurred in the late 1980s and early 1990s, decreased in the mid-1990s, then increased in the past 3 years to levels

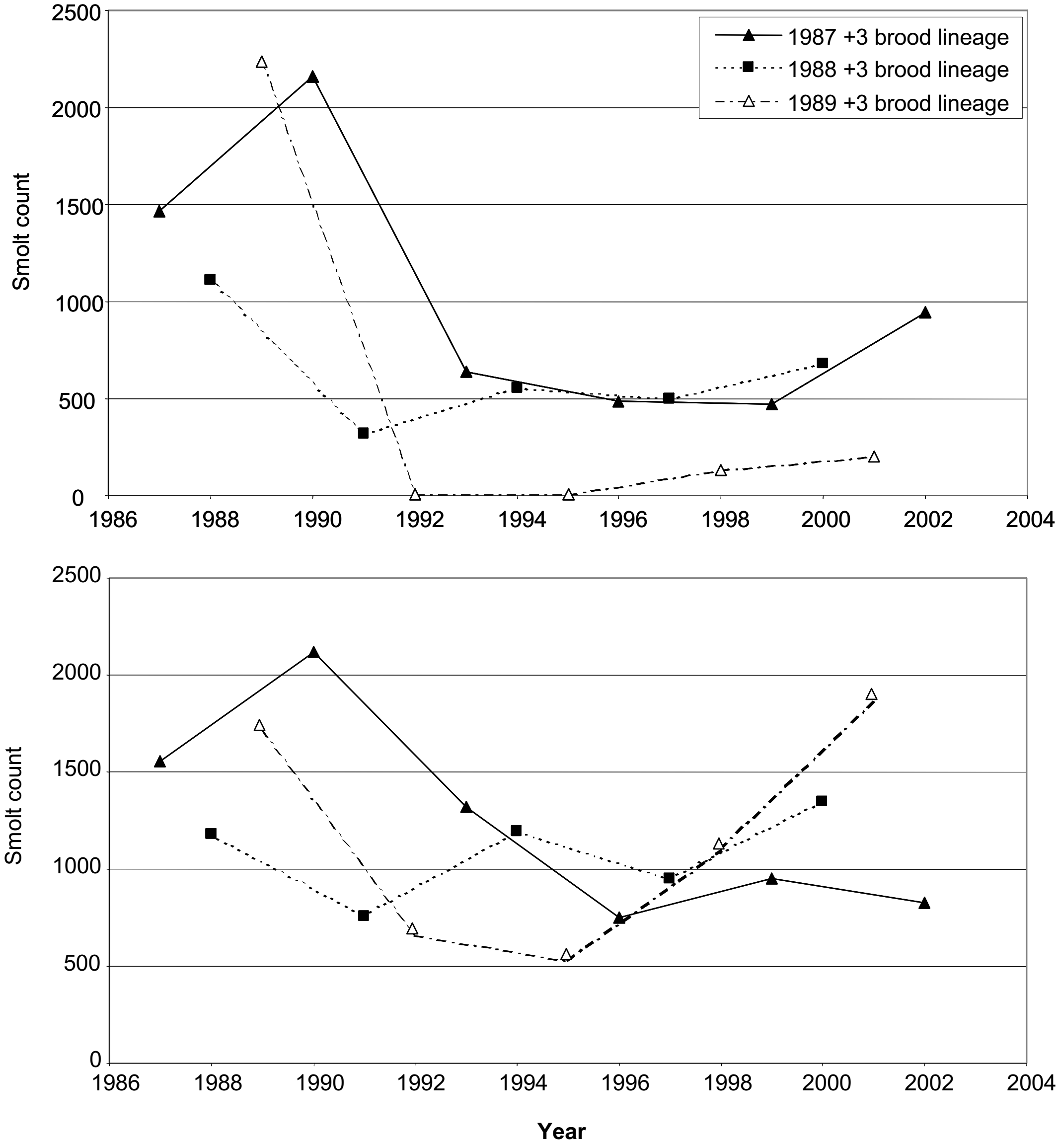

Figure 209. Coho salmon smolt counts (1987–2002) at (top) Little River and (bottom) Caspar Creek, Mendocino County. Lines track brood lineages. Data are counts of smolts uncorrected for trap efficiency and thus should be viewed as coarse indices of abundance. Source: Harris (2002b).

approaching those of the late 1980s (Figure 209). For Little River, a similar pattern was observed from the late 1980s to the mid-1990s; however, only a slight increase in numbers was observed in the last 3 years of records. Smolt counts were higher in each year from 1986 to 1989 than in any year since (Figure 209). When individual brood lineages are tracked, Little River shows a decline in all three brood lineages over the period of record. In contrast, Caspar Creek shows a decline in the 1987 brood lineage, relatively consistent numbers in the 1988 brood lineage, and a decrease in the early to mid-1990s followed by an increase over the last two brood cycles to levels comparable to those observed in 1989 (Figure 209). For both locations, the estimated long-term trend is negative but not significantly different from 0 (Table 80). Likewise, λ values are not significantly different from 1.

Table 80. Population trend analysis for Caspar Creek and Little River smolt outmigrant data. Trends are based on smolt counts uncorrected for trap efficiency (see text). Source: Harris (2002b).

Stream	Geometric means[a] Recent 3-year mean	3-year minimum	3-year maximum	λ[b]	Long-term trend[b]
Caspar Creek	1,278 (829–1,871)	723 (530-953)	1,383 (1,182–2,121)	1.002 (0.851, 1.178)	–0.017 (–0.081, 0.048)
Little River	504 (198–946)	94 (4–640)	1,750 (1,111–2,161)	0.919 (0.669, 1.347)	–0.063 (–0.358, 0.232)

[a] Values in parentheses for geometric means are the range of values observed over the 3-year period.

[b] Values in parentheses for λ and trends are lower and upper bounds for 95% confidence limits.

Juvenile Time Series

Methods

Although recent estimates of adult and smolt abundance are scarce for the Central California Coast coho salmon ESU, estimates (or indices) of juvenile density during summer were made at more than 50 index sites in the past 8 to 18 years. Methods for analyzing these data are described in detail in Section 28. Briefly, data from individual sampling sites were natural log-transformed and normalized to prevent spurious trends arising from different data collection methods or reporting units. Data were then grouped into units thought to represent plausible independent populations based on watershed structure. Trends were then estimated for putative populations by estimating the slope (and associated 95% confidence intervals) for the aggregated data. Analysis was restricted to 1) sites where a minimum of 6 years of data were available, and 2) putative populations where more than 65% of all observations were nonzero values.

Nine geographic areas (putative populations) were represented in the aggregated data, including Pudding Creek, Noyo River, Caspar Creek, Big River, Little River, Big Salmon Creek, Lagunitas Creek, Redwood Creek, and coastal streams south of San Francisco Bay, including Waddell, Scott, and Gazos creeks. Spatially, these sites cover much of the Central California Coast coho salmon ESU; however, several key watersheds are not represented, including the Ten Mile, Navarro, Garcia, Gualala, and Russian rivers. Although considerable sampling has been done in the Ten Mile River basin, the high proportion of zero values precluded analysis of these data.

Results

Overall, analysis of juvenile data provided little evidence of either positive or negative trends for the putative populations examined. Estimated slopes were negative for six populations and positive for three; however, none of the estimated slopes differed significantly from zero (Table 81).

Table 81. Trend slopes and confidence intervals for nine putative coho populations in the Central California Coast coho salmon ESU.

Watershed	No. sites	Aggregate slope	95% confidence interval	
			Lower bound	Upper bound
Pudding Creek	1	–0.019	–0.103	0.065
Noyo River	8	–0.091	–0.195	0.013
Caspar Creek	2	–0.039	–0.109	0.030
Little River	2	–0.044	–0.118	0.029
Big River	2	0.146	–0.001	0.293
Big Salmon Creek	5	–0.005	–0.110	0.100
Lagunitas Creek	3	0.095	–0.123	0.312
Redwood Creek	1	0.091	–0.345	0.527
Waddell/Scott/Gazos creeks	3	–0.111	–0.239	0.018

New Comments

Homer T. McCrary, vice president of Big Creek Lumber, submitted 375 pages primarily composed of excerpts from historical documents related to operation of hatcheries in Santa Cruz County from the early 1900s to 1990 (McCrary 2002). The expressed intent of this compilation was "to assist the efforts of resource professionals, scientists, regulators, fisheries restoration advocates and all interested parties in establishing a more complete historical perspective on salmonid populations." Quantitative information regarding hatchery and stocking histories is discussed in Section 25, subsection, Harvest Impact.

New Hatchery Information

The BRT (Weitkamp et al. 1995) identified four production facilities that had recently produced for release in the Central California Coast coho salmon ESU: the Noyo Egg Collecting Station (reared at Mad River Hatchery) and Don Clausen (Warm Springs) hatchery, both operated by CDFG; Big Creek Hatchery (Kingfisher Flat Hatchery), operated by the Monterey Bay Salmon and Trout Program; and the Silver-King ocean ranching operation. The latter facility closed in the late 1980s.

Noyo Egg Collecting Station

The Noyo Egg Collecting Station (ECS), located on the South Fork Noyo River approximately 17 km inland of Fort Bragg, began operating in 1961 and has collected coho salmon in all but a few years since that time. Fish have historically been reared at the Mad River Hatchery, Don Clausen (Warm Springs) Hatchery, and the Silverado Fish Transfer Station. There are no records of broodstock from other locations being propagated with Noyo fish for release back into the Noyo River system, but a few out-of-ESU transfers directly into the Noyo River system have been recorded, including Alsea and Klaskanine, Oregon, stocks (SSHAG 2003).

Average annual release of coho salmon yearlings was 108,000 from 1987 to 1991 (Weitkamp et al. 1995), declined to about 52,000 between 1992 and 1996, then increased again to about 72,000 fish between 1997 and 2002, inclusive of 2 years during which no yearlings were released (Table 82). Releases were made exclusively to the ECS or elsewhere in the South Fork Noyo River drainage in the past decade. Between 1991 and 2001, adult returns averaged 572 individuals, though these represent incomplete counts in most years, as counting typically ceased after broodstock needs were met (Grass 2002). On average, 91 females were spawned annually during this 11-year period (Grass 1992, 1993, 1995a, 1995b, 1996, 1997, 1998, 1999, 2000, 2001, 2002).

There are no basinwide estimates of natural and artificial production for the Noyo River basin as a whole; however, marking of coho salmon juveniles released from the Noyo ECS on the South Fork Noyo River began in 1997, and returns have been monitored since the 1998–1999 spawning season. In the 1998, 1999, and 2000 broodyears, marked hatchery fish constituted 85%, 70%, and 80%, respectively, of returning adults captured at the ECS.

The BRT (NMFS 1996a) concluded that, although exotic stocks have occasionally been introduced into the Noyo system, the regular incorporation of local natural fish into the hatchery population made the likelihood that this population differs substantially from naturally spawning fish in the ESU low; therefore, the BRT included them in the ESU. Because Central California Coast coho salmon were listed, no significant changes in hatchery practices have occurred. The Noyo ECS operation has been classified as a category 1 hatchery (SSHAG 2003).

Don Clausen (Warm Springs) Hatchery

The Don Clausen Hatchery (also known as Warm Springs stock), located on Dry Creek in the Russian River system 72 km upstream of the mouth, began operating in 1980. Initial broodstock used were from the Noyo River system, and Noyo fish were planted heavily from 1981 to 1996.

Average annual releases of coho salmon from the hatchery decreased from just over 123,000 in the 1987–1991 period to about 57,000 in the years between 1992 and 1996, and Noyo River broodstock continued to constitute about 30% of the releases during the latter period. Production of coho salmon at the facility ceased entirely after 1996 (Table 82). Adult returns averaged 245 fish between 1991 and 1996, but following the cessation of releases, no more than four coho salmon have been trapped at the hatchery in any subsequent year.

Because the Warm Springs population was originally derived from Noyo River stock and continued to receive transfers from the Noyo system throughout its operation, the BRT concluded that the hatchery population was not a part of the ESU.

Beginning in 2001, however, a captive broodstock program was initiated at the Don Clausen facility. A total of 337 juveniles were electro-fished from Green Valley and Mark West Springs creeks, two Russian River tributaries that still appear to support coho salmon, as well as Olema Creek, a tributary to Lagunitas Creek. Specific mating protocols for these fish have not yet been determined. The captive broodstock program proposes to eventually release 50,000 fingerlings and 50,000 yearlings into five Russian River tributaries. Under the captive broodstock program, the Don Clausen Hatchery has been classified as a category 1 hatchery (SSHAG 2003).

Kingfisher Flat (Big Creek) Hatchery

The Monterey Bay Salmon and Trout Project (MBSTP) has operated Kingfisher Flat Hatchery, located on Big Creek, a tributary to Scott Creek, since 1976. The facility is near the site of the former Big Creek Hatchery, which was operated from 1927 to 1942, when a flood destroyed the facility. An additional facility in Santa Cruz County, the Brookdale Hatchery on the San Lorenzo River, operated from 1905 to 1953. Both the Big Creek and Brookdale hatcheries were supplied with eggs taken at an egg-collection facility located on Scott Creek; additional eggs were provided from other hatcheries around the state. Production of coho salmon at both hatcheries was sporadic. There is evidence that coho salmon eggs from Baker Hatchery (Birdsview Station) in Washington State were transferred to Brookdale Hatchery in 1906–1910. Although records documenting where these fish were distributed are unavailable, it is possible that some were released into Scott Creek. In subsequent years, releases from both facilities back into Scott Creek included both Scott Creek fish (1913, 1915, 1929, 1930, 1934, and 1936–1939), as well as fish from Fort Seward, Mendocino County (1932), and Prairie Creek, Humboldt County (1933, 1935, and 1939). Throughout these years, only fry were (generally during July through September) and numbers of fish were relatively small. In the 10 years between 1929 and 1939, during which coho salmon were planted in Scott Creek, the total fry release averaged about 34,000 fish. During the Silver-King operation, broodstock was obtained from Oregon, Washington, British Columbia, and Alaska.

Since 1976, when MBSTP began operating the Kingfisher Flat Hatchery, only local broodstock have been released back into Scott Creek. Some Noyo, Prairie Creek, and San Lorenzo coho salmon were reared at the hatchery in the early 1990s, but were released into the San Lorenzo River rather than Scott Creek. Mating protocols at the hatchery follow a priority scheme in which wild × wild broodstock are used in years of relatively high abundance, wild × hatchery crosses are done when wild fish are less available, and hatchery × hatchery crosses are made when wild fish are unavailable.[56] Under the current management plan, up to 30 females and 45 males can be taken with the restriction that the first 10 spawning pairs observed must be allowed to spawn undisturbed in their natural habitat, and then only 1 in 4 females may be taken to spawn. In recent years, few or no fish have been taken, due to low abundance; however, in 2001, 123 coho were observed and 26 “wild” females were taken for spawning. Of the 123 coho observed, 40% were marked hatchery fish. No other data are available to assess the relative contribution of hatchery versus naturally produced coho salmon.

In its 1996 coho status review update, the BRT concluded that the Kingfisher Flat (Scott Creek) hatchery population should be considered part of the ESU and was essential for ESU recovery (NMFS 1996a). This conclusion was based on the fact that local broodstock was regularly incorporated into the hatchery population in the years that coho were produced between 1905 and 1943, and there have been no out-of-basin or out-of-ESU transfers since the hatchery was restarted in 1976. The MBSTP operation is classified as a category 1 hatchery (SSHAG 2003). For other SSHAG categorizations of hatchery stocks, see Appendix C, Table C-1.

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[56] D. Streig, MBSTP, Davenport, CA. Pers. commun.

Table 82. Average annual releases of coho salmon juveniles (fry and smolts) from hatcheries in the Central California Coast ESU during release years 1987–1991, 1992–1996, and 1997–2003.

Hatchery	**SSHAG category**	**Annual average releases**		
		1987–1991	**1992–1996**	**1997–2002**
Monterey Bay Salmon and Trout	1	25,764[a]	8,645[b]	1,901[b]
Silver-King		95,074[c]	0[d]	0[d]
Noyo Egg Collecting Station	1	107,918[a]	52,012[e]	72,363[e]
Don Clausen (Warm Springs) Hatchery	1	123,157[a]	81,666[f]	12,104[f]
Total		351,913	142,323	86,368

[a] Source: Weitkamp et al. (1995).

[b] No coho salmon released in 1991, 1994, 1997, and 2000; all releases are smolts except for 10,095 fry released in 1996; smolts from San Lorenzo River, Noyo River, and Prairie Creek reared at Big Creek and released into San Lorenzo River are excluded from totals. Sources: MBSTP (1992, 1993, 1994, 1995, 1996); Anderson (1996); Ayers (2004).

[c] Average from 4 years of data (1984–1988). Source: Weitkamp et al. (1995).

[d] Ceased operating in the 1980s.

[e] No yearling coho were released in 1995, 2000, or 2001. Sources: Grass (1992, 1993, 1995a, 1995b, 1996, 1997, 1998, 1999, 2000, 2001, 2002).

[f] Releases included both Warm Springs Hatchery and Noyo River ECS fish. Warm Springs Hatchery ceased releasing coho salmon in 1996. Sources: Cartwright (1994); Williams (1993); Quinones (1994, 1995, 1996, 1997, 1998, 1999); CDFG (2000c); Wilson (2001, 2002).

A captive broodstock program for Scott Creek was initiated at the NMFS Santa Cruz Laboratory in 2003.

Summary

Artificial Propagation

Artificial propagation of coho salmon within the Central California Coast coho salmon ESU has been reduced since it was listed in 1996 (Table 82). The Don Clausen Hatchery ceased production of coho salmon, and releases from the Noyo ECS operation declined over the past 6 years, in part because coho were not produced during 2 of those 6 years. The Monterey Bay Salmon and Trout Program produced few coho salmon for release in the last 6 years due to low adult returns to Scott Creek. Genetic risks associated with out-of-basin transfers appear minimal. However, potential genetic modification in hatchery stocks resulting from domestication selection or low effective population size remains a concern.

Harvest Impacts

Harvest of Central California Coast–origin coho salmon historically occurred in coho- and Chinook-directed commercial and recreational fisheries off the coast of California. Coho landing information for various ports in California is available dating back to the 1950s for commercial harvest and the early 1960s for recreational harvest; however, there are no historical estimates of either harvest or exploitation rates specific to Central California Coast coho salmon.

Likewise, no direct information is available about the ocean distribution of coho salmon; however, it is likely that most Central California Coast–origin coho salmon remain in waters off California and southern Oregon.[57] Thus, harvest management within this region is most relevant for evaluating harvest impacts.

Through the mid-1980s, the season for directed commercial harvest of coho salmon typically lasted 3 to almost 5 months throughout California. In the late 1980s and early 1990s, the commercial salmon seasons throughout California were generally shorter, particular in the region south of Point Delgada. By 1992, the commercial coho salmon season was closed completely from the Oregon border south to Horse Mountain, California, and open only 7 days from Point Arena to San Pedro. Retention of coho salmon by commercial fishers south of Cape Falcon, Oregon, including all of California, has been prohibited since 1993 (PFMC 2002b). Likewise, retention of coho salmon in recreational fisheries was prohibited in 1994 from Cape Falcon, Oregon, south to Horse Mountain, California. This prohibition was extended to include all California waters in 1996 (PFMC 2003b). Nonretention regulations in both commercial and recreational fisheries remain in place throughout coastal California and southern Oregon, but selective fishing for marked hatchery coho salmon has been allowed north of Humbug Mountain, Oregon, since 1999, and some incidental mortality of Central California Coast coho salmon may occur in this fishery. Additionally, coho salmon are also incidentally caught or hooked in Chinook salmon fisheries off California.

Although no estimates of incidental mortality associated with Chinook salmon fisheries are available (PFMC 2003b), nonretention regulations undoubtedly have resulted in a substantial reduction in harvest-related mortality since 1993. The PFMC (2003b) estimates that statewide commercial harvest of coho salmon averaged about 163,000 fish between 1952 and 1991; since 1992 there have been no known landings of coho salmon. Ocean recreational harvest of coho salmon averaged about 34,000 fish from 1962 to 1993. Total estimated incidental and illegal harvest of coho salmon has not exceeded 1,000 fish in any year since nonretention regulations were put in place.

There is no legal inside harvest of coho salmon within the Central California Coast coho salmon ESU; any fishery mortality results from incidental catch-and-release hooking mortality in other fisheries. There are no estimates of inside harvest or mortality of coho salmon in the Central California Coast coho salmon ESU (PFMC 2003b); however, CDFG (2003b) considers the potential for significant incidental mortality (and poaching) to be low because of the minimal overlap between the coho migration season and the steelhead season (CDFG 2003b).

Comparison with Previous Data

New data for the Central California Coast coho salmon ESU includes expansion of presence-absence analyses, an analysis of juvenile abundance in 13 river basins, smolt counts from two streams in the central portion of the ESU, and one adult time series for a population with mixed wild and hatchery fish. The presence-absence analysis suggests possible continued

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[57] Rogue/Klamath hatchery stocks, which serve as fishery surrogate stocks for SONCC coho salmon, are generally distributed south of Humbug Mountain, Oregon. It is likely that Central California Coast coho salmon exhibit a more southerly ocean distribution.

decline of coho salmon between the late 1980s and the late 1990s, a pattern that is mirrored in the limited smolt and adult counts. Juvenile time series suggest no obvious recent change in status, but most observations underlying that analysis were made in the period from 1993 to 2002. Coho salmon populations continue to be depressed relative to historical numbers, and strong indications show that breeding groups have been lost from a significant percentage of streams within their historical range. A number of coho populations in the southern portion of the range appear to be either extinct or nearly so, including those in the Gualala, Garcia, and Russian rivers, as well as smaller coastal streams in and south of San Francisco Bay. Although the 2001 broodyear appeared to be relatively strong, data were not yet available from many of the most at-risk populations within the Central California Coast coho salmon.

No new information has been provided that suggests additional risks beyond those identified in previous status reviews. Termination of hatchery production at the Don Clausen (Warm Springs) Hatchery and reductions in production at the Noyo and Kingfisher Flat (Big Creek) facilities suggest a decrease in potential risks associated with hatcheries; however, the lack of substantive information regarding the relative contribution of hatchery and naturally produced fish at these facilities adds uncertainty as to the potential risks these operations may pose to the genetic integrity of the Noyo River and Scott Creek stocks. Restrictions on recreational and commercial harvest of coho salmon since 1993–1994 have substantially reduced the exploitation rate on Central California Coast coho salmon.

30. Lower Columbia River Coho Salmon ESU

Summary of Previous BRT Conclusions

NMFS reviewed the status of the Lower Columbia River coho salmon ESU in 1996 (NMFS 1996b) and most recently in 2001 (NMFS 2001a). In the 2001 review, the BRT was very concerned that the vast majority (over 90%) of historical populations in the Lower Columbia River coho salmon ESU appear to be either extirpated or nearly so. The two populations with any significant production (Sandy and Clackamas rivers) were at appreciable risk because of low abundance, declining trends, and failure to respond after a dramatic reduction in harvest. The large number of hatchery coho salmon in the ESU was also considered an important risk factor. The majority of the 2001 BRT votes were for "at risk of extinction" with a substantial minority "likely to become endangered."

Listing status: Proposed Threatened.

New Data and Updated Analyses

New data include spawner abundance estimates through 2002 for Clackamas and Sandy river populations (the previous status review had data through 1999 only). In addition, the ODFW conducted surveys of Oregon lower Columbia River coho salmon using a stratified random sampling design in 2002, which provided the first abundance estimates for lower tributary populations (previously only limited index surveys were available. Estimates of the fraction of hatchery-origin spawners accompany the new abundance estimates. In Washington, no surveys of natural-origin adult coho salmon abundance are conducted. WDFW provided updated information through 2002 on natural-origin smolt production from Cedar, Mill, Germany, and Abernathy creeks and the upper Cowlitz River.

New analyses include tentative designation of demographically independent populations, recalculation of metrics reviewed by previous BRTs using additional years of data, estimates of median annual growth rate (λ) using different assumptions about the reproductive success of hatchery fish, a new stock assessment of Clackamas River coho by ODFW (Zhou and Chilcote 2003), and estimates of current and historically available stream kilometers.

Historical Population Structure

As part of its effort to develop viability criteria for lower Columbia River salmon and steelhead, the Willamette/Lower Columbia Technical Recovery Team (WLC-TRT) identified historically demographically independent populations of salmon and steelhead in the lower

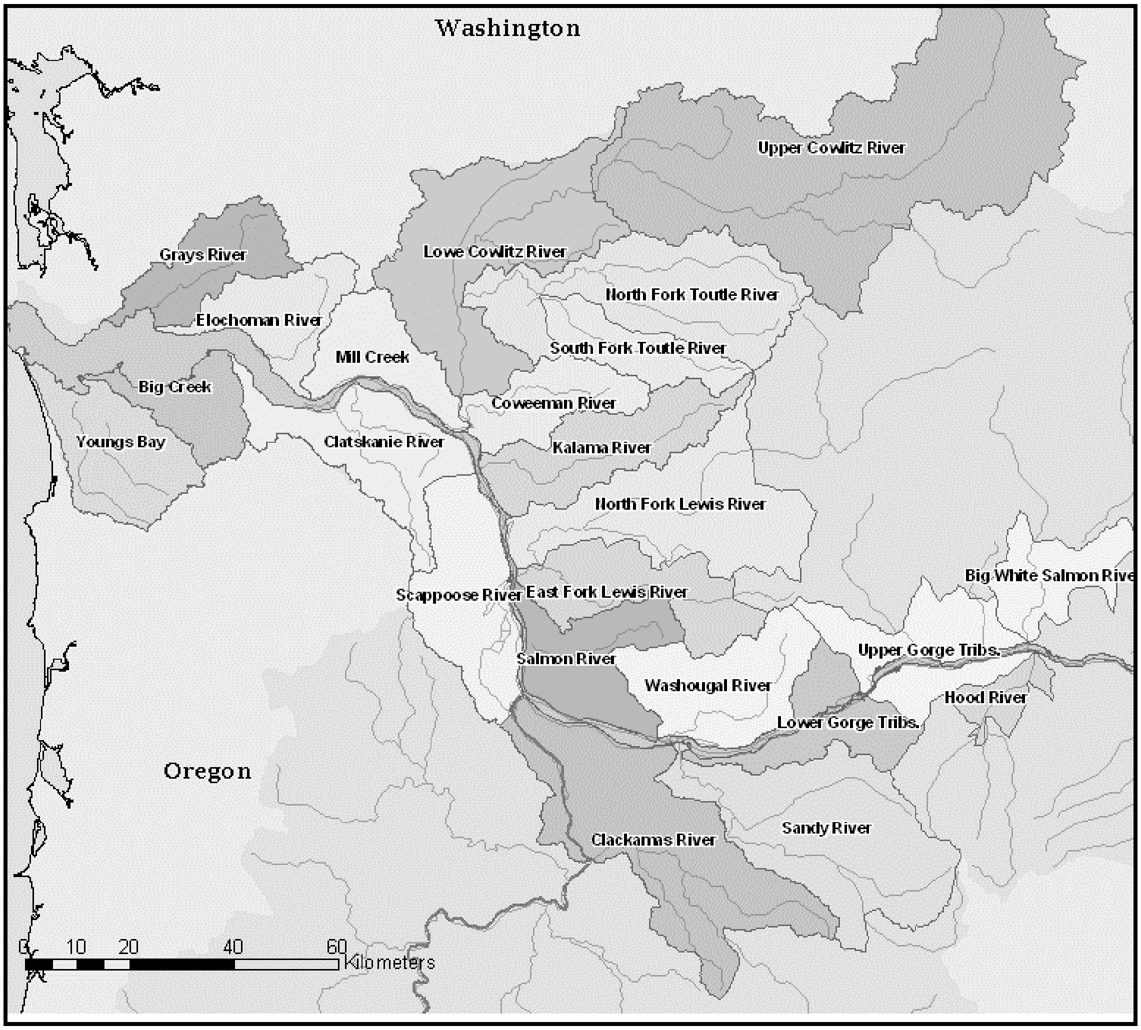

Figure 210. Tentative historical populations of the Lower Columbia River coho salmon ESU. Source: based on work by Willamette/Lower Columbia Technical Recovery Team for Chinook salmon and steelhead (Myers et al. 2002).

Columbia River listed under the ESA (Myers et al. 2002). Population boundaries are based on the definition of VSPs developed by NMFS (McElhany et al. 2000). Based on the WLC-TRT's framework for Chinook salmon and steelhead, the BRT tentatively designated populations of Lower Columbia River ESU coho salmon (Figure 210). A working group at the Northwest Fisheries Science Center hypothesized that the Lower Columbia River coho salmon ESU historically consisted of 23 populations. The WLC-TRT has not yet reviewed these population designations. With the exception of the Clackamas coho, the populations shown in Figure 210 are used as the units for the new analyses in this report.

Previous BRT and ODFW analyses have treated the coho salmon in the Clackamas River as a single population (see previous status review updates [Weitkamp et al. 1995 and NMFS 1996b] for more complete discussion and references). However, recent ODFW analysis (Zhou and Chilcote 2003) supports the hypothesis that coho salmon in the Clackamas River consist of two populations, an early run and a late run. The late-run population is believed to be descended from the native Clackamas River population, and the early run is believed to descend from hatchery fish introduced from Columbia River populations outside the Clackamas River basin. There is uncertainty about the population structure of Clackamas River coho; therefore, in this report, analyses of Clackamas River coho are conducted under both the single-population and two-population hypotheses for comparison.

For other salmonid species, the WLC-TRT partitioned lower Columbia River populations into a number of strata based on major life-history characteristics and ecological zones (McElhany et al. 2003). These analyses suggest that a viable ESU would require a number of viable populations in each stratum. Coho salmon do not have the major life-history variation seen in lower Columbia River steelhead or Chinook salmon, and would thus be divided into strata based only on ecological zones. The strata and associated populations for coho salmon are identified in Table 83.

Abundance and Trends

Recent abundance of natural-origin spawners, and recent fraction of hatchery-origin spawners for Lower Columbia River coho salmon ESU populations are summarized in Table 83. Natural-origin fish are defined as those whose parents spawned in the wild, while hatchery-origin fish are defined as those whose parents were spawned in a hatchery. Some populations (e.g., North Fork Lewis River) spawned above now-impassable barriers; they are completely extirpated. Most other populations, except for the Clackamas and Sandy River populations, are believed to have very little, if any, natural production. References for abundance time series and related data are found in Appendix C, Table C-2.

Clackamas

The Clackamas River population above North Fork Dam is one of only two populations in the ESU for which natural production trends can be estimated. The portion of the population above the dam has a relatively low fraction of hatchery-origin spawners, while they dominate the area below the dam (Table 83). The recent average number of coho salmon above the dam is shown in Table 84, and counts of total adults and natural-origin adults passing North Fork Dam is shown in Figure 211. Prior to 1973, hatchery-origin adults and juveniles were released above North Fork Dam; the time series from 1957 to 1972 contains an unknown fraction of hatchery-origin spawners. Because almost all Lower Columbia River ESU coho salmon females and most males spawn at 3 years of age, a strong cohort structure is produced. Figure 212 shows the three adult cohorts on the Clackamas. As discussed in the section on population structure, multiple hypotheses exist regarding the number of historical and current populations in the Clackamas Basin. Zhou and Chilcote (2003) partitioned current Clackamas River coho above the North Fork Clackamas into two populations (Figure 213). Figure 214 shows the number of juvenile coho outmigrants passing North Fork Dam from 1957 to 2002. The long-term trends and growth rate (λ) estimates over the entire time series for the total count at North Fork Dam and the early run portion have been slightly positive and the short-term trends and λ have been slightly negative (Tables 85 and 86).

The late-run portion of the North Fork Dam count (hypothesized to be the remains of the historical Clackamas River coho population) shows negative trends and growth rates over both

Table 83. Recent abundance of natural-origin spawners and recent fraction of hatchery-origin spawners for Lower Columbia River ESU coho salmon populations (based on ODFW and PGE data).

Ecological zone[a] Putative population	2002 total spawners	2002 hatchery fraction (%)	2002 natural-origin smolts
Coastal			
Youngs Bay & Big Creek	4,473	91	nd
Grays River	nd	nd	nd
Elochoman River	nd	nd	nd
Clatskanie River	229	60	nd
Mill, Germany, Abernathy creeks	nd	nd	22,700
Scappoose River	458	0	nd
Cascade			
Cispus River	nd	nd	168,281
Tilton River	nd	nd	
Upper Cowlitz River	nd	nd	
Lower Cowlitz River	nd	nd	nd
North Fork Toutle River	nd	nd	nd
South Fork Toutle River	nd	nd	nd
Coweeman River	nd	nd	nd
Kalama River	nd	nd	nd
North Fork Lewis River	nd	nd	32,695 (Cedar Creek only)
East Fork Lewis River	nd	nd	nd
Clackamas River	1,001 (above North Fork) 2,402 (below North Fork)	12 (above North Fork) 78 (below North Fork)	nd
Salmon Creek	nd		nd
Sandy River	310 (above Marmot) 271 (below Marmot)	0 (above Marmot) 97 (below Marmot)	nd
Washougal River	nd	nd	nd
Columbia Gorge			
Lower gorge tributaries	nd	nd	nd
White Salmon	nd	nd	nd
Upper gorge tributaries	1,317 (Combined Hood River and Oregon only, upper gorge)	>65[b]	nd
Hood River			nd

[a] Ecological zones are based on ecological community and hydrodynamic patterns.

[b] Contains an unknown (i.e., unmarked) additional fraction of hatchery-origin coho from upstream releases.

the long and short term. However, the confidence intervals on trend and growth rate are large, so there is a great deal of uncertainty. Both the long-term and short-term trends and λ have relatively high probabilities of being less than one (Tables 87 and 88).

Since the late 1980s, the number of preharvest recruits has declined relative to the number of spawners (Figures 215 and 216). Despite upturns in the last 2 years, the population has had more years below replacement since 1990 than above. Thus, even with the dramatic reductions in harvest rate (Figure 217), the population failed to respond during the 1990s because of this recruitment failure. Although the recent increases in recruitment are encouraging, the

Table 84. Recent abundance estimates for subset of Lower Columbia River ESU coho populations.

Population	Years for recent means	Recent geometric mean	Recent arithmetic mean
Clackamas (above North Fork Dam)			
Total	2000–2002	2,122	2,453
Early run	1996–1999	302	531
Late run	1996–1999	35	100
Sandy (above Marmot Dam)	2000–2002	643	739

population has not regained earlier levels, and whether they will persist is not known. The recent increases in recruitment are attributable in some part to increased marine survival, which cannot be predicted with any certainty. Based on stock assessment analysis that assumes the Clackamas River coho consist of two populations, Zhou and Chilcote (2003) concluded that the early (introduced) run had a relatively low risk of extinction, whereas the late (native) run had a relatively high risk of extinction.

Sandy

The Sandy River population above Marmot Dam and the Clackamas River populations above North Fork Dam are the only populations in the Lower Columbia River coho salmon ESU for which natural production trends can be estimated. The portion of the Sandy River population above Marmot Dam has almost no hatchery-origin spawners, while they dominate the area below the dam (Table 83). The recent average number of coho salmon above Marmot Dam is shown in Table 84. Figure 217 shows the total adult count passing the dam, while Figure 218 shows the three adult cohorts on the Sandy River.

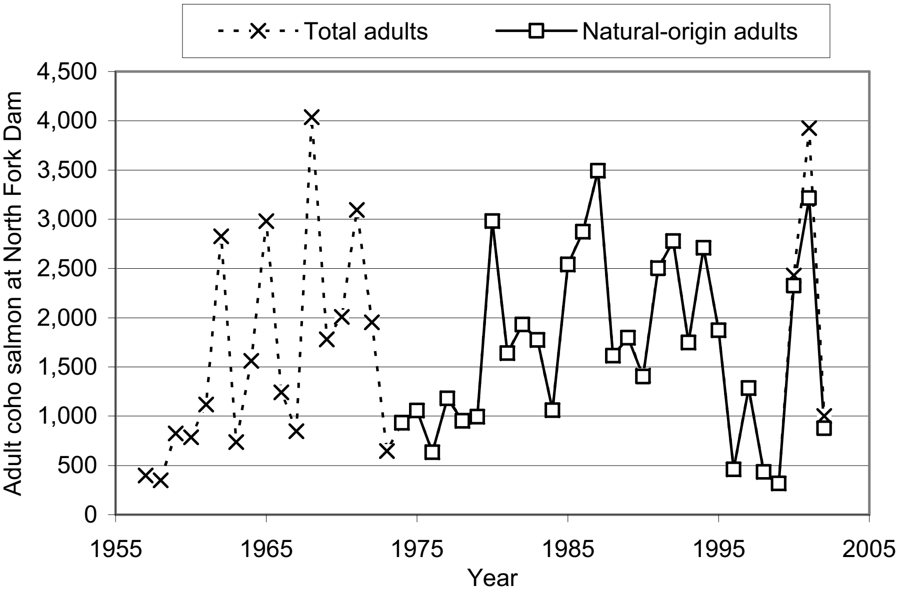

Figure 211. Clackamas North Fork Dam counts of adult (3-year-old) coho salmon, 1957–2002.

Table 85. Long-term trend and growth rate for subset of Lower Columbia River ESU coho salmon populations (95% confidence intervals are in parentheses). The long-term analysis used the entire data set.

Population	Years for trend[a]	Trend of total spawners	Years for λ[b]	Median growth rate (λ)[c]	
				Hatchery = 0	Hatchery = wild
Clackamas (above North Fork Dam)					
Total	1957–2002	1.009	1973–2002	1.028	1.026
		(0.994–1.024)		(0.898–1.177)	(0.897–1.174)
Early run	1973–1998	1.080	1973–1998	1.085	1.085
		(1.015–1.149)		(0.944–1.248)	(0.944–1.248)
Late run	1973–1998	0.926	1973–1998	0.958	0.958
		(0.863– 0.993)		(0.834– 1.102)	(0.834–1.102)
Sandy	1977–2002	0.997	1977–2002	1.012	1.012
		(0.941–1.056)		(0.874–1.172)	(0.874–1.172)

[a] See Table 84 for years.

[b] Since the fraction of hatchery-origin spawners prior to 1973 in the Clackamas River is unknown, λ estimates for the Clackamas River use data from 1973 onward.

[c] The λ calculation estimates the natural growth rate after accounting for hatchery-origin spawners. The λ estimate is calculated under two hypotheses about the reproductive success of hatchery-origin spawners: Hatchery = 0, hatchery fish are assumed to have zero reproductive success; Hatchery = wild, hatchery fish are assumed to have the same reproductive success as natural-origin fish.

The long-term and short-term trends for the counts at Marmot Dams are both slightly negative (Tables 85 and 86). The long-term λ is slightly positive and the short-term λ is slightly negative (Tables 85 and 86). However, the confidence intervals on trend and growth rate are large, so there is a great deal of uncertainty. Both the long-term and short-term trends and λ have relatively high probabilities of being less than one (Tables 87 and 88). The late 1980s recruitment failure observed in the Clackamas River is also present in the Sandy River population (Figures 219 and 220). If anything, it may be more pronounced in the Sandy River system; overall coho salmon abundance levels are lower. Again, despite reductions in harvest (Figure 221), the Sandy River coho population has failed to recover to earlier recruitment levels. The 2002 return showed a decline from 2000 and 2001 abundance levels (Figure 217).

Other Oregon Populations

ODFW initiated a large effort in 2002 to obtain abundance estimates of lower Columbia River coho salmon using a random stratified sampling protocol similar to that used to estimate abundance of Oregon coastal coho salmon. Results from this survey are presented in Table 83. These surveys indicate that hatchery-origin spawners dominate Oregon Lower Columbia River ESU coho salmon, but there are some potential pockets of natural production (e.g., Scappoose Creek). With data for one year only, it is difficult reach conclusions about the abundance of coho salmon in Oregon populations downstream of the Willamette River. Marine survival for Lower Columbia River ESU coho salmon returning in 2002 was relatively high and the lower Columbia River tributary counts in 2002 are likely to be higher than in low marine survival years. Prior to 2002, ODFW conducted coho salmon spawner surveys in the lower Columbia River. We combined these surveys to obtain spawners-per-mile information at the scale of our

Table 86. Short-term trend and growth rate for subset of Lower Columbia River ESU coho populations (95% confidence intervals are in parentheses).

Population	Years for trend[a]	Trend of total spawners	Years for λ	Median growth rate (λ)[b] Hatchery = 0	Median growth rate (λ)[b] Hatchery = wild
Clackamas (above North Fork Dam)					
Total	1990–2002	0.949 (0.832–1.083)	1990–2002	0.975 (0.852–1.116)	0.970 (0.848–1.110)
Early run	1990–1998	0.884 (0.601–1.302)	1990–1998	0.902 (0.785–1.037)	0.902 (0.785–1.037)
Late run	1990–1998	0.734 (0.406–1.325)	1990–1998	0.843 (0.734–0.969)	0.843 (0.734– 0.969)
Sandy	1990–2002	0.964 (0.841–1.105)	1977–2002	0.979 (0.845–1.133)	0.978 (0.845–1.132)

[a] Short-term data sets include data from 1990 to the most recent available year.

[b] The λ calculation estimates the natural growth rate after accounting for hatchery-origin spawners. The λ estimate is calculated under two hypotheses about the reproductive success of hatchery-origin spawners: Hatchery = 0, hatchery fish are assumed to have zero reproductive success; Hatchery = wild, hatchery fish are assumed to have the same reproductive success as natural-origin fish.

Table 87. Probability that the long-term abundance trend or growth rate of Lower Columbia River ESU coho salmon is less than 1.

Population	Years for trend	Probability trend < 1	Years for λ	Probability λ < 1* Hatchery = 0	Probability λ < 1* Hatchery = wild
Clackamas (above North Fork Dam)					
Total	1957–2002	0.123	1973–2002	0.283	0.296
Early run	1993–1998	0.008	1973–1998	0.148	0.148
Late run	1973–1998	0.984	1973–1998	0.724	0.724
Sandy	1977–2002	0.544	1977–2002	0.426	0.427

* Hatchery = 0, hatchery fish are assumed to have zero reproductive success; Hatchery = wild, hatchery fish are assumed to have the same reproductive success as natural-origin fish.

Table 88. Probability that the short-term abundance trend or growth rate of Lower Columbia River ESU coho salmon is less than 1.

Population	Years for trend	Probability trend < 1	Years for λ	Probability λ < 1* Hatchery = 0	Probability λ < 1* Hatchery = wild
Clackamas (above North Fork Dam)					
Total	1990–2002	0.799	1990–2002	0.582	0.600
Early run	1990–1998	0.762	1990–1998	0.711	0.711
Late run	1990–1998	0.872	1990–1998	0.836	0.836
Sandy	1990–2002	0.716	1990–2002	0.564	0.566

* Hatchery = 0, hatchery fish are assumed to have zero reproductive success; Hatchery = wild, hatchery fish are assumed to have the same reproductive success as natural-origin fish.

Table 89. Estimates of natural coho salmon juvenile outmigrants from Washington Lower Columbia River streams. Estimates are based on expansions from smolt traps, not total census.

Out-migrant year	Cedar Creek[a]	Mill Creek[b]	Abernathy Creek[b]	Germany Creek[b]	East Fork Lewis River[c]	Cowlitz River above Cowlitz Falls[d]
1997	–	–	–	–	–	17,490
1998	38,354	–	–	–	–	196,520
1999	27,987	–	–	–	–	88,788
2000	20,282	–	–	–	4,514–9,028	236,960
2001	20,695	6,324	6,991	8,157	–	796,948
2002	32,695	9,500	6,200	7,000	–	168,281

[a] Cedar Creek is a tributary of the North Fork Lewis River population.
[b] Mill, Germany, and Abernathy creeks are combined into a single population unit for BRT analysis.
[c] The East Fork Lewis River estimate shows a range based on uncertainties about trap efficiency.
[d] The Cowlitz River above Cowlitz Falls is partitioned into three independent populations (upper Cowlitz, Cispus, and Tilton rivers).

population units (Figures 222–225). In many years over the last two decades, these surveys have observed no natural-origin coho salmon spawners. Based on the spawners-per-mile survey data, previous assessments have concluded that coho salmon in these populations are extinct or nearly so (ODFW 1995a, NMFS 2001a).

Washington Populations

Hatchery production also dominates the Washington side of this ESU, and no populations are known to be naturally self-sustaining. A National Research Council study (NRC 1996) indicated that 97% of 425 fish surveyed on the spawning grounds were first-generation hatchery fish. There are no estimates of spawner abundance for Washington Lower Columbia River coho salmon ESU populations. However, WDFW recently conducted trapping of juvenile outmigrant coho (Table 89), and these data indicate that some natural production is occurring in the Lewis River and Mill-Germany-Abernathy creek populations. However, there is no direct way to determine whether these populations would be naturally self-sustaining in the absence of hatchery-origin spawners. WDFW suggests that juvenile outmigrant production seen in the monitored streams is typical of other Washington Lower Columbia River ESU streams and that a fairly substantial number of natural-origin spawners may return to the lower Columbia River each year. Preliminary WDFW calculations suggest that the natural preharvest recruitment from the monitored streams alone may be 17,000 adults (assuming 4% marine survival) (Haymes 2003).

The population above Cowlitz Falls is also capable of natural outmigrant production (Table 89). However, these populations are not considered currently self-sustaining.[58] Three dams block anadromous passage to the upper Cowlitz River. Currently, adult coho salmon

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[58] See Footnote 9.

Table 90. Total coho salmon hatchery releases into the Columbia River basin (data from Fish Passage Center 2001, 2002, 2003).

Year	Hatchery releases
2000	29,902,509
2001	25,730,650
2002	20,011,742

(some of hatchery origin) are collected below the lower dam (Mayfield Dam) and trucked to the area above the upper dam (Cowlitz Falls Dam). There is no appreciable downstream passage through the dams, so juvenile outmigrants are collected at Cowlitz Falls Dam and trucked below Mayfield Dam. At this time, collection efficiency of outmigrating juveniles at Cowlitz Falls is so low (40–60%) that the spawners cannot replace themselves (i.e., fewer adult coho salmon return from the relatively low number of outmigrants that are released below Mayfield Dam than are planted above Cowlitz Falls Dam). Thus, hatchery production (in addition to the trap-and-haul operation) maintains the populations.

New Hatchery Information

Hatchery Production

Hatchery production dominates the Lower Columbia River coho salmon ESU. Recent coho salmon releases in the Columbia River basin (including releases upstream of the ESU boundary) are shown in Table 90. The total expected return of hatchery coho salmon to the Columbia River basin in 2002 was over a million adults (ODFW News Release, 13 September 2002; at the time of this report, final 2002 return data were not available).

Loss of Habitat from Barriers

Steel and Sheer (2003) analyzed the number of stream kilometers historically and currently available to salmon populations in the lower Columbia River (Table 91). Stream kilometers usable by salmon are determined based on simple gradient cutoffs and on the presence of impassable barriers. This approach overestimates the number of usable stream kilometers, because it does not take into consideration aspects of habitat quality other than gradient. However, the analysis does indicate that the number of kilometers of stream habitat currently accessible is greatly reduced from the historical condition for some populations.

ESU Summary

Based on the updated information provided in this report, information contained in previous status reviews, and the WLC-TRT's preliminary analyses, we have tentatively identified the number of historical and currently viable populations for the Lower Columbia River coho salmon ESU. Only two putative populations have demonstrated appreciable levels of natural production (Clackamas and Sandy rivers). There is only very limited information on the

Table 91. Loss of habitat from barriers in the Lower Columbia River coho salmon ESU.

Population	**Potential current habitat (%)**[a]	**Potential historical habitat (km)**[b]	**Current/ historical habitat ratio**[c]
Youngs Bay	178	195	91
Grays River	133	133	100
Big Creek	92	129	71
Elochoman River	85	116	74
Clatskanie River	159	159	100
Mill, Germany, Abernathy creeks	117	123	96
Scappoose Creek	122	157	78
Cispus River[d]	0	76	0
Tilton River[d]	0	93	0
Upper Cowlitz River[d]	4	276	1
Lower Cowlitz River	418	919	45
North Fork Toutle River	209	330	63
South Fork Toutle River	82	92	89
Coweeman River	61	71	86
Kalama River	78	83	94
North Fork Lewis River	115	525	22
East Fork Lewis River	239	315	76
Clackamas River	568	613	93
Salmon Creek	222	252	88
Sandy River	227	286	79
Washougal River	84	164	51
Lower gorge tributaries	34	35	99
Upper gorge tributaries	23	27	84
White Salmon River	0	71	0
Hood River	35	35	100
Total	3,285	5,275	62

[a] The potential current habitat is the kilometers of stream below all currently impassable barriers between a gradient of 0.5% and 4%.

[b] The potential historical habitat is the kilometers of stream below historically impassable barriers between a gradient of 0.5% and 4%.

[c] The current:historical habitat ratio is the percent of the historical habitat that is currently available. This table does not consider habitat quality.

[d] The Cispus, Tilton, and upper Cowlitz habitats are listed in this analysis as currently inaccessible because volitional passage is not possible. However, a trap-and-haul reintroduction program for these populations has been initiated.

remainder of the 21 putative populations, but most were considered extirpated, or nearly so, during the low marine survival period of the 1990s (reviewed in NMFS 2001a). Recently initiated spawner surveys by ODFW and juvenile outmigrant trapping by WDFW indicate there is some natural coho salmon production in the lower Columbia River. However, hatchery-origin

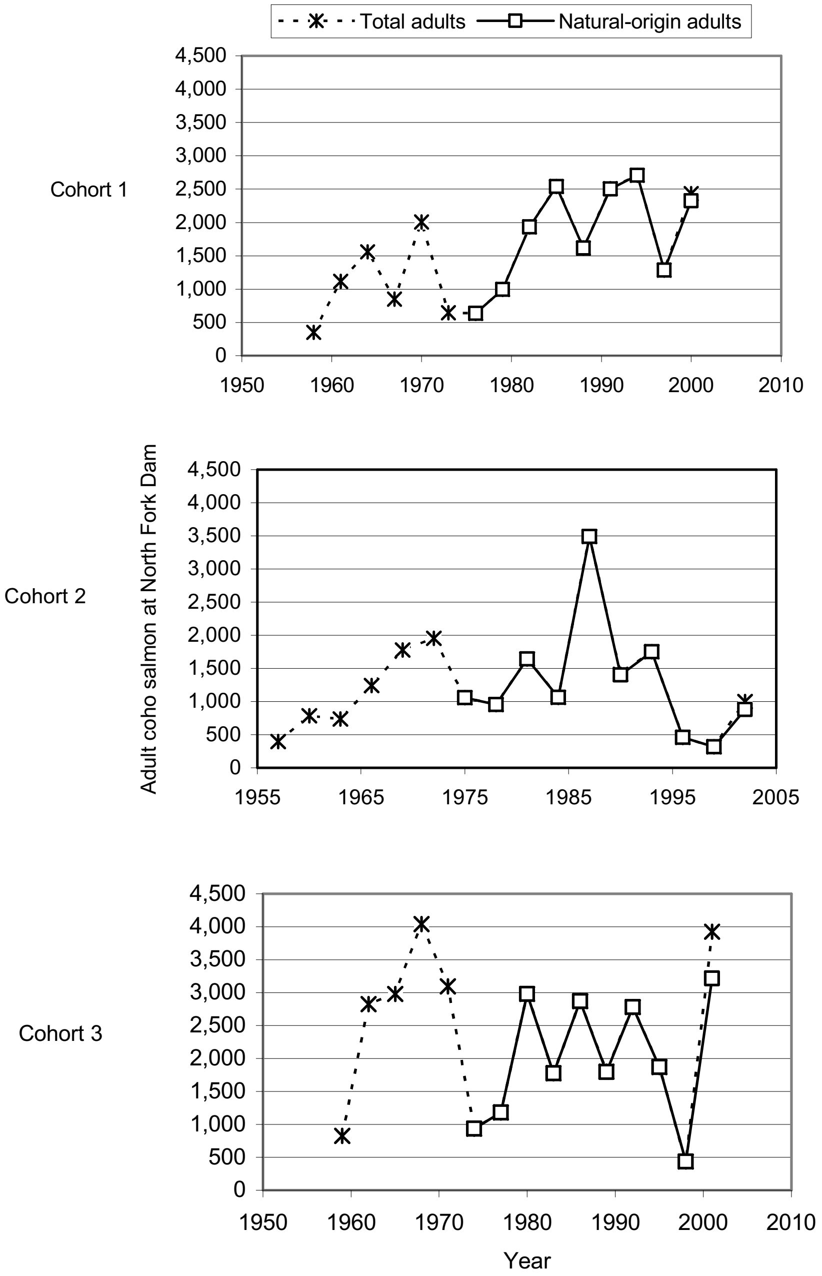

Figure 212. Clackamas North Fork Dam counts of adult (3-year-old) coho salmon by cohort, 1957–2002.

spawners dominate the majority of populations, and little data indicates they would naturally persist in the long term. Of the two populations where natural production can be evaluated, both have experienced recruitment failure over the last decade. Recent abundances of the two populations are relatively low (especially the Sandy River), placing them in a range where environmental, demographic, and genetic stochasticity can be significant risk factors.

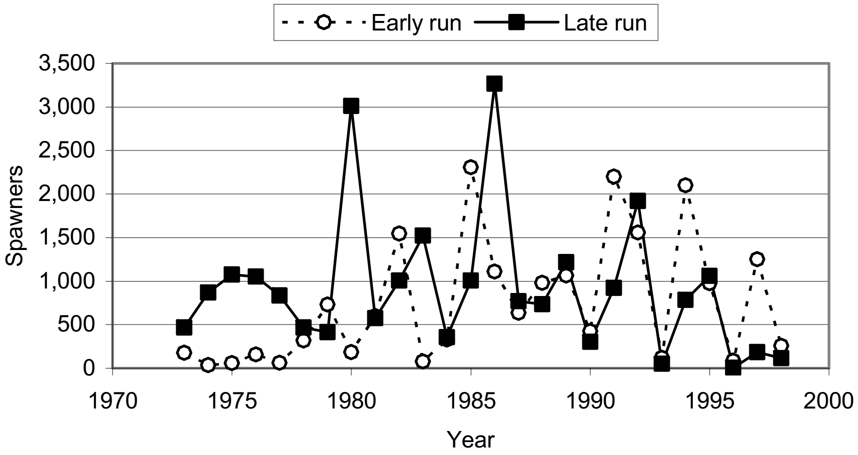

Figure 213. Clackamas River early and late-run coho salmon, 1973–1998. Run designation is based on a maximum likelihood approach, assuming two populations with different mean run times. Source: Zhou and Chilcote (2003).

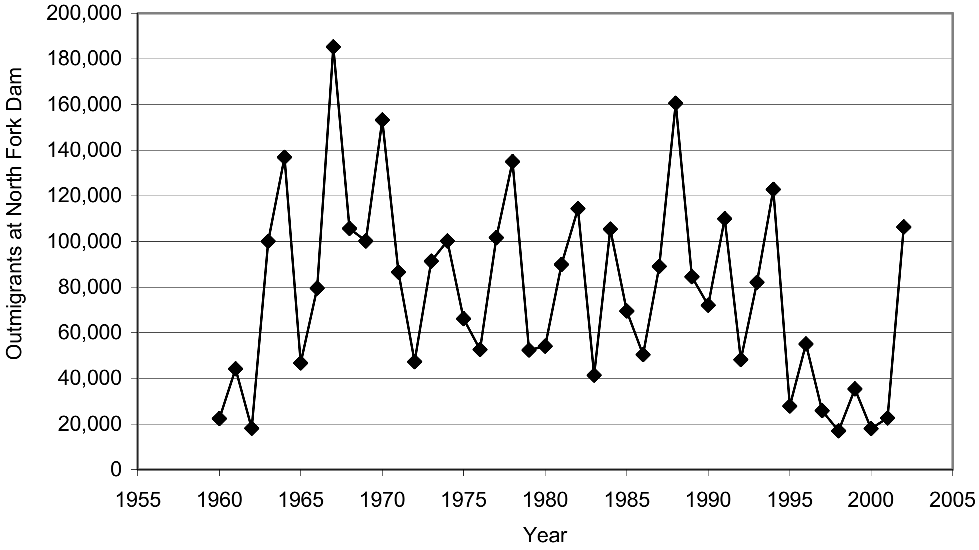

Figure 214. Total outmigrating juvenile coho salmon passing Clackamas North Fork Dam, 1959–2003.[59]

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[59] D. Cramer, Portland General Electric, Portland, OR. Pers. commun., 5 June 2003.

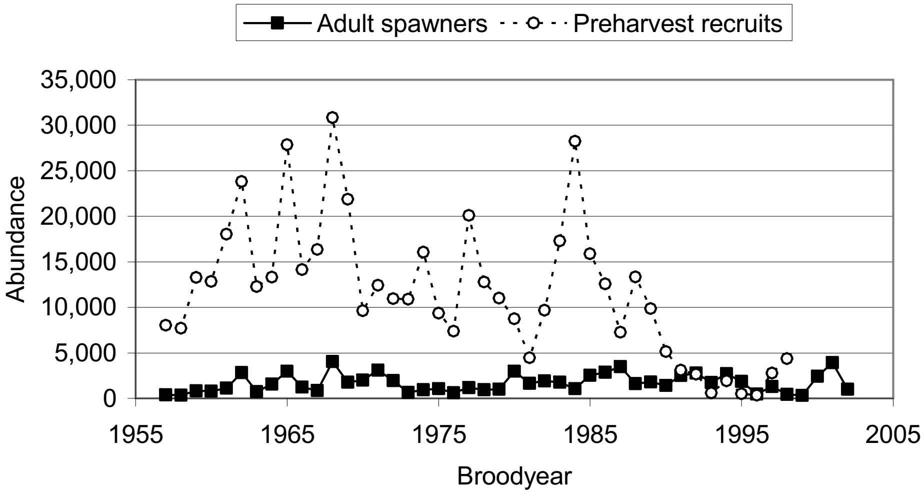

Figure 215. Estimate of preharvest coho salmon recruits and spawners in the Clackamas River, 1957–1998. Source: Based on adult counts at North Fork Dam.[60]

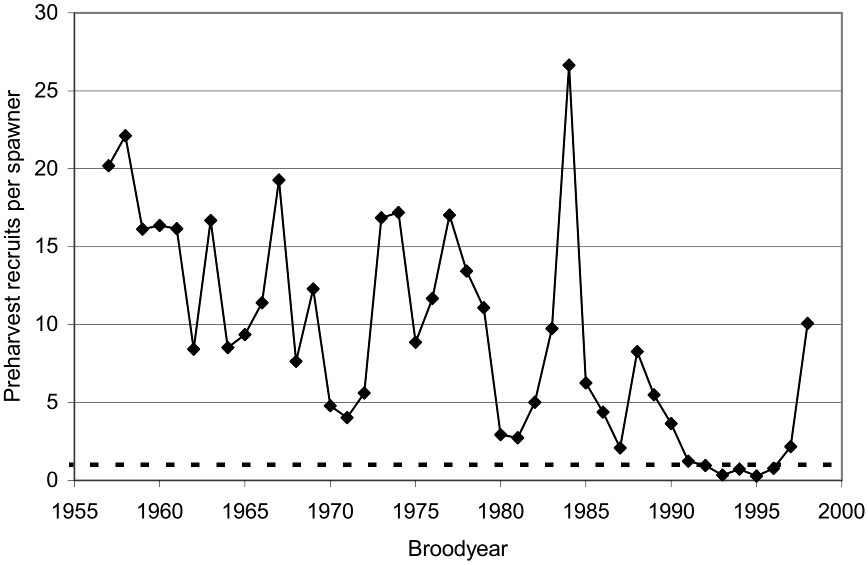

Figure 216. Estimate of preharvest coho salmon recruits per spawner in the Clackamas River, 1957–1998. The dashed line indicates the replacement level. Source: Based on adult counts at North Fork Dam.[61]

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[60] See Footnote 59.

[61] See Footnote 59.

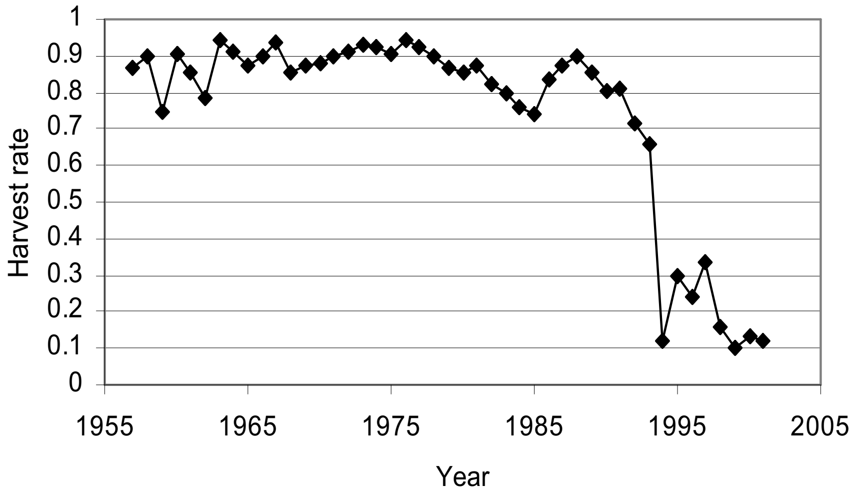

Figure 217. Clackamas River natural-origin coho salmon harvest rate, 1957–1999. The reduction in harvest rate was achieved by a switch to retention-only marked hatchery fish and timing the fishery to protect natural runs.[62]

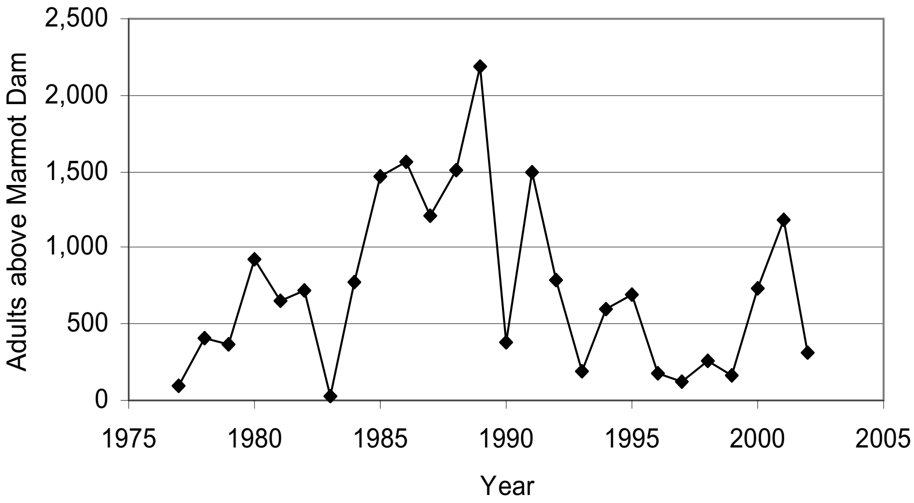

Figure 218. Count of adult (≥3 year old) coho salmon at the Marmot Dam on the Sandy River, 1977–2002. Almost all spawners above Marmot Dam are of natural origin. For no year is the proportion of hatchery-origin spawners estimated to be greater than 2.5%.

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[62] M. Chilcote, Oregon Department of Fish and Wildlife, Fish Division/conservation and recovery, Salem, OR. Pers. commun.

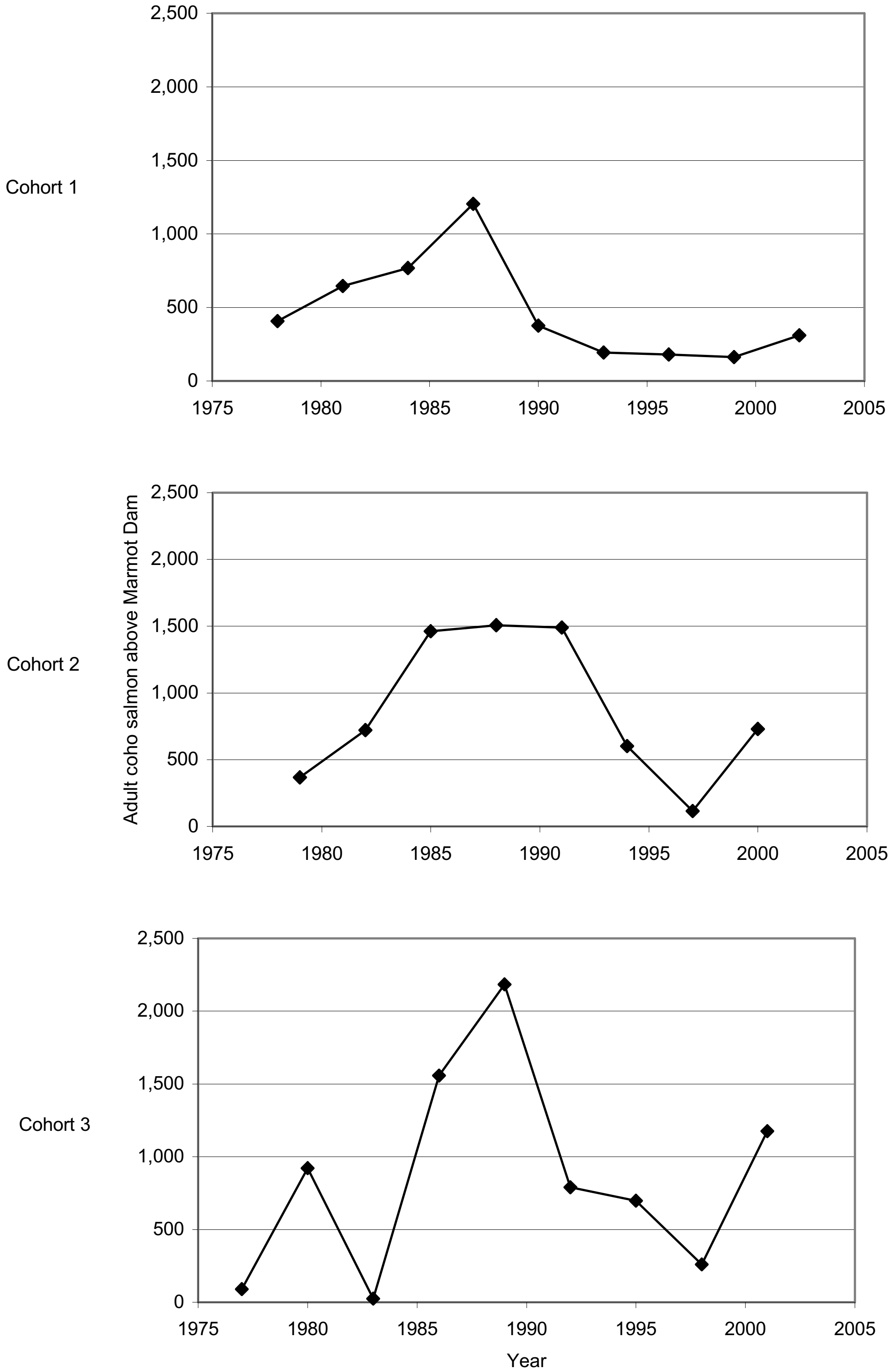

Figure 219. Count of adult (≥3 year old) coho salmon at Marmot Dam on the Sandy River by cohort. Almost all spawners above Marmot Dam are of natural origin. For no year is the proportion of hatchery-origin spawners estimated to be greater than 2.5%.

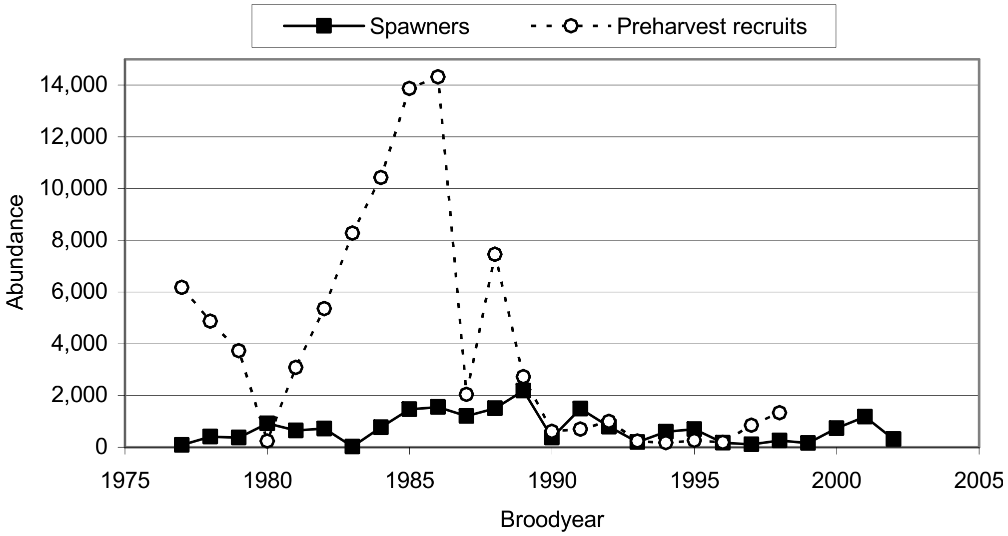

Figure 220. Estimate of preharvest coho salmon recruits and spawners in the Sandy River, 1977–2002. Source: Based on adult counts at Marmot Dam.[63]

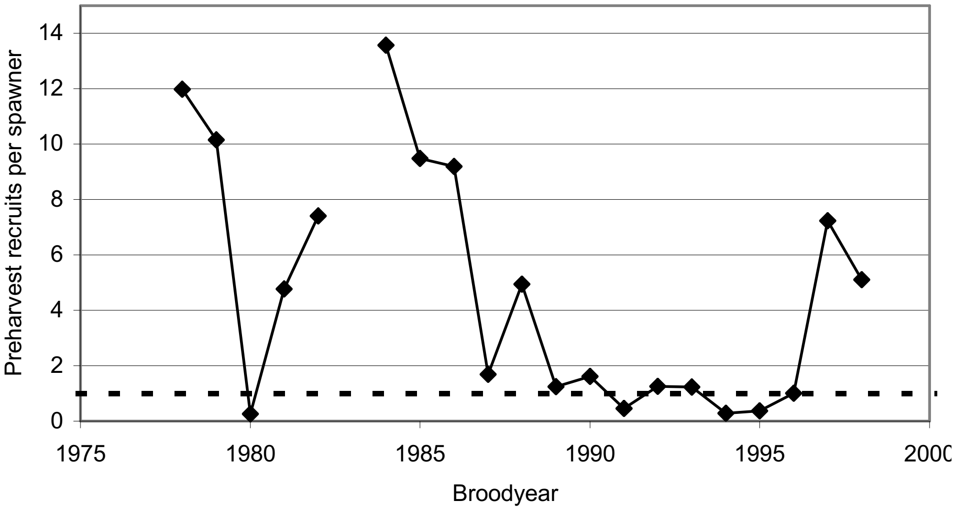

Figure 221. Estimate of preharvest coho salmon recruits per spawners in the Sandy River, 1977–2002. The dashed line indicates the replacement level. The 1977 broodyear preharvest recruits-per-spawner estimate is 68, and the 1983 broodyear estimate is 318. Source: Based on adult counts at Marmot Dam.[64]

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[63] See Footnote 59.

[64] See Footnote 59.

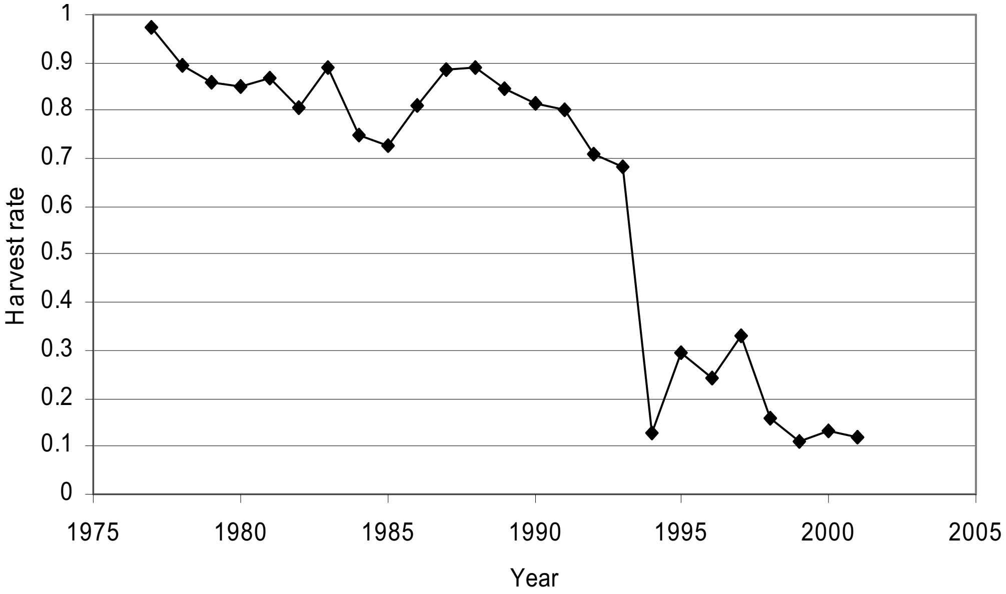

Figure 222. Sandy River natural-origin coho salmon harvest rate, 1977–2002. The reduction in harvest rate was achieved by switch to retention-only marked hatchery fish and timing the fishery to protect natural runs.[65]

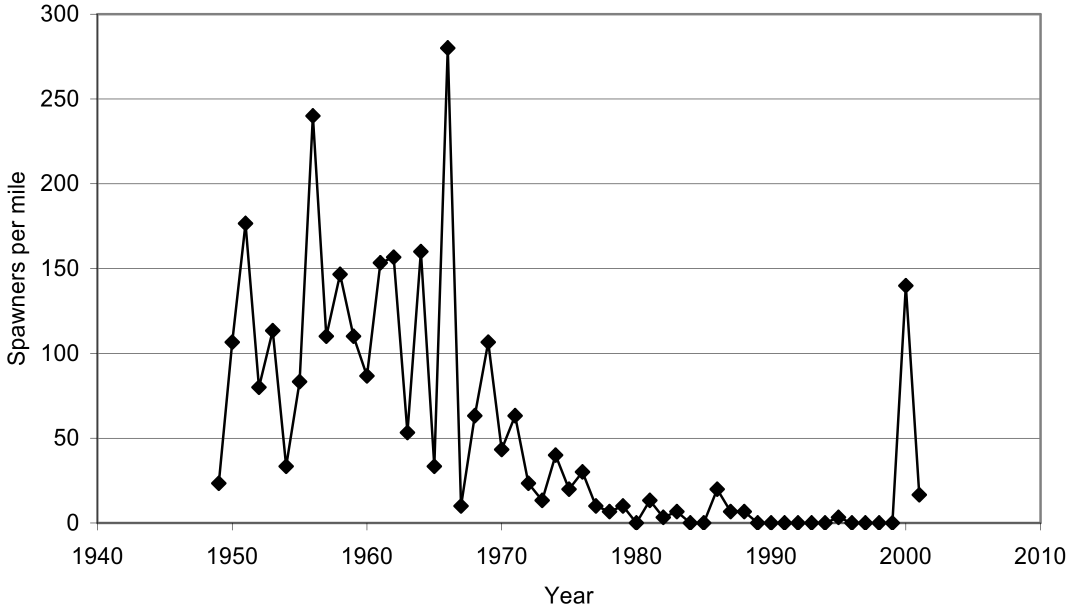

Figure 223. Youngs Bay coho salmon spawners per mile, 1949–2001.

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[65] See Footnote 62.

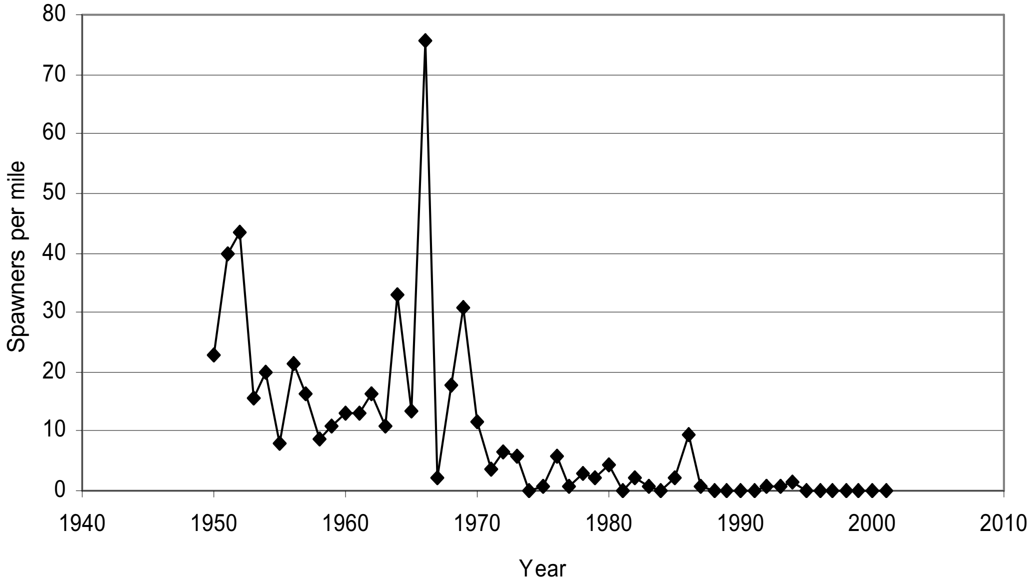

Figure 224. Big Creek coho salmon spawners per mile, 1949–2001.

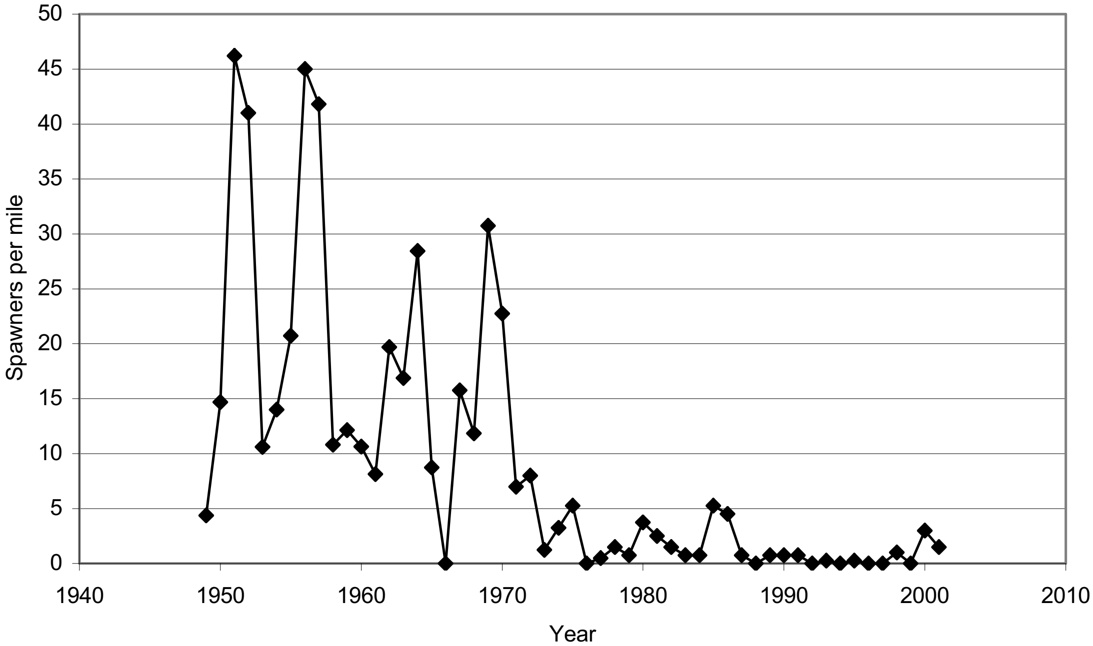

Figure 225. Clatskanie River coho salmon spawners per mile, 1949–2001.

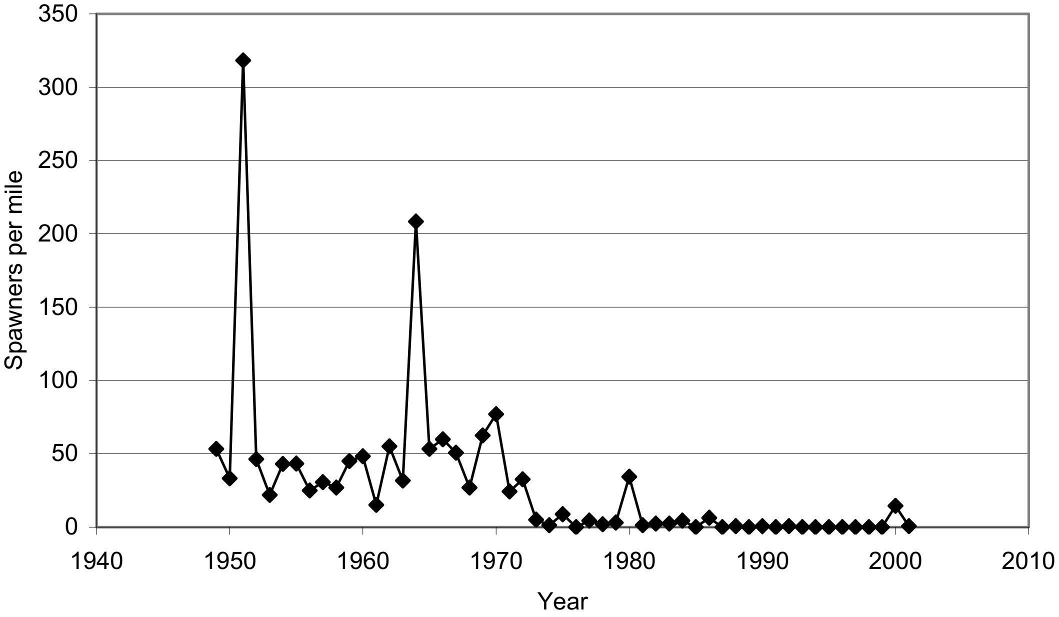

Figure 226. Scappoose River spawners per mile, 1949–2001.

31. Coho Salmon BRT Conclusions

Oregon Coast Coho Salmon ESU

The Oregon Coast coho salmon ESU continues to present challenges to those assessing extinction risk. The BRT found several positive features compared to the previous assessment in 1997. Adult spawners for the ESU in 2001 and 2002 exceeded the number observed for any year in the past several decades, and preharvest run size rivaled some of the high values seen in the 1970s. Some notable increases in spawners have occurred in many streams in the northern part of the ESU, which was the most depressed area at the time of the last status review evaluation. Hatchery reforms have continued, and the fraction of natural spawners that are first-generation hatchery fish has been reduced in many areas, compared to highs in the early to mid-1990s.

On the other hand, the recent years of good returns were preceded by 3 years of low spawner escapements—the result of 3 consecutive years of recruitment failure, in which the natural spawners did not replace themselves, even in the absence of any directed harvest. These 3 years of recruitment failure, which immediately followed the last status review in 1997, are the only such instances that have been observed in the entire time series of data collected for Oregon Coast coho salmon. Whereas the recent increases in spawner escapement have resulted in long-term trends in spawners that are generally positive, the long-term trends in productivity in this ESU are still strongly negative.

The BRT votes reflected ongoing concerns for the long-term health of this ESU: a majority (56%) of the FEMAT votes were cast in the "likely to become endangered" category, with a substantial minority (44%) falling in the "not likely to become endangered" category (Table 92). Although the BRT considered the significantly higher returns in recent years to be encouraging, most members felt that the factor responsible for the increases was more likely to be unusually favorable marine productivity conditions than improvement in freshwater productivity. The majority of BRT members felt that to have a high degree of confidence that the ESU is healthy, high spawner escapements should be maintained for a number of years, and the freshwater habitat should demonstrate the capability of supporting high juvenile production from years of high spawner abundance. As indicated in the risk matrix results, the BRT considered the decline in productivity to be the most serious concern for this ESU (mean score 3.2; Table 93). With all directed harvest for these populations already eliminated, harvest management (i.e., reducing harvest rates) can no longer compensate for declining productivity. The BRT was concerned that if the long-term decline in productivity reflects deteriorating conditions in freshwater habitat, this ESU could face very serious risks of local extinctions during the next cycle of poor ocean conditions. With the cushion provided by strong returns in the last 2 to 3 years, the BRT had much less concern about short-term risks associated with abundance (mean score 1.9).

Table 92. Tally of FEMAT vote distribution regarding the status of four coho salmon ESUs reviewed by the coho salmon BRT. Each of 13 BRT members allocated 10 points among the three status categories.

ESU	Danger of extinction	Likely to become endangered	Not likely to become endangered
Oregon Coast	0	73	57
Southern Oregon/Northern California Coast	29	87	14
Central California Coast	96	34	0
Lower Columbia River	88	42	0

Table 93. Summary of risk scores (1 = low to 5 = high) for four VSP categories (see Factors Considered in Status Assessments subsection for a description of the risk categories) for the four coho salmon ESUs reviewed. Data presented are means (range).

ESU	Abundance	Growth rate/productivity	Spatial structure and connectivity	Diversity
Oregon Coast	1.9 (1–3)	3.2 (2–4)	2.3 (1–3)	2.5 (2–3)
Southern Oregon/Northern California Coast	3.8 (2–5)	3.5 (2–5)	3.1 (2–4)	2.8 (2–4)
Central California Coast	4.8 (4–5)	4.5 (4–5)	4.7 (4–5)	3.6 (2–5)
Lower Columbia River	4.4 (4–5)	4.2 (3–5)	4.2 (2–5)	4.5 (4–5)

A minority of BRT members felt that the large number of spawners in the last few years demonstrate that this ESU is currently not at significant risk of extinction or likely to become endangered. Furthermore, these members felt that the recent years of high escapements, closely following years of recruitment failure, demonstrate that populations in this ESU have the resilience to bounce back from years of depressed runs.

Southern Oregon/Northern California Coast Coho Salmon ESU

A majority (67%) of BRT votes fell in the "likely to become endangered" category, although votes in the endangered category outnumbered those in the "not warranted" category by 2 to 1 (Table 92). The BRT found moderately high risks for abundance and growth rate/production, with mean matrix scores of 3.5 to 3.8, respectively, for these two categories. The BRT considered risks to spatial structure (mean score = 3.1) and diversity (mean score = 2.8) to be moderate (Table 93).

The BRT remained concerned about low population abundance throughout the Southern Oregon/Northern California Coast coho salmon ESU relative to historical numbers and long-term downward trends in abundance; however, the paucity of data on escapement of naturally produced spawners in most basins continued to hinder risk assessment. A reliable time series of adult abundance is available only for the Rogue River. These data indicate that long-term

(22-year) and short-term (10-year) trends in mean spawner abundance are upward in the Rogue; however, the positive trends reflect effects of reduced harvest (rather than improved freshwater conditions) because trends in preharvest recruits are flat. Less-reliable indices of spawner abundance in several California populations reveal no apparent trends in some populations and suggest possible continued declines in others. Additionally, the BRT considered the relatively low occupancy rates of historical coho salmon streams (between 37% and 61% from broodyears 1986 to 2000) as an indication of continued low abundance in the California portion of this ESU. The relatively strong 2001 broodyear, likely the result of favorable conditions in both freshwater and marine environments, was viewed as a positive sign, but was a single strong year following more than a decade of generally poor years.

The moderate risk matrix scores for spatial structure reflected a balancing of several factors. On the negative side was the modest percentage of historical streams still occupied by coho salmon (suggestive of local extirpations or depressed populations). The BRT also remains concerned about the possibility that losses of local populations have been masked in basins with high hatchery output, including the Trinity, Klamath, and Rogue systems. The extent to which strays from hatcheries in these systems are contributing to natural production remains uncertain; however, we generally believe that hatchery fish and progeny of hatchery fish constitute the majority of production in the Trinity River and may be a significant concern in parts of the Klamath and Rogue systems as well. On the positive side, extant populations can still be found in all major river basins within the ESU. Additionally, the relatively high occupancy rate of historical streams observed in broodyear 2001 suggests that much habitat remains accessible to coho salmon. The BRT's concern for the large number of hatchery fish in the Rogue, Klamath, and Trinity river systems was also evident in the risk rating of moderate for diversity.

Central California Coast Coho Salmon ESU

A large majority (74%) of the BRT votes fell into the endangered category, with the remainder falling into the "likely to become endangered" category (Table 92). The BRT found Central California Coast coho salmon to be at very high risk in three of four risk categories, with mean scores of 4.8, 4.5, and 4.7 for abundance, growth rate/productivity, and spatial structure, respectively (Table 93). Scores for diversity (mean 3.6) indicated BRT members considered Central California Coast coho salmon to be at moderate or increasing risk with respect to this risk category. The BRT's principal concerns continue to be low abundance and long-term downward trends in abundance of coho salmon throughout the ESU, as well as extirpation or near extirpation of populations across most of the southern two-thirds of the ESU's historical range, including several major river basins. Potential loss of genetic diversity associated with range reductions or loss of one or more brood lineages, coupled with historical influence of hatchery fish, were primary risks to diversity identified by the BRT. Improved oceanic conditions, coupled with favorable stream flows, apparently contributed to a strong year class in broodyear 2001, as evidenced by an increase in detected occupancy of historical streams. However, data were lacking for many river basins in the southern two-thirds of the ESU, where populations are considered at greatest risk. Although viewed as a positive sign, the strong year follows more than a decade of relatively poor returns. The lack of current estimates of naturally produced spawners for any populations within the ESU—and hence the need to use primarily presence-absence information to assess risk—continues to concern the BRT.

Lower Columbia River Coho Salmon ESU

The BRT reviewed the status of the Lower Columbia River coho salmon ESU in 2000, so relatively little new information was available. A majority (68%) of the likelihood votes for Lower Columbia River coho salmon ESU fell in the "danger of extinction" category, with the remainder falling in the "likely to become endangered" category (Table 92). As indicated by the risk matrix totals (Table 93), the BRT had major concerns for this ESU in all VSP risk categories (mean scores ranged from 4.2 for spatial structure/connectivity and growth rate/productivity to 4.5 for diversity). The most serious overall concern was the scarcity of naturally produced spawners throughout the ESU, with attendant risks associated with small population, loss of diversity, and fragmentation and isolation of the remaining naturally produced fish. In the only two populations with significant natural production (Sandy and Clackamas rivers), short- and long-term trends are negative, and productivity (as gauged by preharvest recruits) is down sharply from recent (1980s) levels. On the positive side, adult returns in 2000 and 2001 were up noticeably in some areas, and evidence for limited natural production has been found in some areas outside the Sandy and Clackamas rivers.

The paucity of naturally produced spawners in this ESU can be contrasted with the very large number of hatchery-produced adults. Although the scale of the hatchery programs, and the great disparity in relative numbers of hatchery and wild fish, produce many genetic and ecological threats to the natural populations, collectively these hatchery populations contain a great deal of genetic resources that might be tapped to help promote restoration of more widespread naturally spawning populations.

SOCKEYE SALMON

32. Background and History of Sockeye Salmon Listings

Sockeye salmon (*Oncorhynchus nerka*) spawn in North America from the Columbia River in Oregon north to the Noatak River in Alaska; and in Asia from Hokkaido, Japan, north to the Anadyr River in Russia (Atkinson et al. 1967, Burgner 1991). The vast majority of sockeye salmon spawn in inlet or outlet streams of lakes or in lakes themselves. The juveniles of these "lake-type" sockeye salmon rear in lake environments for 1 to 3 years, migrate to sea, and return to natal lake systems to spawn after 1 to 4 years in the ocean. However, some sockeye salmon populations spawn in rivers without juvenile lake-rearing habitat. Their juveniles rear in slow-velocity sections of rivers for 1 or 2 years (river-type) or migrate to sea as underyearlings, and thus rear primarily in salt water (sea-type) (Wood 1995). As with lake-type sockeye salmon, river- and sea-type sockeye salmon return to natal spawning habitat after 1 to 4 years in the ocean.

Certain self-perpetuating, nonanadromous populations of *O. nerka* that become resident in lake environments over long periods of time are called kokanee in North America. Genetic differentiation among sockeye salmon and kokanee populations indicates that kokanee are polyphyletic, having arisen from sockeye salmon on multiple independent occasions, and that kokanee may occur sympatrically or allopatrically with sockeye salmon. Numerous studies (reviewed in Gustafson et al. 1997) indicate that sockeye salmon and kokanee exhibit a suite of heritable differences in morphology, early development rate, seawater adaptability, growth, and maturation. These differences appear to be divergent adaptations, which arose from different selective regimes associated with anadromous versus nonanadromous life histories. These studies also provide evidence that sympatric populations of sockeye salmon and kokanee can be both genetically distinct and reproductively isolated (see citations in Gustafson et al. 1997). Occasionally, a proportion of juveniles in an anadromous sockeye population remains in the rearing lake environment throughout life and is observed on the spawning grounds together with their anadromous siblings. Ricker (1938) first used the terms residual sockeye and residuals to refer to these resident, nonmigratory progeny of anadromous sockeye salmon.

In April 1990 NMFS initiated a status review of sockeye salmon in the Salmon River basin and received a petition from the Shoshone-Bannock Tribes of the Fort Hall Indian Reservation to list Snake River sockeye salmon as endangered under ESA (NMFS 1990, 1991b). The NMFS BRT conducted a status review and unanimously agreed that there was insufficient information available to determine, with a reasonable degree of certainty, the origin of the current sockeye salmon gene pool in Redfish Lake (Waples et al. 1991a). After some discussion, the BRT reached a strong consensus that, in this instance, obligations as resource stewards required them to proceed under the assumption that recent sockeye salmon in Redfish Lake were descended from the original sockeye salmon gene pool. Therefore, as stipulated in the species definition paper (Waples 1991), the anadromous component of *O. nerka* was considered separately from the nonanadromous (kokanee) component in determining whether an ESA listing was warranted. The decision to treat Redfish Lake sockeye salmon as distinct from kokanee led the BRT to conclude that the Redfish Lake sockeye salmon were in danger of extinction (Waples et al. 1991a). Subsequently, a proposed rule to list Snake River sockeye salmon as endangered was published (NMFS 1991b). After considering 183 written comments and testimony from public hearings, NMFS published its final listing determination (NMFS 1991c), which designated Snake River sockeye salmon as an endangered species.

In September 1994, in response to a petition seeking protection for Baker Lake, Washington, sockeye salmon under the ESA and more general concerns about the status of West Coast salmon and steelhead, NMFS initiated a coastwide status review of sockeye salmon in Washington, Oregon, and California, and formed a BRT to conduct the review. After considering available information on genetics, phylogeny and life history, freshwater ichthyogeography, and environmental features that may affect sockeye salmon, the BRT identified six sockeye salmon ESUs—Ozette Lake, Okanogan River, Lake Wenatchee, Quinault Lake, Baker River, and Lake Pleasant—and one provisional ESU, Big Bear Creek. The BRT reviewed population abundance data and other risk factors for these ESUs. They concluded that one (Ozette Lake) was likely to become endangered in the foreseeable future and that the remaining ESUs were not in significant danger of becoming extinct or endangered, although the team had substantial conservation concerns for some of them (Gustafson et al. 1997). In March 1998, NMFS published a proposed rule to list the Ozette Lake sockeye salmon ESU as threatened under the ESA, and to place the Baker River sockeye salmon ESU on the candidate list. Due to the lack of natural spawning habitat and the vulnerability of the entire population to problems in artificial habitats, NMFS proposed to add the Baker River ESU to the list of candidate species (NMFS 1998g). Subsequently, based on the updated NMFS status review (NMFS 1999d) and other information received, NMFS published its final listing determination (NMFS 1999e), which designated the Ozette Lake sockeye salmon ESU as threatened and removed the Baker River ESU from the candidate list.

In considering the ESU status of resident of *O. nerka* forms, the key issue is evaluating the strength and duration of reproductive isolation between resident and anadromous forms. Many kokanee populations appear to have been strongly isolated from sympatric sockeye populations for long periods. Because the two forms experience very different selective regimes over their life cycles, reproductive isolation provides an opportunity for adaptive divergence in sympatry. Kokanee populations that fall into this category are not generally considered part of sockeye ESUs. On the other hand, resident fish appear to be much more closely integrated into some sockeye populations. For example, in some situations, anadromous fish may give rise to progeny that mature in freshwater (as is the case with residual sockeye), and some resident fish may have anadromous offspring. In these cases, where there is presumably some regular, or at least episodic, genetic exchange between resident and anadromous forms, they should be considered part of the same ESU.

The sockeye salmon BRT[66] met in January, March, and April 2003 to discuss new data and to determine whether any modification of the original BRT's conclusions were warranted as a result of the new information. This report summarizes new information and the preliminary BRT conclusions on the Snake River sockeye salmon ESU in Idaho and the Ozette Lake sockeye salmon ESU in Washington.

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[66] BRT for the updated status review for West Coast sockeye salmon included Thomas Cooney, Dr. Richard Gustafson, Dr. Robert Iwamoto, Gene Matthews, Dr. Paul McElhany, Dr. Mary Ruckelshaus, Dr. Thomas Wainwright, Dr. Robin Waples, Dr. John Williams, and Dr. Gary Winans, from Northwest Fisheries Science Center (NWFSC); Dr. Peter Adams and Dr. Eric Bjorkstedt, from Southwest Fisheries Science Center (SWFSC); and Dr. Reginald Reisenbichler from the Northwest Biological Science Center, U.S. Geological Survey, Biological Resources Division, Seattle.

33. Snake River Sockeye Salmon ESU

Summary of Previous BRT Conclusions

NMFS conducted the first formal ESA status review for salmon in the Pacific Northwest in response to a 1990 petition to list sockeye salmon from Redfish Lake in Idaho as an endangered species. The distinctiveness of this population became apparent early in the process: it spawns at a higher elevation (2,000 m) and has a longer freshwater migration (1,500 km) than any other sockeye salmon population in the world (Waples et al. 1991a). Nor was the precarious nature of the anadromous run in doubt: in the fall of 1990, during the course of the status review, no adults were observed at Lower Granite Dam or entering the lake, and only one fish was observed in each of the 2 previous years. However, a population of kokanee also existed in Redfish Lake, and the relationship between the sockeye and kokanee was not well understood. This issue was complicated by uncertainty regarding the effects of Sunbeam Dam, which stood for over 2 decades about 32 km downstream from Redfish Lake. By all accounts, the dam was a serious impediment to anadromous fish, but opinions differed as to whether it was an absolute barrier. Some argued that the original sockeye population in Redfish Lake was extirpated as a result of Sunbeam Dam and that adult returns in recent decades were simply the result of sporadic seaward drift of kokanee (Chapman et al. 1990). According to this hypothesis, the original sockeye gene pool was extinct and the remaining kokanee population was not at risk because of its reasonably large size (approximately 5,000 to 10,000 spawners per year). An alternative hypothesis held that the original sockeye salmon population managed to persist in spite of Sunbeam Dam, either by intermittent passage of adults or recolonization from holding areas downstream of the dam. The fact that the kokanee population spawns in the inlet stream (Fishhook Creek) in August and September and that all the recent observations of sockeye spawning have been on the lake shore in October and November was cited as evidence that the sockeye and kokanee represent separate populations. According to this hypothesis, the sockeye population was critically endangered and perhaps on the brink of extinction.

At the time of the status review, the BRT unanimously agreed that there was not enough information to determine which of the above hypotheses were true (Waples 1991). Although the kokanee population had been genetically characterized and determined to be quite distinctive compared to other *O. nerka* populations in the Pacific Northwest, no adult sockeye were available for sampling, so the BRT could not evaluate whether the two forms shared a common gene pool. When pressed to make a decision regarding the ESU status of Redfish Lake *O. nerka*, the BRT concluded that, because they could not determine with any certainty that the original sockeye gene pool was extinct, they should assume that it did persist and was separate from the kokanee gene pool. This conclusion was strongly influenced by consideration of the irreversible consequences of erring in the other direction (i.e., not listing the species based on the assumption that kokanee and sockeye populations were a single gene pool, which later proved not to be the case, the species could easily go extinct before the error was detected).

The status review of Redfish Lake sockeye salmon is the only instance in which the BRT was asked to apply the precautionary principle in its deliberations. In subsequent evaluations, when the "best available scientific information" was insufficient to distinguish with any certainty among competing hypotheses regarding key ESA questions, the BRT has simply reported this result and tried to characterize the degree of uncertainty in the team's conclusions. Decisions about how best to apply the precautionary principle in the face of uncertainty in making listing determinations were left to the NMFS management and policy arm.

Based on results of the status review, NMFS proposed a listing of Redfish Lake sockeye as endangered in April 1991. When finalized in late 1991, this decision represented the first ESA listing of a Pacific salmon population in the Pacific Northwest. At the time of the listing, the only population that the BRT and NMFS were confident belonged in this ESU was the beach-spawning population of sockeye from Redfish Lake. Historical records indicated that sockeye once occurred in several other lakes in the Stanley Basin, but no adults were observed in these lakes for many decades and their relationship to the Redfish Lake ESU was uncertain.

Listing status: Endangered.

New Data and Updated Analyses

Four adult sockeye salmon returned to Redfish Lake in 1991; they were taken into captivity to join several hundred smolts collected in spring 1991 as they outmigrated from Redfish Lake. The adults were spawned and their progeny reared to adulthood along with the outmigrants as part of a captive broodstock program, whose major goal was to perpetuate the gene pool for a short period of time (one or two generations) to give managers a chance to identify and address the most pressing threats to the population. As a result of this program and related research, a great deal of new information was gained about the biology of Redfish Lake *O. nerka* and limnology of the lakes in the Stanley Basin. Genetic data collected from the returning adults and the outmigrants showed that they were genetically similar but distinct from the Fishhook Creek kokanee. However, otolith microchemistry data (Rieman et al. 1994) indicated that many of the outmigrants had a resident female parent. These results inspired a search of the lake for another population of resident fish that was genetically similar to the sockeye. These efforts led to discovery of a relatively small number (perhaps a few hundred) kokanee-sized fish that spawn at approximately the same time and place as the sockeye. These fish, termed residual sockeye salmon, are considered to be part of the listed ESU. Subsequent genetic analysis (Winans et al. 1996, Waples et al. 1997) established the following relationships between extant populations of *O. nerka* from the Stanley Basin and other populations in the Pacific Northwest:

- Native populations of *O. nerka* from the Stanley Basin (including Redfish Lake sockeye salmon and kokanee and Alturas Lake kokanee) are genetically quite divergent from all other North American *O. nerka* populations that have been examined.
- Within this group, Redfish Lake sockeye and kokanee are genetically distinct, and Alturas Lake kokanee are most similar to Redfish Lake kokanee.

- Two gene pools of *O. nerka* were identified in Stanley Lake—one may be the remnant of a native gene pool that survived rotenone treatments in the lake, while the other can be traced to introductions from Wizard Falls Hatchery in Oregon.
- No trace of the original gene pool of *O. nerka* has been found in Pettit Lake.

The population that spawned in Pettit Lake in recent decades can be traced to introductions of kokanee from northern Idaho; those populations in turn can be traced to stock transfers of Lake Whatcom (Washington) kokanee early in the last century.

Between 1991 and 1998, 16 naturally produced adult sockeye salmon returned to the weir at Redfish Lake (Table 94) and were incorporated into the captive broodstock program. This program, overseen by the Stanley Basin Sockeye Technical Oversight Committee, produced groundbreaking research in captive broodstock technology (Hebdon et al. 1999, Kline and Willard 2001, Frost et al. 2002) and limnology (Kohler et al. 2002). The program used three different rearing sites to minimize chances of catastrophic failure and produced several hundred thousand eggs and juveniles, as well as several hundred adults, for release into the wild (Table 95). The program reached a milestone in 2000, when more than 200 adults from the program returned to Redfish Lake. Currently, the captive broodstock program is being maintained as a short-term safety net, pending decisions about longer-term approaches to recovery of the ESU.

Table 94. Adult anadromous sockeye salmon returns to the Redfish Lake Creek weir, 1954–1968, and the Redfish Lake Creek trap and Sawtooth Fish Hatchery weir, 1991–2002. Sources: Redfish Lake Creek weir data are from Bjornn et al. (1968).[a]

Year	Adults	Year	Adults
1954	998	1987	16
1955	4,361	1988	1
1956	1,381	1989	1
1957	523	1990	0
1958	55	1991	4
1959	290	1992	1
1960	75	1993	8
1961	11	1994	1
1962	39	1995	0
1963	395	1996	1
1964	335	1997	0
1965	17	1998	1
1966	61	1999	7[c]
1967–1984	nd[b]	2000	257[c]
1985	11	2001	26[c]
1986	29	2002	22[c]

[a] Data for 1991–2001 are from L. Hebdon, Idaho Department of Fish and Game, Nampa, ID. Pers. commun., 6 January 2003.

[b] No data are available for 1967–1984.

[c] Progeny of captive broodstock program.

Table 95. Releases of progeny from the Redfish Lake sockeye salmon captive broodstock program into Redfish, Alturas, and Pettit lakes, 1993–2002.*

Year	Eggs	Presmolts	Smolts	Adults
Redfish Lake				
1993	–	–	–	20
1994	–	14,000	–	65
1995	–	82,000	4,000	–
1996	105,000	2,000	12,000	120
1997	85,000	152,000	–	80
1998	–	95,000	38,000	–
1999	–	24,000	5,000	21
2000	–	48,000	–	120
2001	–	43,000	14,000	69
2002	–	107,000	39,000	190
Alturas Lake				
1995	–	–	–	–
1996	–	–	–	–
1997	20,000	100,000	–	20
1998	–	39,000	–	–
1999	–	13,000	–	–
2000	–	12,000	–	77
2001	–	12,000	–	–
2002	–	6,000	–	–
Pettit Lake				
1995	–	9,000	–	–
1996	–	–	–	–
1997	–	9 ,000	–	–
1998	–	7,000	–	–
1999	20,000	3,000	–	–
2000	65,000	6,000	–	–
2001	–	11,000	–	–
2002	31,000	28,000	–	–

* L. Hebdon, Idaho Department of Fish and Game, Nampa, ID. Pers. commun., 6 January 2003.

The Snake River Salmon Recovery Team (Bevan et al. 1994; NMFS 1995a) suggested that to be considered recovered under ESA, the Snake River sockeye salmon ESU should have viable populations in three different lakes, with at least 1,000 naturally produced spawners per year in Redfish Lake and at least 500 in each of two other Stanley Basin lakes. As a step toward addressing this recommendation, progeny from the Redfish Lake captive broodstock program were released in Pettit and Alturas lakes as well. In 1991, about 100 outmigrants from Alturas Lake were collected at the same time as the Redfish Lake outmigrants and reared to maturity as a separate population in captivity. However, because of funding and space limitations and uncertainties about priorities for propagating this population, the resulting adults were released into the lake rather than being kept for spawning and another generation of captive rearing. Because the Alturas Lake kokanee spawn earlier than Redfish Lake sockeye salmon, and the kokanee spawn in the inlet stream, it is hoped that the introduction of Redfish Lake sockeye into Alturas Lake will not adversely affect this native gene pool.

34. Ozette Lake Sockeye Salmon ESU

Summary of Previous BRT Conclusions

Status and Trends

The 5-year average (geometric mean) estimated abundance of Ozette Lake sockeye salmon ESU for the period 1994–1998 was 580, slightly below the average of 700 (for the years 1992–1996) reported by Gustafson et al. (1997). This decrease is largely because the earlier average included two dominant brood-cycle years, although the recent average includes only one. The 1998 count of 984 was substantially higher than the count of 498 that was observed 4 years (one generation) earlier. This count may result primarily from a change in counting methods; a video camera was installed in 1998, and the operation period of the weir was expanded (7 May–14 August), resulting in a more complete count of all fish passing the weir.[67] It is likely that counts for previous years underestimated total spawner abundance, but the magnitude of this bias is unknown.

Analyses of trends using data through 1998 indicate that the short-term (10-year) trend improved from a decline of 9.9% per year in Gustafson et al. (1997) to a relatively low, 2%, annual increase. How much this increase was influenced by the change in counting methods in 1998 is not known. The long-term trend remained slightly downward (–2%).

Threats

The BRT identified a variety of threats to the continued existence of sockeye salmon populations in Ozette Lake ESU, including siltation of beach-spawning habitat and potential genetic effects of past interbreeding with genetically dissimilar kokanee. The BRT received an analysis of logging history in the Ozette Basin from Rayonier Northwest Forest Resources (Meier 1998). This analysis indicated that most logging in the basin has occurred since the mid-1950s: in 1953, only 8.7% of the basin had been logged, while 60% had been logged by 1981. Thus, logging occurred largely after the substantial decline in sockeye salmon catch in the early 1950s.

Previous BRT Conclusions

The BRT last reviewed the Ozette Lake sockeye salmon ESU status in November 1998. Their conclusion was that the ESU was likely to become endangered in the foreseeable future. The main uncertainties arose from questions about the reliability of abundance estimates and the historical presence of inlet-spawning sockeye salmon in the basin. Perceived risks were focused on low current abundance and trends and variability in abundance. At the time of the last status assessment, escapements averaging less than 1,000 adults per year implied a moderate degree of

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[67] M. Crewson, Makah Indian Tribe, Neah Bay, WA. Pers. commun., 21 August 1998.

risk from small-population genetic and demographic variability, with little room for further declines before abundances reach critically low levels. Other concerns included siltation of beach-spawning habitat, very low current abundance, as compared to harvests in the 1950s, and potential genetic effects of past interbreeding with genetically dissimilar kokanee.

Listing status: Threatened.

New Data and Updated Analyses

ESU Status at a Glance

Historical peak abundance	3,000–18,000
Historical populations	1+
Extant populations	1
5-year geometric mean escapement	2,267

ESU Structure

The Puget Sound TRT considers the Lake Ozette sockeye salmon ESU to be composed of one historical population, 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). Recently, mature adults have been located at other beach locations within the lake (e.g., Umbrella Beach, Ericson's Bay, Baby Island, and Boot Bay), but whether spawning occurred in those locations is not known (Makah Fisheries Management 2000). Similarly, occasional spawners are found sporadically in other tributaries to the lake, but not in as high numbers or as consistently as in Umbrella Creek. The Umbrella Creek spawning aggregation was started through collections of lake-spawning adults as initial broodstock, and in recent years all broodstock has been collected from returning adults to Umbrella Creek (Makah Fisheries Management 2000). The extent to which sockeye spawned historically in tributaries to the lake is controversial (Gustafson et al. 1997), but it is clear that multiple beach-spawning aggregations of sockeye occurred historically, and that genetically distinct kokanee currently spawn in large numbers in all surveyed lake tributaries (except Umbrella Creek and Big River). The two remaining beach-spawning aggregations are probably fewer than the number of aggregations that occurred historically, but there is insufficient evidence to determine how many subpopulations occurred in the ESU historically.

Much of the existing spawning in recent years occurs in the spawning aggregation created via fry releases into Umbrella Creek. The status of the historically well-documented spawning aggregations at Allen's and Olsen's beaches is not well understood because of the difficulties in observing spawners and sampling carcasses in the tannin-rich lake.

Updated Status Information

Because of the concerns about the status of Ozette Lake sockeye salmon ESU, the Lake Ozette steering committee was established (composed of representatives from the Makah Tribe, Olympic National Park, WDFW, and citizen's groups) to organize recovery activities for sockeye. Makah Fisheries initiated a hatchery program designed to supplement existing beach spawners in 1983 (beach spawner supplementation ceased with the 1995 broodyear) and later to introduce sockeye to lake tributaries (intentional releases to tributaries began in broodyear 1992) (see subsection, Updated Threats Information). Therefore, all the abundance information presented contains an unknown fraction of hatchery fish.

Information on abundance of Ozette Lake sockeye salmon ESU comes from visual counts at a weir across the lake outlet; therefore the counts represent total run size. The estimates of total run size were revised upward after the 1997 status review due to resampling of data using new video counting technology (Figure 227).

The Makah Fisheries biologists estimate that previous counts of adult sockeye salmon returning to the lake were underestimates, and they have attempted to correct run-size estimates based on their assessments of human error and variations in interannual run timing (Makah Fisheries Management 2000; Table 96). The run-size estimates are very uncertain—an estimate of the 95% confidence interval around the 2001 count is N = 3,717 (2,815–5,416) (Fieberg 2002). The most recent 5-year geometric mean of sockeye salmon returning to Lake Ozette is 2,267 adults. Because run-size estimates before 1998 are likely to be even more unreliable than recent counts, and new counting technology has resulted in an increase in estimated run sizes, no statistical estimation of trends is reported. The current trends in abundance are unknown for the beach spawning aggregations. Although overall abundance appears to have declined from historical levels, whether this resulted in fewer spawning aggregations, lower abundances at each aggregation, or both, is not known.

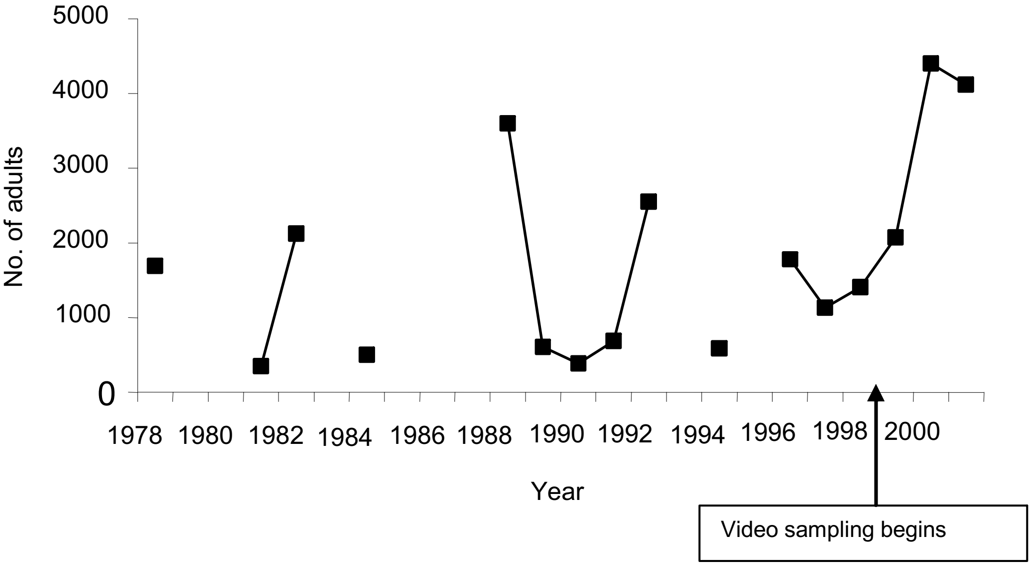

Figure 227. Estimated numbers of adult sockeye salmon entering Lake Ozette, 1978–2001. Sources: Makah Fisheries Management (2000) and Crewson (2003).

The adults remain in the lake for an extended period of time (return April–August; spawn late October–February) before spawning on beaches or in the tributaries, and the prespawning mortality is not known. Therefore, it is not clear what escapement levels to the spawning aggregations might be.

The sockeye salmon returning to Umbrella Creek have averaged more than 10% of the total run size to Lake Ozette from 1995 to 1999, and possibly this fraction has been higher in the last 2 years (Makah Fisheries Management 2000, M. Crewson[68]). A portion of the Umbrella Creek hatchery sockeye were marked as juveniles beginning in the late 1980s, and results of monitoring these marks on returning adults indicates that natural-origin spawners in Umbrella Creek in 1999 ranged from 21.4% to 52.9% (Makah Fisheries Management 2000).

Table 96. Estimated run size of natural-origin recruits to Lake Ozette and Umbrella Creek, and the fraction of hatchery-origin fish returning to Umbrella Creek for Lake Ozette sockeye salmon, 1978–2001. Sources: Makah Fisheries Management (2000) and Crewson (2003).

Year	**Total run size**	**Lake Ozette natural origin**	**Umbrella Creek natural origin**	**Umbrella Creek hatchery origin**
1978	1,690	nd	nd	nd
1979	nd	nd	nd	nd
1980	nd	nd	nd	nd
1981	350	nd	nd	nd
1982	2,123	nd	nd	nd
1983	nd	nd	nd	nd
1984	502	nd	nd	nd
1985	nd	nd	nd	nd
1986	nd	nd	nd	nd
1987	nd	nd	nd	nd
1988	3,599	nd	nd	nd
1989	603	nd	nd	nd
1990	385	nd	nd	nd
1991	684	nd	nd	nd
1992	2,548	nd	nd	nd
1993	nd	nd	nd	nd
1994	585	nd	nd	nd
1995	nd	nd	nd	44
1996	1,778	1,699	79	0
1997	1,133	998	nd	135
1998	1,406	1,310	nd	96
1999	2,076	1,676	149	251
2000	4,399	1,293[a]		3,106
2001	4,116	591	3,525[b]	

nd = no data.

[a] Total combines Lake Ozette natural origin and Umbrella Creek natural origin.

[b] Total combines Umbrella Creek natural origin and Umbrella Creek hatchery origin.

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[68] See Footnote 67.

Table 97. Percentages of 5-year-old fish sampled from otoliths in carcasses in sockeye salmon subpopulations in Lake Ozette, 2000–2001.[a]

	2000		2001	
Subpopulation	**Percent 5-year-olds**	**No. of samples**	**Percent 5-year-olds**	**No. of samples**
Olsen's Beach	2.1	47	1.2	81
Allen's Beach	0	51	0	7
Umbrella Creek	3.8	183	18.5[b]	195

[a] M. Crewson, Makah Fisheries, Neah Bay, WA. Pers. commun., 21 August 1998.

[b] One out of 195 fish sampled from Umbrella Creek was a 6-year-old.

Age data from otolith samples in 2000 and 2001 in Umbrella Creek and Allen's and Olsen's beaches suggest that a small fraction of 5-year-old fish do occur in Umbrella Creek and Olsen's Beach subpopulations (Table 97). These age data affect previous estimates of returns from different broodyears, since early analyses assumed 100% 4-year-old sockeye.

Based on examination of carcasses retrieved from Allen's and Olsen's beaches for otolith marks applied to hatchery fish, straying of hatchery fish from the Umbrella Creek program appears to be very low (Makah Fisheries Management 2000).

Updated Threats Information

The Makah Fisheries staff has been working with the Lake Ozette steering committee to identify factors for decline in Lake Ozette sockeye salmon. Thus far, primary sources of threats to VSP parameters include:

- loss of adequate quality and quantity of spawning and rearing habitat,
- predation and disruption of natural predator-prey relationships,
- introduction of nonnative fish and plant species,
- past overexploitation,
- poor ocean conditions, and
- interactions among those factors.

There has been no directed harvest on Lake Ozette sockeye salmon since 1982, and commercial fisheries stopped in 1974 (Gustafson et al. 1997, Makah Fisheries Management 2000).

Previous releases of hatchery fish in Lake Ozette have been relatively low magnitude, but some of the releases were from sockeye salmon stocks outside the ESU or were from Ozette kokanee-sockeye hybrids (Gustafson et al. 1997). The latest artificial propagation program in Lake Ozette focused on sockeye salmon introductions into Big River and Umbrella Creek tributaries; chosen because of their apparent suitable spawning habitat and relatively low numbers of naturally spawning kokanee. The Umbrella Creek Hatchery has been in place since

1982. The first egg source was from the Quinault River, and progeny were hatched at Umbrella Creek, reared in a net pen in Lake Ozette, and released in June 1983. From 1983 to 1999, all eggs were collected from Olsen's or Allen's beach spawners. Beginning in 2000, the source for future broodstock for tributary releases will be from returns to tributaries, primarily Umbrella Creek. The SSHAG group (SSHAG 2003) determined that the Umbrella Creek Hatchery stock would have a category score of 1 or 2 (see Appendix D, Table D-1).

The Makah Tribe and the NMFS Marine Mammal Lab have monitored predation on Lake Ozette sockeye salmon by harbor seals and river otters, and biologists believe that prespawning predation rates could be significant. Predation by otters and seals has been observed in the lake and in the outlet river, especially in the vicinity of the counting weir (Makah Fisheries Management 2000). In addition, predation scars (ranging from scratches to bite marks to lack of heads) on carcasses sampled and adults counted are noted.

The majority of Lake Ozette and the Ozette River lie within the boundaries of Olympic National Park, but private timber companies own the majority of the land in the Lake Ozette watershed (Makah Fisheries Management 2000). Recent accelerated timber harvest, road-building activity, and forest-practice and water-quality violations are reported in an analysis by the Makah Tribe (Makah Fisheries Management 2000). New activities related to mitigating and improving degraded habitat quality could include the Forest and Fish Agreement (if implemented).

35. Sockeye Salmon BRT Conclusions

Snake River Sockeye Salmon ESU

The BRT members were unanimous in their assessment this ESU's status: 100% of the likelihood votes were in the "danger of extinction" category (Table 98). Mean risk matrix scores were extremely high (4.9–5.0) for every VSP element (Table 99). On the positive side, the captive broodstock program initiated as an emergency measure in 1991 has, at least temporarily, rescued this ESU from the brink of extinction, and associated research has provided a great deal of information about the biology of this species and its environment. The return of over 200 adults from the hatchery program in 2000 is considered encouraging, but the status of the natural population remains extremely precarious. Only 16 naturally produced adults have returned since the listing in 1991, and all were taken into the captive program.

Ozette Lake Sockeye Salmon ESU

A majority (70%) of the BRT votes for the Ozette Lake sockeye salmon ESU were cast in the "likely to become endangered" category, with the remainder about equally split between the "danger of extinction" and "not likely to become endangered" categories (Table 98). Moderately high concerns for all VSP elements are indicated by mean risk matrix scores ranging from 3.0 for diversity to 3.8 for spatial structure (Table 99). Risk assessment for this ESU continues to be hampered by very incomplete data. Although significant efforts to improve this situation have

Table 98. Tally of FEMAT vote distribution regarding the status of two sockeye salmon ESUs reviewed. Thirteen BRT members allocated 10 points among the three status categories.

ESU	**Danger of extinction**	**Likely to become endangered**	**Not likely to become endangered**
Snake River	130	0	0
Ozette Lake	21	91	18

Table 99. Summary of risk scores (1 = low to 5 = high) for four viable salmonid population categories for the Snake River and Ozette Lake sockeye salmon ESUs. Data presented are means (range).

ESU	**Abundance**	**Growth rate/productivity**	**Spatial structure and connectivity**	**Diversity**
Snake River	5.0 (5–5)	5.0 (5–5)	4.9 (4–5)	5.0 (5–5)
Ozette Lake	3.7 (3–4)	3.5 (3–4)	3.8 (3–5)	3.0 (2–4)

[*] For a description of the risk categories, see the subsection, Factors Considered in Status Assessments, in Section 1, Introduction.

been taken recently, the process of perfecting the new techniques and adjusting for biases in previous data is still in progress. Recent evaluations have cast even more doubt on the usefulness of population data prior to about 1997, which further complicates the assessment of an ESU for which data are already very limited.

It appears that overall abundance is low for this population, which represents an entire ESU, and may be substantially below historical levels. The BRT was concerned about reports that habitat degradation in the lake has resulted in loss of numerous sites suitable for beach spawners, but accurately assessing the situation is difficult because of poor visibility in the lake. The number of returning adults in the last few years has increased, but a substantial (but uncertain) fraction of these appear to be of hatchery origin, leading again to uncertainty regarding growth rate and productivity of the natural component of the ESU. Another uncertainty noted by the BRT related to reports that prespawning predation by harbor seals and river otters may be significant, but how large a factor this is and how it compares with historical patterns is not known.

CHUM SALMON

36. Background and History of Chum Salmon Listings

Chum salmon (*Oncorhynchus keta)* are semelparous, spawn primarily in freshwater, and apparently exhibit obligatory anadromy, as there are no recorded landlocked or naturalized freshwater populations (Randall et al. 1987). The species is known for the enormous canine-like fangs and striking body color (a calico pattern, with the anterior two-thirds of the flank marked by a bold, jagged, reddish line and the posterior third by a jagged black line) of spawning males. Females are less flamboyantly colored and lack the extreme dentition of the males.

The species has the widest natural geographic and spawning distribution of any Pacific salmonid, primarily because its range extends farther along the shores of the Arctic Ocean than other salmonids. Chum salmon have been documented to spawn from Korea and the Japanese island of Honshu, east around the rim of the North Pacific Ocean to Monterey Bay in California. Presently, major spawning populations are found only as far south as Tillamook Bay on the northern Oregon coast. The species' range in the Arctic Ocean extends from the Laptev Sea in Russia to the Mackenzie River in Canada. Chum salmon may historically have been the most abundant of all salmonids: Neave (1961) estimated that prior to the 1940s, chum salmon contributed almost 50% of the total biomass of all salmonids in the Pacific Ocean. Chum salmon also grow to be among the largest of Pacific salmon, second only to Chinook salmon in adult size, with individual chum salmon reported up to 108.9 cm in length and 20.8 kg in weight (Pacific Fisherman 1928). Average size for the species is around 3.6–6.8 kg (Salo 1991).

Chum salmon spend more of their life history in marine waters than other Pacific salmonids. Chum salmon, like pink salmon, usually spawn in coastal areas, and juveniles outmigrate to sea water almost immediately after emerging from the gravel that covers their redds (Salo 1991). This ocean-type migratory behavior contrasts with the stream-type behavior of some other species of the genus *Oncorhynchus* (e.g., coastal cutthroat trout, steelhead, coho salmon, and most types of Chinook and sockeye salmon), which usually migrate to sea at a larger size, after months or years of freshwater rearing. This means survival and growth in juvenile chum salmon depends less on freshwater conditions than on favorable estuarine conditions. Another behavioral difference between chum salmon and species that rear extensively in freshwater is that chum salmon form schools, presumably to reduce predation (Pitcher 1986), especially if their movements are synchronized to swamp predators (Miller and Brannon 1982).

The first ESA status review of West Coast chum salmon (Johnson et al. 1997) was published in December 1997. It identified four ESUs: 1) Puget Sound/Strait of Georgia chum salmon ESU, which includes all chum salmon populations from Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca up to and including the Elwha River, with the exception of summer-run chum salmon from Hood Canal; 2) Hood Canal summer-run chum salmon ESU, which includes summer-run populations from Hood Canal and Discovery and Sequim bays on the Strait of Juan de Fuca; 3) Pacific Coast chum salmon ESU, which includes all natural populations from the Pacific coasts of California, Oregon, and Washington, west of the Elwha River on the Strait of Juan de Fuca; and 4) Columbia River chum salmon ESU.

In March 1998, NMFS published a *Federal Register* notice describing the four ESUs and proposed a rule to list two—Hood Canal summer-run and Columbia River ESUs—as threatened under ESA (NMFS 1998h). In March 1999, the two ESUs were listed as proposed, with the exception that the Hood Canal summer-run ESU was extended westward to include summer-run fish recently documented in the Dungeness River (NMFS 1999f).

NMFS convened a BRT to update the status of listed chum salmon ESUs coastwide. The chum salmon BRT[69] met in January 2003 in Seattle, Washington, to review updated information on each ESU under consideration.

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[69] The BRT for the updated chum salmon status review included, from the Northwest Fisheries Science Center: Tom Cooney, Dr. Robert Iwamoto, Dr. Robert Kope, Gene Matthews, Dr. Paul McElhany, Dr. James Myers, Dr. Mary Ruckelshaus, Dr. Thomas Wainwright, Dr. Robin Waples, and Dr. John Williams; from the Southwest Fisheries Science Center: Dr. Peter Adams, Dr. Eric Bjorkstedt, and Dr. Steve Lindley; from the Alaska Fisheries Science Center (Auke Bay Laboratory): Alex Wertheimer; and from the U.S. Geological Survey Biological Resource Division: Dr. Reginald Reisenbichler.

37. Hood Canal Summer-Run Chum Salmon ESU

Summary of Previous BRT Conclusions

The status of Hood Canal summer-run chum salmon was formally assessed during a coastwide status review (Johnson et al. 1997). In November 1998, a BRT was convened to update the status of the ESU by summarizing information received after that review and comments on the 1997 status review and to present BRT conclusions concerning ESU delineation and risk assessment for chum salmon in Washington, Oregon, and California (NMFS 1999f).

Status and Trends

In 1994, petitioners identified 12 streams draining into Hood Canal as recently supporting spawning populations of summer-run chum salmon. At the time of the petition, summer-run chum salmon runs in five of these streams may already have been extinct, and those in six of the remaining seven showed strong downward trends. Similarly, summer-run chum salmon in Discovery and Sequim bays were also at low levels of abundance. Spawner surveys in 1995 and 1996 revealed substantial increases in the number of summer-run chum salmon returning to some streams in Hood Canal and the Strait of Juan de Fuca. However, serious concerns remained (Johnson et al. 1997). First, the population increases in 1995 and 1996 were limited to streams on the western side of Hood Canal, especially the Quilcene River system, while streams on the southern and eastern sides of Hood Canal continued to have few or no returning spawners. Second, a hatchery program initiated in 1992 was at least partially responsible for adult returns to the Quilcene River system. Third, the strong returns to the west side streams were the result of a single, strong year class, although declines in most of these streams were severe and spanned two decades. Last, greatly reduced incidental harvest rates in recent years probably contributed to the increased abundance of summer-run chum salmon in this ESU. Spawning escapement to the ESU was estimated to be 10,013 fish in 1997 and 5,290 fish in 1998. Of these totals, 8,734 spawners in 1997 and 3,959 spawners in 1998 returned to streams with supplementation programs.

Previously Reported Threats

A variety of threats to the continued existence of summer-run chum salmon populations in Hood Canal were identified in the status review (Johnson et al. 1997), including degradation of spawning habitat, low river flows, possible competition among hatchery fall-run chum salmon juveniles and naturally produced summer-run chum salmon juveniles in Hood Canal, and high levels of incidental harvest in salmon fisheries in Hood Canal and the Strait of Juan de Fuca.

Previous BRT Conclusions

The status of the Hood Canal summer-run chum salmon ESU was last reviewed in November 1998, when the BRT concluded that the ESU was likely to become endangered in the foreseeable future. The BRT's primary concerns relating to this ESU's status were low current abundance relative to historical numbers, extirpation of historical populations on the east side of Hood Canal, declining trends, and low productivity. Other concerns included the increasing urbanization of the Kitsap Peninsula, recent increases in pinniped populations in Hood Canal, and recent increases in spawning escapement that were associated primarily with hatchery supplementation programs. Concerns were mitigated to some extent by recent reforms in hatchery practices for fall-run chum salmon and measures taken by the state and tribes to reduce harvest impacts on summer-run chum salmon.

Listing status: Threatened.

New Data and Updated Analyses

ESU Status at a Glance

Historical peak abundance	N/A
Historical populations	16
Extant populations	8
1999–2002 geometric mean escapement per extant population	10–4,500
1999–2002 arithmetic mean escapement per extant population	52–4,700
Recent (1990–2002) trend per extant population	0.82–1.62 (median = 1.17)
Long-term trend per extant population	0.88–1.08 (median = 0.94)

ESU Structure

The Hood Canal summer-run chum salmon ESU is composed of 16 historically independent populations, 8 of which are presumed to be extant currently (Table 100). Most of the extirpated populations occur on the eastern side of Hood Canal, and some of the 7 putatively extinct stocks are the focus of extensive supplementation programs under way in the ESU (WDFW and PNPTT 2000, 2001).

Hood Canal summer-run chum salmon are part of an extensive rebuilding program developed and implemented beginning in 1992 by the state and tribal comanagers (WDFW and PNPTT 2000, 2001.) The Summer-Run Chum Salmon Conservation Initiative involves six supplementation and two reintroduction projects. The largest supplementation program occurs at

Table 100. Historical populations of summer-run chum salmon in the Hood Canal chum salmon ESU. Source: WDFW and PNPTT (2001).

Stock	Status
Union River	Extant
Lilliwaup Creek	Extant
Hamma Hamma River	Extant
Duckabush River	Extant
Dosewallips River	Extant
Big/Little Quilcene rivers	Extant
Snow/Salmon creeks	Extant
Jimmycomelately Creek	Extant
Dungeness River	Unknown
Big Beef Creek	Extinct
Anderson Creek	Extinct
Dewatto Creek	Extinct
Tahuya River	Extinct
Skokomish River	Extinct
Finch Creek	Extinct
Chimacum Creek	Extinct

the Big Quilcene River fish hatchery; beginning with the 1997 broodyear, all fry from the Quilcene facility have been adipose fin clipped. Summer-run chum salmon hatchery fish in Salmon Creek have been thermally marked since 1992, and other supplementation programs in Hood Canal recently instigated thermal mass marking of otoliths to distinguish between hatchery- and natural-origin spawners. Reintroduction programs were initiated in Big Beef and Chimacum creeks. Small numbers of marked fish collected in streams (i.e., ≤3 per stream) over the 1999–2000 season indicate that some straying of summer-run chum salmon from the Big Quilcene River supplementation program is occurring in other Hood Canal streams (WDFW and PNPTT 2001).

The methods for summary statistics reported below are described in Section 2 of this report. We report summary statistics only for the eight extant populations of summer-run chum salmon in Hood Canal; where information is available, a few additional populations experiencing hatchery reintroductions or natural recolonization are included in some tables for completeness. More detailed information on the sources, data years, and nature of the information reported below is summarized in Appendix E for each population.

Abundance of Natural Spawners

Recent 4-year (1999–2002) geometric mean abundance of summer-run chum salmon in Hood Canal streams containing extant populations ranges from 10 to just over 4,500 spawners (median = 576, mean = 1,064) (Table 101, Figures 228–241). Estimates for the fraction of hatchery fish in the combined Quilcene and Salmon/Snow populations are as high as 28–51%, indicating that the supplementation program is resulting in spawners in streams (Table 101). In addition to the supplementation programs, reintroduction of hatchery fish to previously occupied streams is occurring in Big Beef and Chimacum creeks. Recent geometric mean escapements

Table 101. Abundance and estimated fraction of hatchery fish in natural escapements of Hood Canal summer-run chum salmon spawning populations. Source: Data are from WDFW and PNPTT (2000, 2001); Puget Sound TRT database, unpublished data available from N. Sands, Northwest Fisheries Science Center, Seattle.

		4-year escapement (1999–2002)		**Percent hatchery origin in natural escapement (1995–2001)**
Population	**Current status**	**Geometric mean (min.–max.)**	**Arithmetic mean**	
Jimmycomelately[d]	Extant	10 (1–192)	52	na
Salmon[a]/Snow	Extant	1,521 (463–5,921)	2,441	0–69
Combined Quilcene	Extant	4,512 (3,065–6,067)	4,665	5–51
Lilliwaup[a]	Extant	13 (1–775)	202	na
Hamma Hamma[c]	Extant	558 (173–2,260)	783	na
Duckabush	Extant	382 (92–942)	507	na
Dosewallips	Extant	919 (351–1,627)	1,057	na
Union[e]	Extant	594 (159–1,426)	769	na
Chimacum	Extinct, reintroduction	198 (0–903)	464	100 (>1999)
Big Beef[b]	Extinct, reintroduction	17 (0–826)	376	100 (>1999)
Dewatto	Extinct, natural recolonization	9 (2–32)	14	na

[a] Supplementation program began in 1992; recent low spawner numbers in Lilliwaup due in part to large fraction of return used for broodstock (J. Ames, Washington Department of Fish and Wildlife, Olympia, WA. Pers. commun., 28 March 2003).

[b] Reintroduction program began in 1996.

[c] Supplementation program began in 1997.

[d] Supplementation program began in 1999; recent low spawner numbers were due in part to large fraction of return used for broodstock (J. Ames, Washington Department of Fish and Wildlife, Olympia, WA. Pers. commun., 28 March 2003).

[e] Supplementation program began in 2000.

from those programs are 17 and 198 adults respectively (over 800 adults in a single year returned to each stream), suggesting that hatchery juveniles released several years ago are successfully returning as adults to spawn.

The eight extant summer-run chum salmon stocks in Hood Canal are spawning in 13 streams, primarily on the western side of Hood Canal. The spatial distribution of the summer-run chum salmon populations in Hood Canal is being extended through reintroduction programs in Big Beef and Chimacum creeks, and through an apparent natural recolonization in the Dewatto River.[70]

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[70] J. Ames, Washington Department of Fish and Wildlife, Olympia. Pers. commun., 28 March 2003.

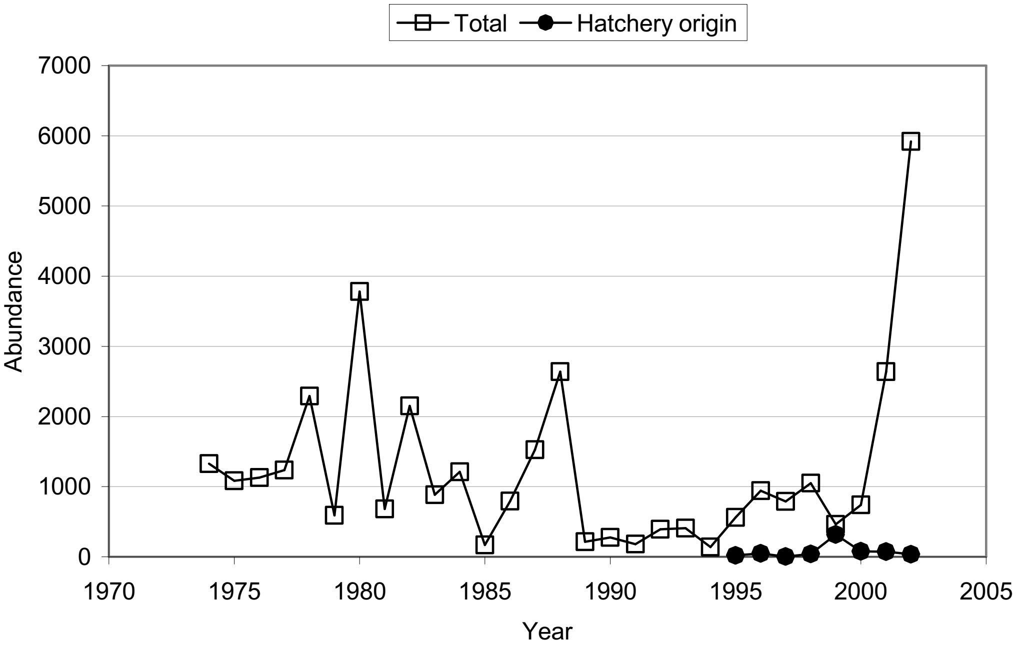

Figure 228. Salmon/Snow creeks summer-run chum salmon annual spawner abundance versus year by population, 1974–2002.

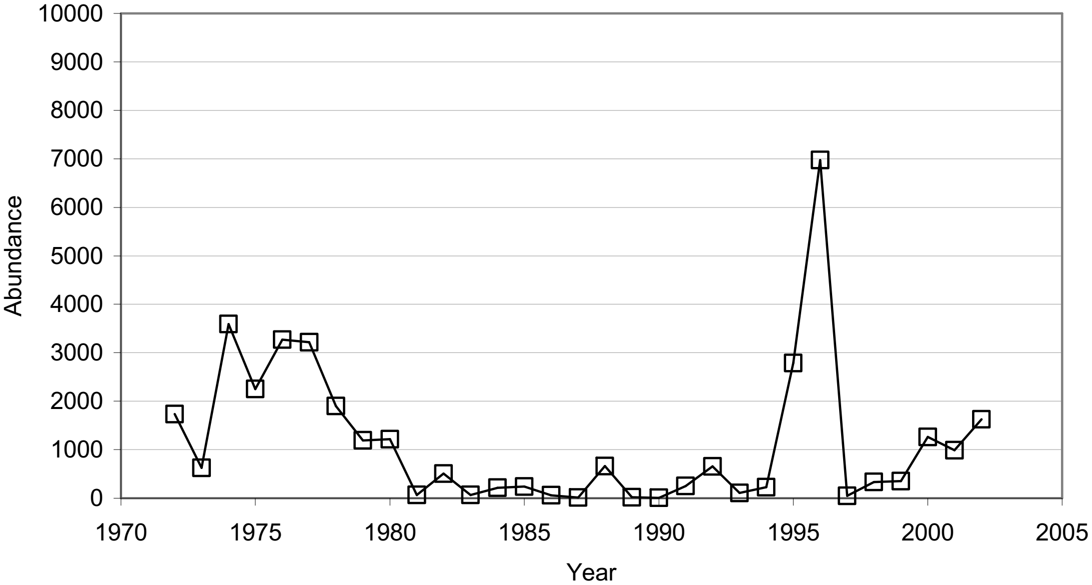

Figure 229. Dosewallips River summer-run chum salmon annual spawner abundance versus year by population, 1972–2002.

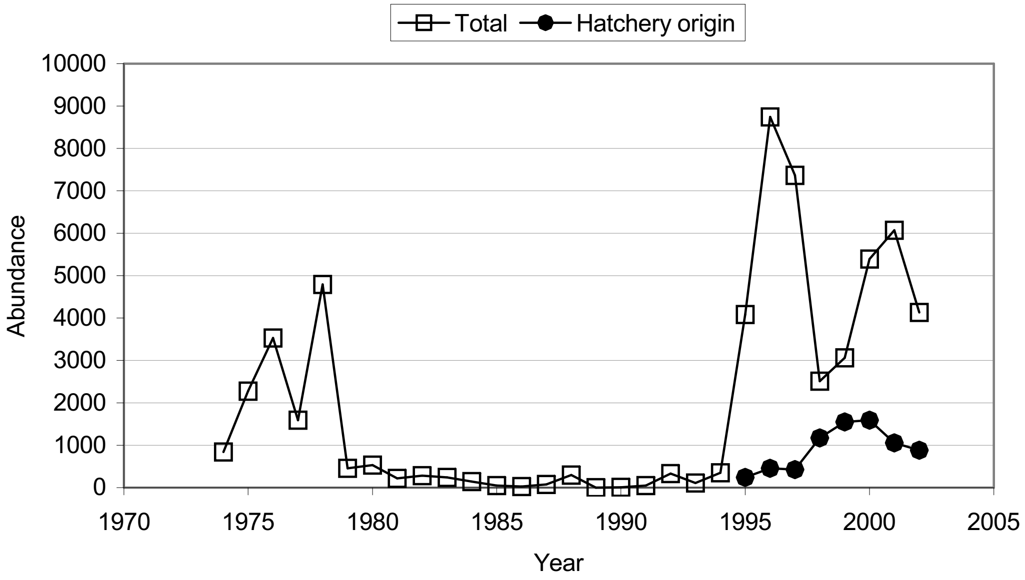

Figure 230. Combined Quilcene River summer-run chum salmon annual spawner abundance versus year by population, 1974–2002.

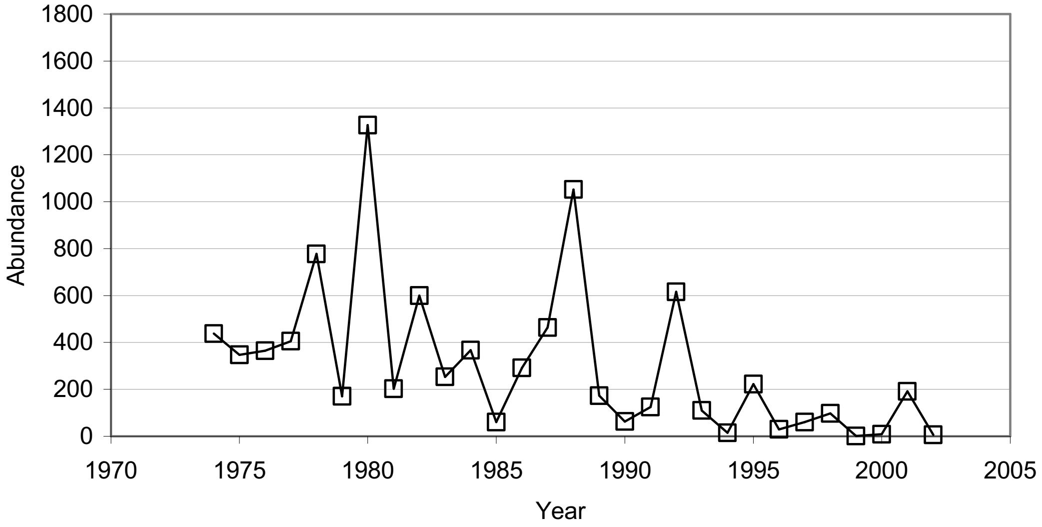

Figure 231. Jimmycomelately Creek summer-run chum salmon annual spawner abundance versus year by population, 1974–2002.

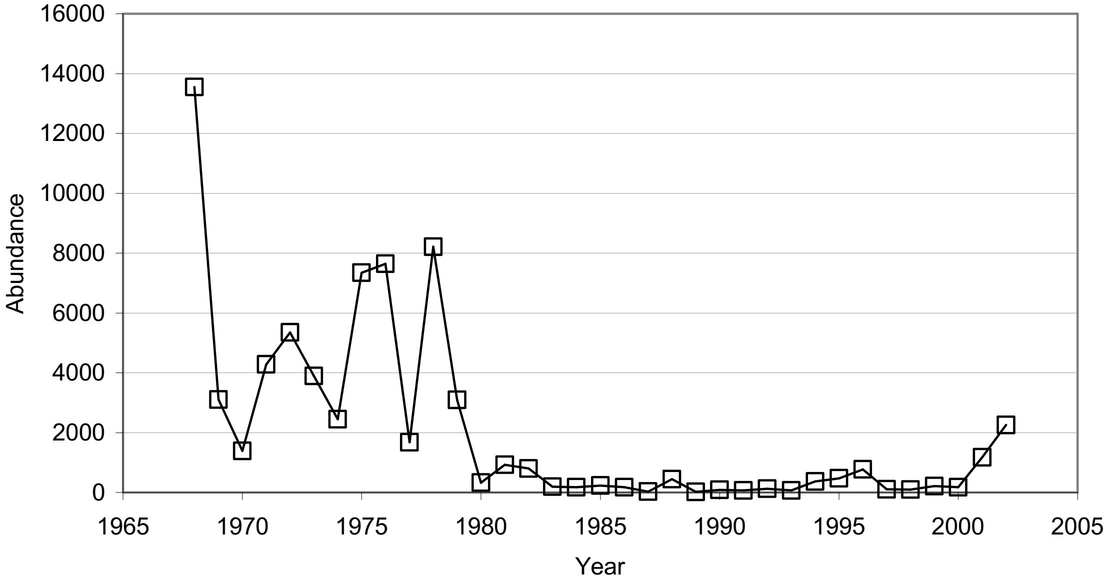

Figure 232. Hamma Hamma River summer-run chum salmon annual spawner abundance versus year by population, 1968–2002.

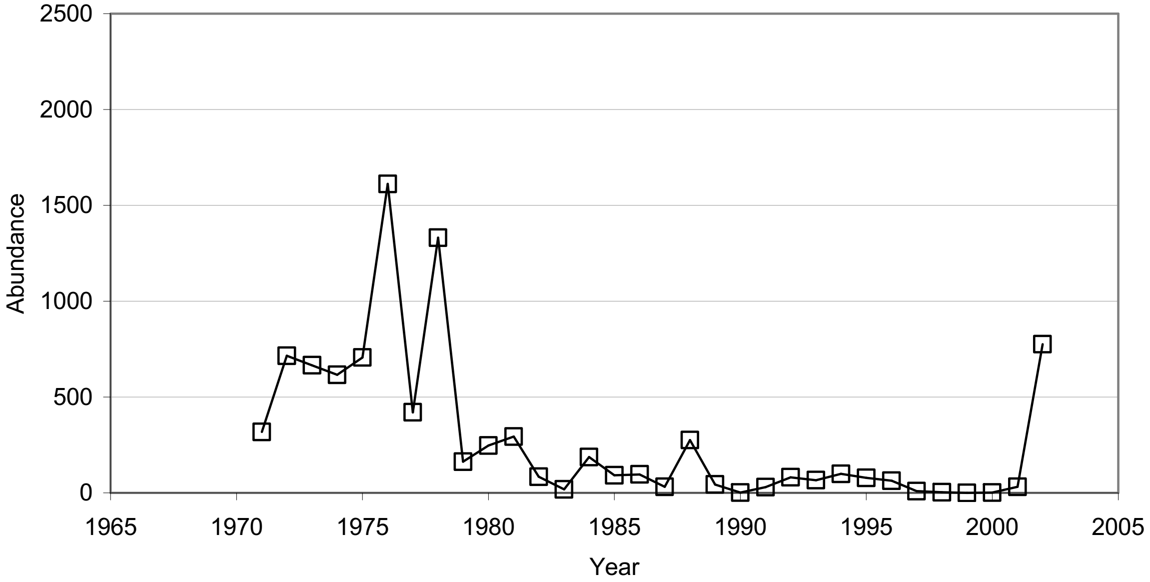

Figure 233. Lilliwaup River summer-run chum salmon annual spawner abundance versus year by population, 1971–2002.

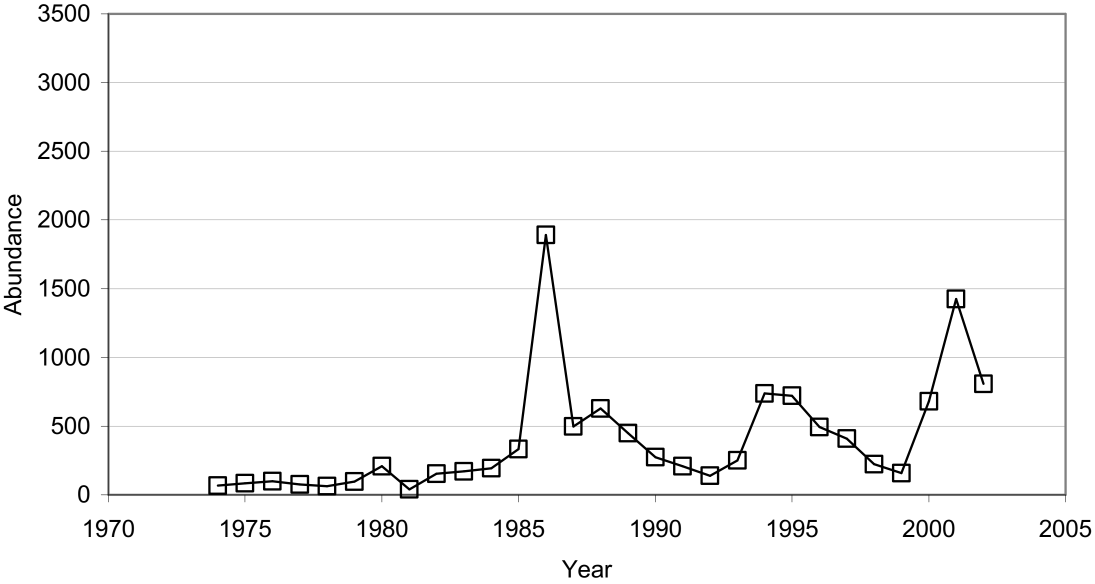

Figure 234. Union River summer-run chum salmon annual spawner abundance versus year by population, 1974–2002.

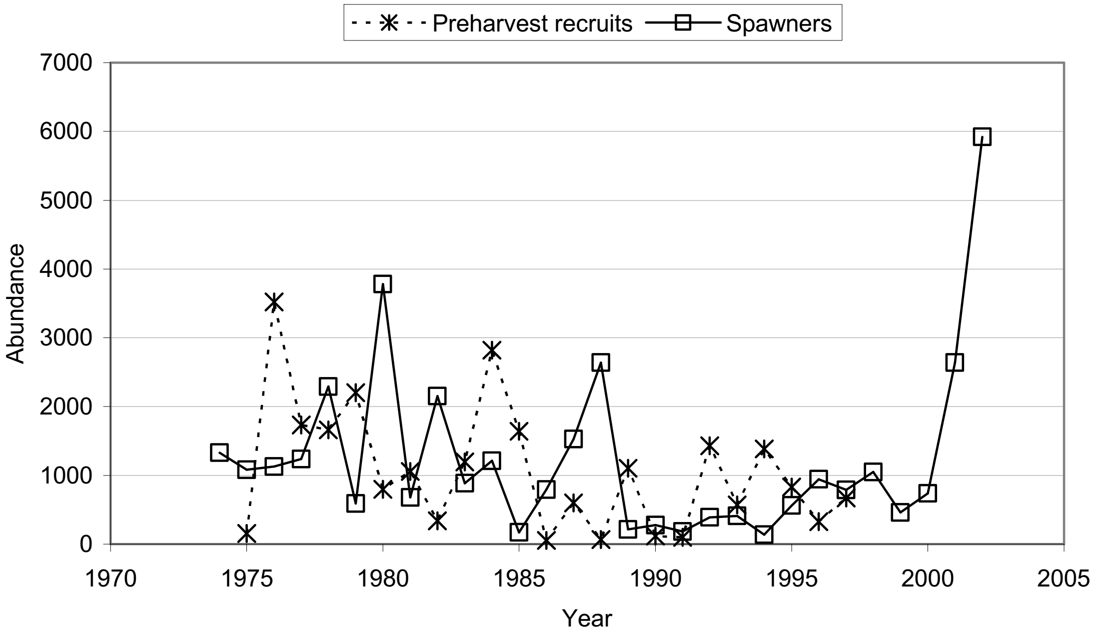

Figure 235. Salmon/Snow creeks summer-run chum salmon recruit and spawner abundance versus year by population, 1974–2002.

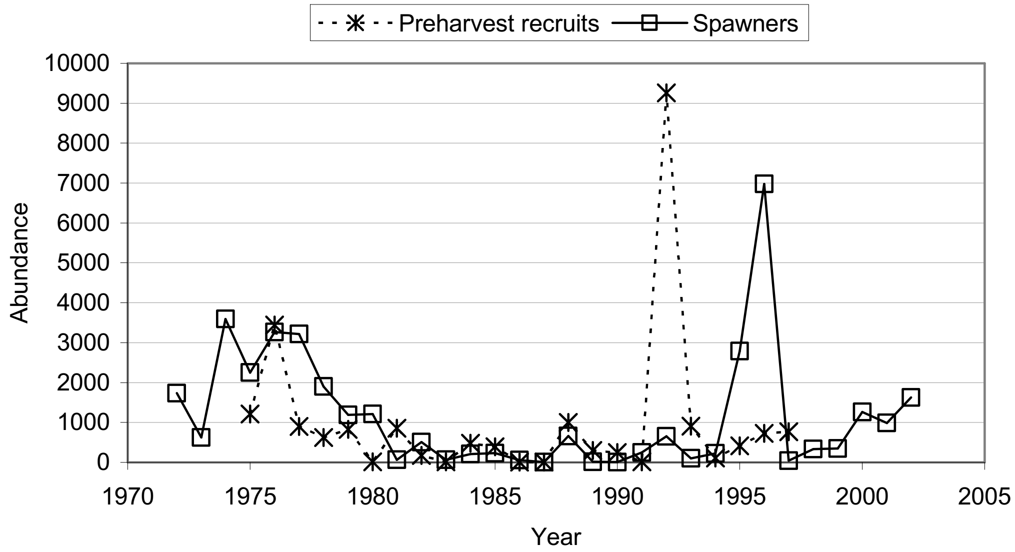

Figure 236. Dosewallips River summer-run chum salmon recruit and spawner abundance versus year by population, 1972–2002.

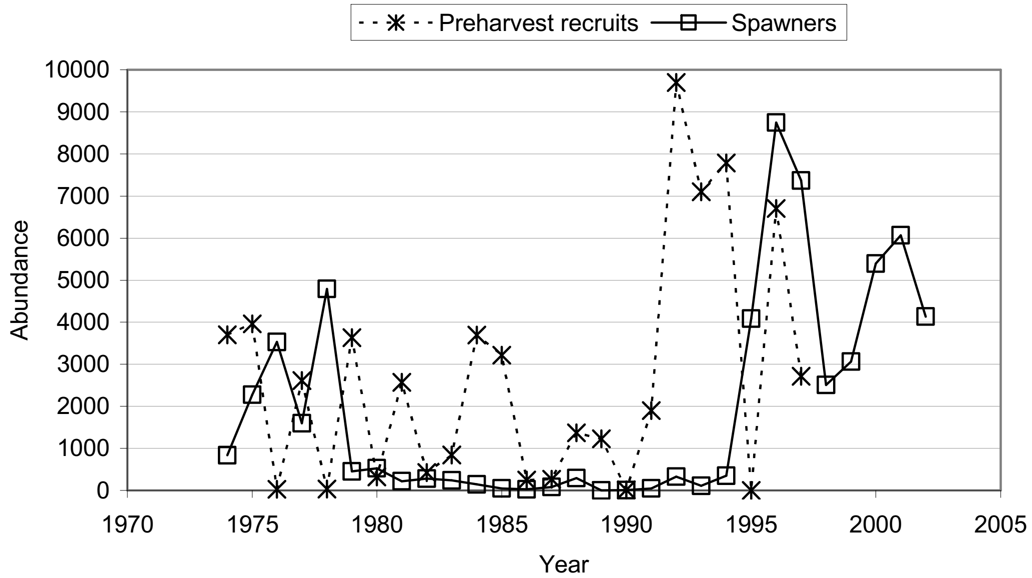

Figure 237. Combined Quilcene River summer-run chum salmon recruit and spawner abundance versus year by population, 1974–2002.

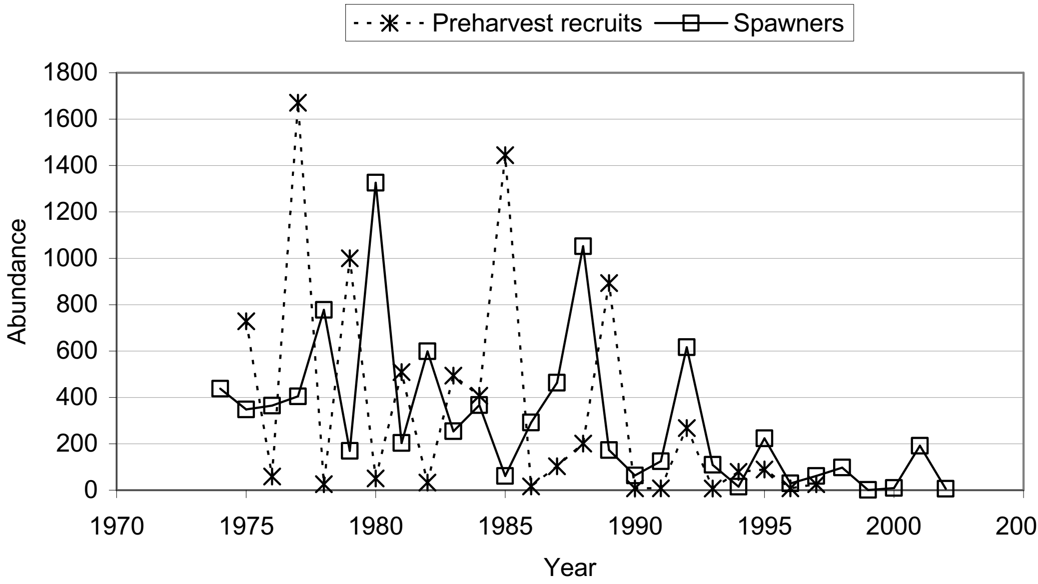

Figure 238. Jimmycomelately Creek summer-run chum salmon recruit and spawner abundance versus year by population, 1974–2002.

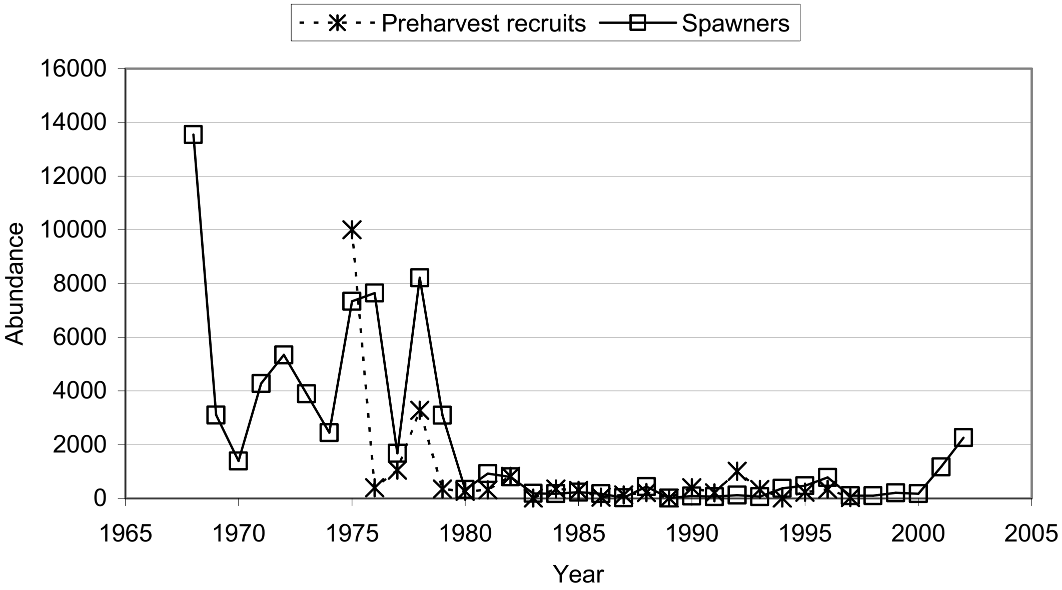

Figure 239. Hamma Hamma River summer-run chum salmon recruit and spawner abundance versus year by population, 1968–2002.

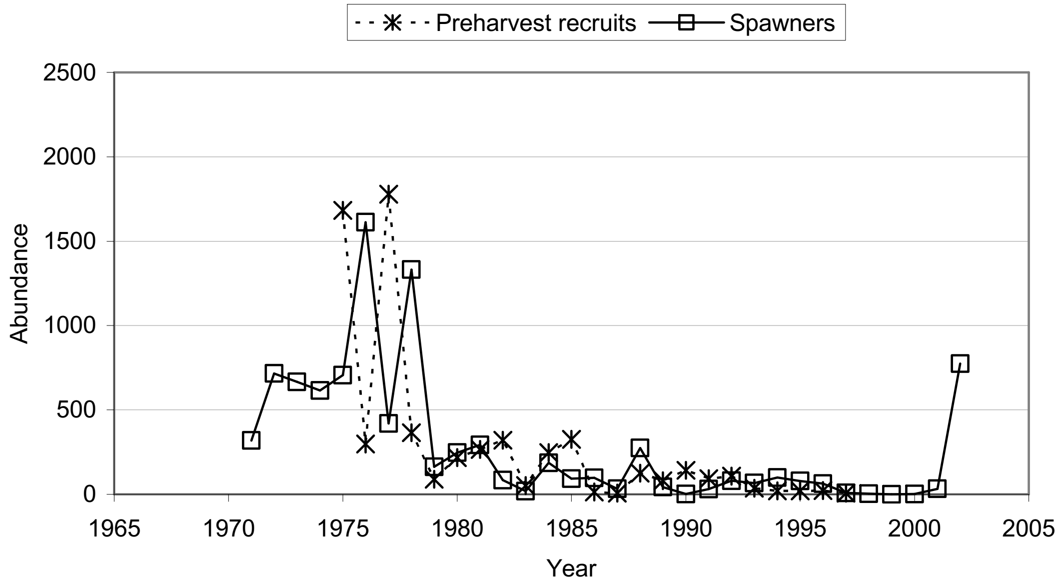

Figure 240. Lilliwaup River summer-run chum salmon recruit and spawner abundance versus year by population, 1971–2002.

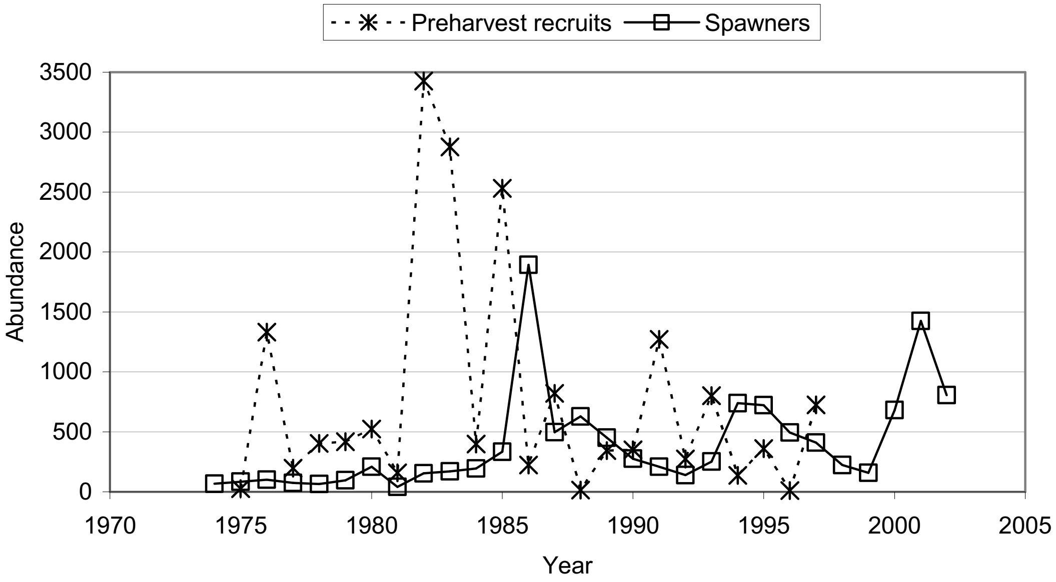

Figure 241. Union River summer-run chum salmon recruit and spawner abundance versus year by population, 1974–2002.

Trends in Natural Spawners

Long-term trends in abundance for extant naturally spawning populations of summer-run chum salmon in Hood Canal indicate that only two populations (combined Quilcene and Union rivers) are increasing in abundance over the length of available time series (Table 102). The median long-term trend over all populations is 0.94, indicating that most populations are declining at a rate of 6% per year. The range in long-term trend across the extant populations in Hood Canal is from 0.88 in the Jimmycomelately and Lilliwaup populations to 1.08 in the Union population. The Quilcene population's positive growth rate is almost surely due to the supplementation program on that stream.

In contrast to long-term trends, most of the naturally spawning populations of Hood Canal summer-run chum salmon exhibit increasing abundance over the short term—seven of eight extant populations in the ESU increased in abundance from 1990 to 2002 (Table 102). These recent increases likely reflect the supplementation programs in some streams and possibly recent improvements in ocean conditions. Short-term median population growth rates (λ) were calculated using two assumptions about the reproductive success of naturally spawning hatchery fish: the reproductive success was 0 (i.e., H0), or the reproductive success was equal to that of wild fish (i.e., H1). Differing assumptions about the reproductive success of hatchery fish only affected calculations of short-term λ for two populations because of the dearth of information on the fraction of hatchery fish in time series (Table 102). The median short-term λ (1.18) and short-term trend (1.17) over all populations are very similar. The most impressive short-term

Table 102. Estimates of long- and short-term trends, short-term median population growth rate (λ), and their 95% confidence intervals (CI) for natural spawners in extant Hood Canal summer-run chum salmon populations. Source: Data are from WDFW and PNPTT (2000, 2001); Puget Sound TRT database, unpublished data, available from N. Sands, Northwest Fisheries Science Center, Seattle, WA 98119.

Population	**Data years**	**Long-term trend (95% CI)**	**Short-term trend[a] (95% CI)**	**Short-term λ[b] (± lnSE)**
Big/Little Quilcene[c]	1974–2002	1.05 (0.96–1.16)	1.62 (1.31–2.01)	1.39 (0.22)
Dosewallips	1972–2002	0.96 (0.90–1.04)	1.25 (0.94–1.63)	1.17 (0.24)
Duckabush	1968–2002	0.91 (0.87–0.96)	1.14 (0.96–1.36)	1.1 (0.17)
Hamma Hamma	1968–2002	0.90 (0.86–0.94)	1.20 (1.04–1.40)	1.3 (0.19)
Jimmycomelately	1974–2002	0.88 (0.84–0.93)	0.815 (0.64–1.03)	0.85 (0.16)
Lilliwaup	1971–2002	0.88 (0.83–0.92)	1.00 (0.74–1.37)	1.19 (0.44)
Salmon/Snow[c]	1974–2002	0.99 (0.94–1.03)	1.24 (1.12–1.37)	1.23 (0.10)[c]
Union	1974–2002	1.08 (1.05–1.12)	1.10 (1.00–1.22)	1.15 (0.10)

[a] Short term is 1990 to 2002.

[b] Short-term λ is calculated assuming the reproductive success of hatchery-origin spawners is equivalent to that of wild-origin spawners (in cases where information on hatchery fish is available).

[c] Estimates of the fraction of hatchery fish are available only for the combined Quilcene and Salmon/Snow populations for the years 1995–2000.

increase in natural spawner abundance occurred in the Quilcene population (trend = 1.62, λ = 1.39), where the supplementation program appears to be succeeding in returning natural spawners to the Big and Little Quilcene rivers. The only population with a declining short-term trend and growth rate is the Lilliwaup, where many of the returning spawners have been collected for broodstock in the supplementation program.

Updated Information on Potential Threats

The Puget Sound TRT estimated annual fishery exploitation rates for each summer-run chum salmon population in the Hood Canal ESU (Table 103). Exploitation rates are calculated as the percentage of the total return that is caught in fisheries (i.e., total return = catch + broodstock take + escapement). The estimated numbers of adults harvested (i.e., catch) from Washington and Canadian fisheries are supplied by the comanagers.[71] Catch data are available for Hood Canal summer-run chum salmon from 1974 to the present.

Exploitation rates on the eight extant Hood Canal summer-run chum salmon populations averaged 25% (median = 15%; range 8%–56%) in the earliest 5 years of data availability (1974–1978). The annual exploitation rates increased in the 1980s as a result of increased coho

Table 103. Average annual exploitation rates on populations of Hood Canal summer-run chum salmon during three time periods, 1974–2002. Sources: Data are from WDFW and PNPTT (2000, 2001).*

Population	1974–1978 mean exploitation rate (%)	1979–1997 mean exploitation rate (%)	1998–2002 mean exploitation rate (%)
Big/Little Quilcene	28	64	13
Lilliwaup	55	43	3
Dosewallips	15	34	3
Duckabush	15	34	3
Hamma Hamma	15	34	3
Jimmycomelately	8	17	1
Union	56	43	5
Salmon/Snow	11	18	1
Mean	25	36	4
Median	15	34	3
Anderson	13	34	Extinct
Big Beef	15	10	Extinct
Dewatto	55	37	Extinct
Tahuya	56	39	Extinct
Mean	35	30	–
Median	35	36	–

*Puget Sound TRT database, unpublished data, available from N. Sands, Northwest Fisheries Science Center, Seattle, WA; N. Lampsakis, Point No Point Treaty Council, Kingston, WA. Pers. commun., 28 March 2003.

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[71] N. Lampsakis, Point No Point Treaty Council, Kingston, WA. Pers. commun., 28 March 2003.

fisheries in the area, and they have since dropped to an average of 4% (median = 3%; range 1%–13%) in the most recent 5-year period, 1998–2002 (Table 103). The most intensive harvest occurred on Hood Canal summer-run chum salmon during the period 1979–1991, when the total exploitation rate on the aggregate of Hood Canal summer-run stocks reached up to 81% in 1989 (WDFW and PNPTT 2000, 2001) and most recent run reconstruction from N. Lampsakis.[72] During the high harvest years (1979–1991), exploitation rates on the eight extant individual summer-run chum salmon populations averaged 47% (median = 44%; range 21%–86%).

Estimates of hatchery strays to Hood Canal tributaries were made only recently, coinciding with the instigation of hatchery programs to supplement summer-run chum salmon spawning on some streams. Releases of hatchery fish in the tributaries began in 1992 for the Big Quilcene River and Salmon Creek, so estimates of returning adult hatchery fish presently are available only for those streams (Table 104). The marking of hatchery-origin fish began recently in a number of streams (fin clips began in Quilcene in 1997, and otolith marks began in 1992 in Salmon Creek, 1997 in Lilliwaup and Hamma Hamma, 1998 in Big Beef Creek, 1999 in Chimacum and Jimmycomelately creeks, and 2000 in Union River). Therefore, distinguishing hatchery-produced from naturally born summer-run chum salmon was not possible in most Hood Canal streams until 2001.

Information on recent releases of hatchery juvenile summer-run chum salmon into Hood Canal streams is reported in Table 105. Average annual juvenile summer-run chum salmon releases in streams receiving hatchery fish ranged from 15,000 to 320,000 (average = 92,000) juveniles per year between 1993 and 2001. SSHAG identified all hatchery stocks of Hood Canal summer-run chum salmon as category 1a or 1b (Appendix E, Table E-1).

Table 104. Average estimated annual returns of hatchery summer-run chum salmon to the spawning grounds of extant populations of summer-run chum salmon in Hood Canal. Source: WDFW and PNPTT (2000, 2001); Puget Sound TRT, unpublished data, available from N. Sands, Northwest Fisheries Science Center, Seattle, WA 98119.

Population	**Year supplementation program started with broodstock takes**	**Average annual hatchery return to stream (minimum–maximum)**	**Hatchery return years**
Big/Little Quilcene	1992	941 (241–1619)	1995–2002
Dosewallips	None	NA	
Duckabush	None	NA	
Hamma Hamma	1998	NA	
Jimmycomelately	1999	NA	
Lilliwaup	1992	NA	
Salmon/Snow	1992	78 (2–319)*	1995–2002
Union	2000	NA	

* Estimated from Salmon Creek only.

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[72] See Footnote 71.

Table 105. Numbers of hatchery-origin juvenile summer-run chum salmon released into Hood Canal streams, 1993–2001. Source: Waknitz (2002).

Watershed	Years	Hatchery/stock	Release site	Total	Annual mean
Salmon Creek	1995–2001	Salmon Creek/Salmon Creek	Salmon Creek	366,743	52,391
Jimmycomelately Creek	2000–2001	Jimmycomelately Creek/Jimmycomelately Creek	Jimmycomelately Creek	29,780	14,890
Chimacum Creek	1999–2001	Chimacum Creek/Salmon Creek	Chimacum Creek	248,148	82,716
Big Quilcene River	1993–2001	Quilcene National Fish Hatchery/Big Quilcene River	Big Quilcene River	2,918,878	324,319
Hamma Hamma River	1998–2001	Hood Canal/Hamma Hamma	John Creek	121,000	30,250
Lilliwaup Creek	1995–1997	Long Live the Kings, Lilliwaup/ Lilliwaup Creek	Lilliwaup Creek	93,600	31,200
Big Beef Creek	1997–2001	Big Beef Creek/Big Quilcene River	Big Beef Creek	621,332	124,266
Union River	2001	Hood Canal/Union River	Union River	75,876	75,876

Additional potential threats to Hood Canal summer-run chum salmon include negative interactions with hatchery fish (fall-run Chinook, coho, pink, and fall-run chum salmon) through predation, competition and behavior modification, or disease transfer. The Hood Canal Summer-Run Chum Salmon Conservation Initiative reports annually on the predicted risks associated with each of the hatchery species on summer-run chum salmon (WDFW and PNPTT 2000, 2001). In the original report, the comanagers summarized what they considered to be the most important historical factors for decline for Hood Canal summer-run chum salmon (Table 106). Specific mitigation measures were identified for those hatchery programs deemed to pose a risk to summer-run chum salmon, and most of the mitigation measures had been implemented by 2000. In addition, some programs were discontinued.

Marine mammal predation on summer-run chum salmon in Hood Canal has been monitored by the Washington Department of Fish and Wildlife (WDFW) since 1998. The most recent results from these studies estimate that a few harbor seals are killing hundreds of summer-run chum salmon each year (WDFW and PNPTT 2001). Estimates of seal predation ranged from 2% to 29% of the summer-run chum salmon returning to each river annually.

New activities related to mitigating and improving degraded habitat quality in Hood Canal are reported in the Supplemental Report No. 3 under the comanagers' Summer-Run Chum Salmon Conservation Initiative (WDFW and PNPTT 2001). Such activities include new shoreline management rules issued by Washington Department of Ecology (but no resulting change in shoreline master programs yet), Jefferson County improved some development codes under the Growth Management Act, Clallam County provided limited improvements in upgrading its Critical Areas Ordinance in 1999, and Washington State Salmon Recovery

Funding Board has funded several habitat improvement projects. The BRT did not attempt to estimate the collective impacts of these projects on the status of Hood Canal summer-run chum salmon.

Table 106. Impact ratings of regionwide historical factors for decline of summer-run chum salmon in Hood Canal and Strait of Juan de Fuca streams. Source: Impact ratings from WDFW and PNPTT (2000).

Factor		**Hood Canal**	**Strait of Juan de Fuca**
Climate	Ocean conditions	Undetermined	Undetermined
	Estuarine conditions	Undetermined	Undetermined
	Freshwater conditions	Moderate	Major
Ecological interactions	Wild fall-run chum salmon	Low or not likely	Low or not likely
	Hatchery fall-run chum salmon	Low or not likely	Low or not likely
	Other salmonids (including hatchery)	Moderate	Low or not likely
	Marine fish	Low or not likely	Low or not likely
	Birds	Low or not likely	Low or not likely
	Marine mammals	Low or not likely	Low or not likely
Habitat	Cumulative impacts	Major	Major
Harvest	Canadian preterminal catch	Low or not likely	Moderate
	U.S. preterminal catch	Low or not likely	Low or not likely
	Terminal catch	Major	Low or not likely

38. Columbia River Chum Salmon ESU

Summary of Previous BRT Conclusions

NMFS last provided an updated status report on the Columbia River chum salmon ESU in 1999 (NMFS 1999g). As documented in the 1999 report, the previous BRT was concerned about the dramatic declines in abundance and contraction in distribution from historical levels. The previous BRT was also concerned about the low productivity of the extant populations, as evidenced by flat trend lines at low population sizes. A majority of the previous 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.

Listing status: Threatened.

New Data and Updated Analyses

New data include spawner abundance through 2000, with a preliminary estimate for 2002, new information on the hatchery program, and new genetic data describing the current relationship of spawning groups. New analyses include designation of relatively demographically independent populations, recalculation of previous BRT metrics with additional years' data, estimates of median annual growth rate (λ), and estimates of current and historically available stream kilometers.

Results of New Analyses

Historical population structure

As part of its effort to develop viability criteria for Columbia River ESU chum salmon, the WLC-TRT identified historical demographically independent populations (Myers et al. 2002). Population boundaries are based on the definition of VSPs developed by McElhany et al. 2000. Myers et al. (2002) hypothesized that the ESU historically consisted of 16 populations (Figure 242). These populations are the units used for the new analyses in this report.

The WLC-TRT partitioned Columbia River chum salmon populations into a number of strata based on ecological zones (McElhany et al. 2002). The WLC-TRT analysis suggests that a viable ESU would need multiple viable populations in each stratum. The strata and associated chum salmon populations are identified in Table 107.

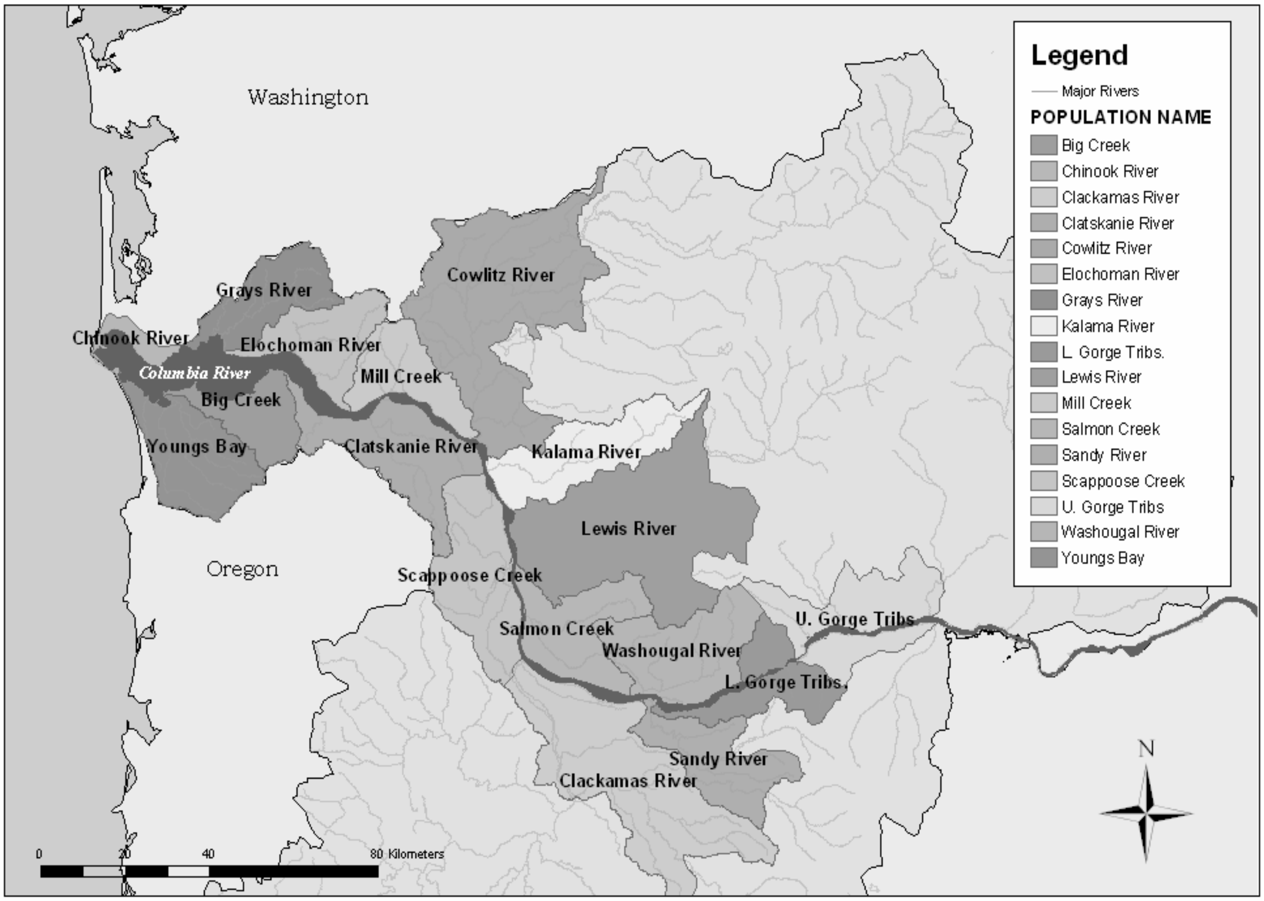

Figure 242. Historical chum salmon populations in the Columbia River chum salmon ESU. This map does not reflect the most recent modification of the population designation, which merged Grays River and Chinook River chum salmon into a single population for a total of 16 populations (Myers et al. 2002).

Abundance, Distribution, and Trends

Chum salmon in the Columbia River once numbered in the hundreds of thousands of adults, and at times approached a million per year (Figure 243). The total number of chum salmon returning to the Columbia River in the last 50 years averaged perhaps a few thousand per year, returning to a very restricted subset of the historical range (Table 108 and Figures 243 and 244). The status of individual populations is discussed below. References for abundance time series and related data are in Appendix E, Table E-2. Significant spawning occurs in only 2 of the 16 historical populations, meaning that 88% of the historical populations are extirpated, or nearly so. The two extant populations are at Grays River and the lower Columbia Gorge (Figure 243). The status of individual populations and groups of populations are discussed below.

Table 107. Historical population structure of Columbia River chum salmon. The populations are portioned into ecological zones, which are based on ecological community and hydrodynamic patterns.

Ecological zone	Population	EDT estimate of historical abundance[a]
Coastal	Youngs Bay	nd[b]
	Grays River	7,511
	Big Creek	nd
	Elochoman River	nd
	Clatskanie River	nd
	Mill, Abernathy, Germany creeks	nd
	Scappoose Creek	nd
Cascade	Cowlitz River	141,582
	Kalama River	9,953
	Lewis River	89,671
	Salmon Creek	nd
	Clackamas River	nd
	Sandy River	nd
	Washougal River	15,140
Columbia Gorge	Lower gorge tributaries	>3,141
	Upper gorge tributaries	>8,912
Total		>283,421

[a] The EDT estimate of historical abundance is based on analysis by WDFW of equilibrium abundance under historical habitat conditions (Busack and Rawding 2003).

[b] nd = no data.

Table 108. Recent abundance estimates for lower Columbia Gorge and two Grays River chum salmon populations. The majority of Columbia River chum salmon spawn as part of these populations.

Population	Years for recent means	Recent geometric mean	Recent arithmetic mean
Grays River*			
Rawding estimate	1994–1998	704	812
Hymer estimate	1996–2000	331	576
Lower Columbia Gorge	1996–2000	425	490

* Two different time series estimates are available for the Grays River population, Rawding (2001c) and Hymer (2000).

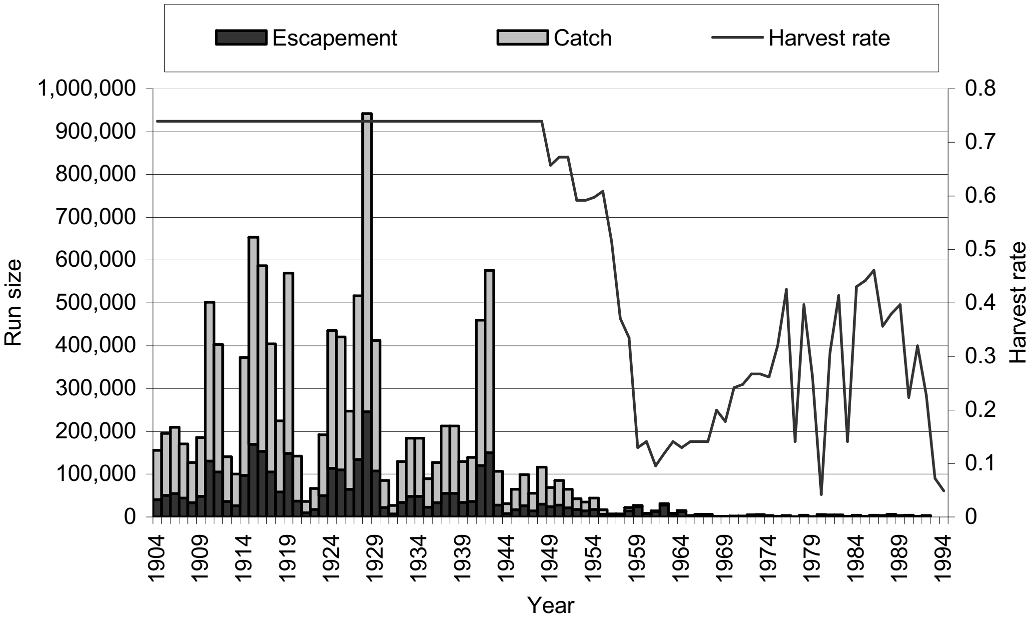

Figure 243. Columbia River chum salmon returns, 1904–1994.

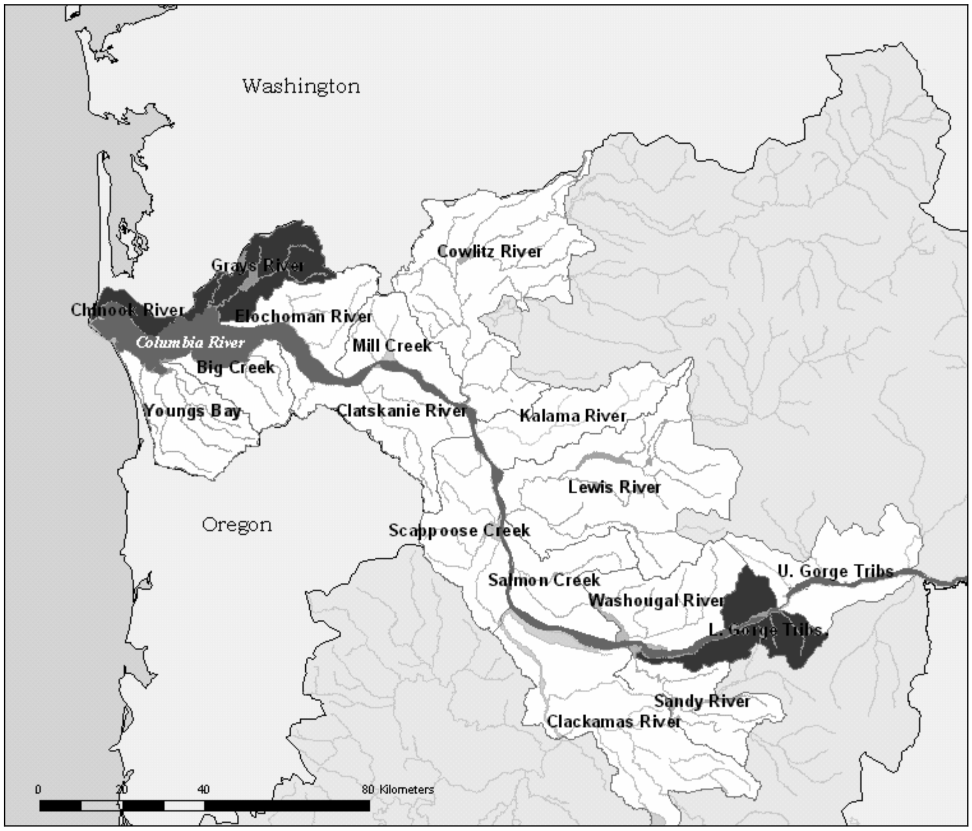

Figure 244. Extant Columbia River chum salmon populations.

Grays River

The majority of chum salmon spawning in the Grays River currently occurs in less than 1.1 km of the river. Prior to its destruction in a 1998 flood, approximately 50% of the Grays River population spawning occurred in an artificial spawning channel created by WDFW in 1986. Two time series of abundance were available for the Grays River chum salmon population (Tables 109 and 110 and Figures 245 and 246). One data set by Hymer (2000) covers the years 1944–2000. The other data set covers 1967–1998; it was provided by Dan Rawding of WDFW (Rawding 2001c) to correct some perceived errors in the expansions used in the Hymer (2000) data set. The Rawding estimates are believed to be more accurate, but both data sets are included in this report because the Hymer series includes estimates both earlier and more recent than the Rawding data set. The Rawding data set shows a small upward trend (λ) from 1967 to 1998 (Table 109), and a low probability that the population is declining (Table 110). However, the longer Hymer data set indicates that both long- and short-term trends are negative over the period 1950–2000, with a high probability that the trend and λ values are less than one. The Rawding data were insufficient to estimate the short-term trend (i.e., since 1990).

Table 109. Trend and growth rate for a Lower Columbia Gorge and two Grays River chum salmon populations (95% confidence intervals are in parentheses).

		Long term[a]		Short term[b]	
Population	**Years of time series**	**Trend in abundance**	**Median growth rate (λ^c)**	**Trend in abundance**	**Median growth rate (λ^c)**
Grays River[d]					
Rawding estimate	1967–1998	1.058 (1.021–1.096)	1.043 (0.957–1.137)	Not enough data	Not enough data
Hymer estimate	1951–2000	0.990 (0.965–1.016)	0.954 (0.855–1.064)	0.904 (0.661–1.235)	0.807 (0.723–0.900)
Lower Columbia Gorge	1950–2000	0.979 (0.961–0.997)	0.984 (0.883–1.096)	1.003 (0.882–1.141)	1.001 (0.899–1.116)

[a] The long-term analysis used the entire data set (see Table 74 for years).

[b] Short-term data sets include data from 1990 to the most recent available year.

[c] The λ calculation is an estimate of what the natural growth rate would have been after accounting for hatchery-origin spawners.

[d] Two different time series estimates are available for the Grays River population, Rawding (2001c) and Hymer (2000).

Table 110. Probability that the abundance trend or growth rate of Columbia River chum salmon is less than 1.

Population	**Years of time series**	**Long term**		**Short term**	
		Probability trend < 1	**Probability $\lambda < 1$**[a]	**Probability trend < 1**	**Probability $\lambda < 1$**[a]
Grays River[b]					
Rawding estimate	1967–1998	0.001	0.197	Not enough data	Not enough data
Hymer estimate	1951–2000	0.776	0.774	0.759	0.934
Lower Columbia Gorge	1950–2000	0.987	0.657	0.478	0.494

[a] The λ calculation is an estimate of what the natural growth rate would have been after accounting for hatchery-origin spawners.

[b] Two different time series estimates are available for the Grays River population, Rawding (2001c) and Hymer (2000).

Final abundance estimates for 2002 were also not available, but preliminary estimates were received.[73] The preliminary estimates suggest a substantial increase in abundance in 2002 over what was observed over the last 50 years. Survey crews handled over 7,000 chum salmon carcasses in the Grays River in 2002, but the total population size is in the neighborhood of 10,000 adults (Figure 245). However, a new chum salmon hatchery program in the Grays River that started in 1999 confounds the abundance estimates because hatchery returns are included in the 10,000-adult estimate. The hatchery fish were otolith marked, so it will be possible to determine the fraction of hatchery-origin spawners once the otoliths are read; however, that information is not available at this time. The Chinook River population, a subpopulation of the Grays River population, had essentially no chum salmon in recent years until hatchery fish returned in 2002. In 2002, a preliminary estimate of 600 chum salmon returned to the Chinook River, suggesting a 1% return of 3-year-olds from the hatchery fish. Potential causes of this increase in 2002 are discussed below. No estimates of 2001 abundance were available from WDFW at the time of this report, although the run was described as “large, though not as large as 2002.”

Lower Columbia Gorge population

The lower Columbia Gorge population consists of a number of subpopulations immediately below Bonneville Dam. The subpopulations include Hardy Creek, Hamilton Creek, Ives Island, and the Multnomah area. Both the Ives Island and Multnomah area subpopulations spawn in the Columbia main stem. The time series used for analysis of the lower Columbia Gorge population is based on summing the abundance in Hardy Creek, Hamilton Creek, and the artificial spawning channel in Hamilton Creek (Tables 107–109, Figures 247–248). There is some question about whether or not these data provided a representative index of the population, because it does not include the mainstem spawning areas. Depending on flow conditions, chum salmon may alternate between the tributaries and the main stem, causing counts in only a subset

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[73] See Footnote 9.

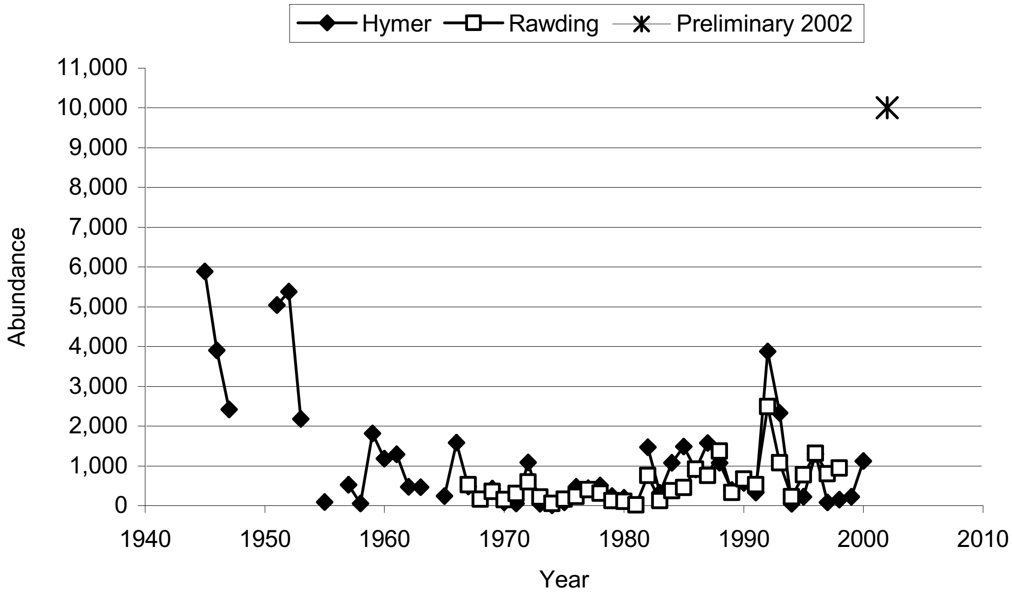

Figure 245. Grays River chum salmon abundance estimates, 1945–2000. The two data sets (Rawding, 2001c, and Hymer, 2000) use different information and expansions to estimate the Grays River chum salmon abundance. The 2002 data are preliminary and include an unknown number of hatchery-origin spawners. Source: D. Rawding, Washington Department of Fish and Wildlife, Vancouver.

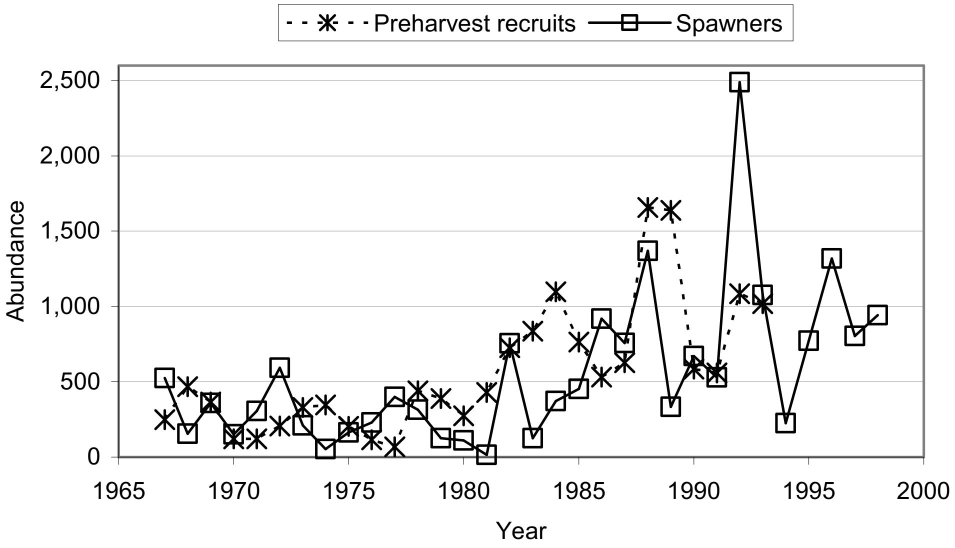

Figure 246. Grays River chum salmon recruits and spawners, 1966–1998. Source: Based on a data set provided by D. Rawding, Washington Department of Fish and Wildlife, Region 5, 2108 Grand Ave., Vancouver (2002; see Appendix E, Table E-2).

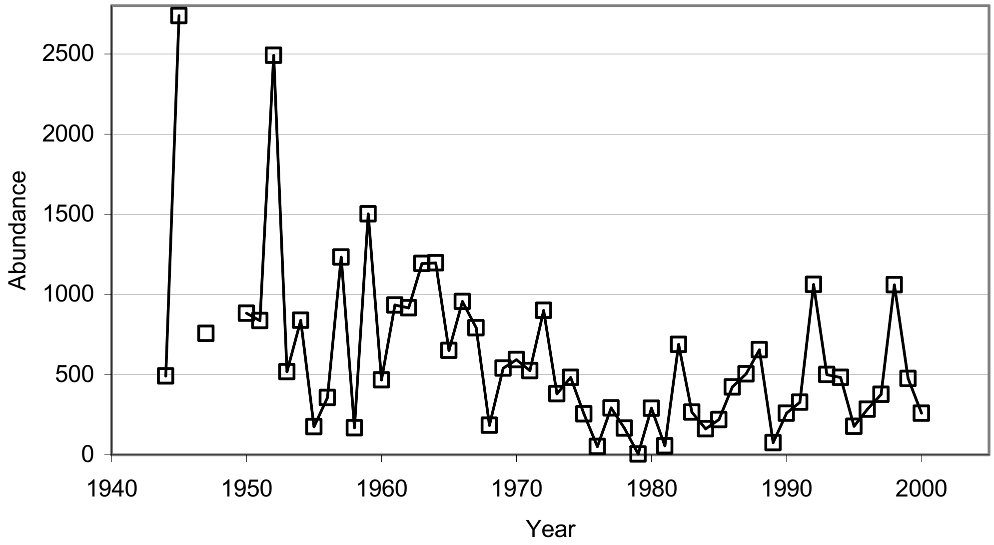

Figure 247. Hamilton and Hardy creeks (lower Columbia Gorge population) chum salmon spawner abundance, 1944–2000.

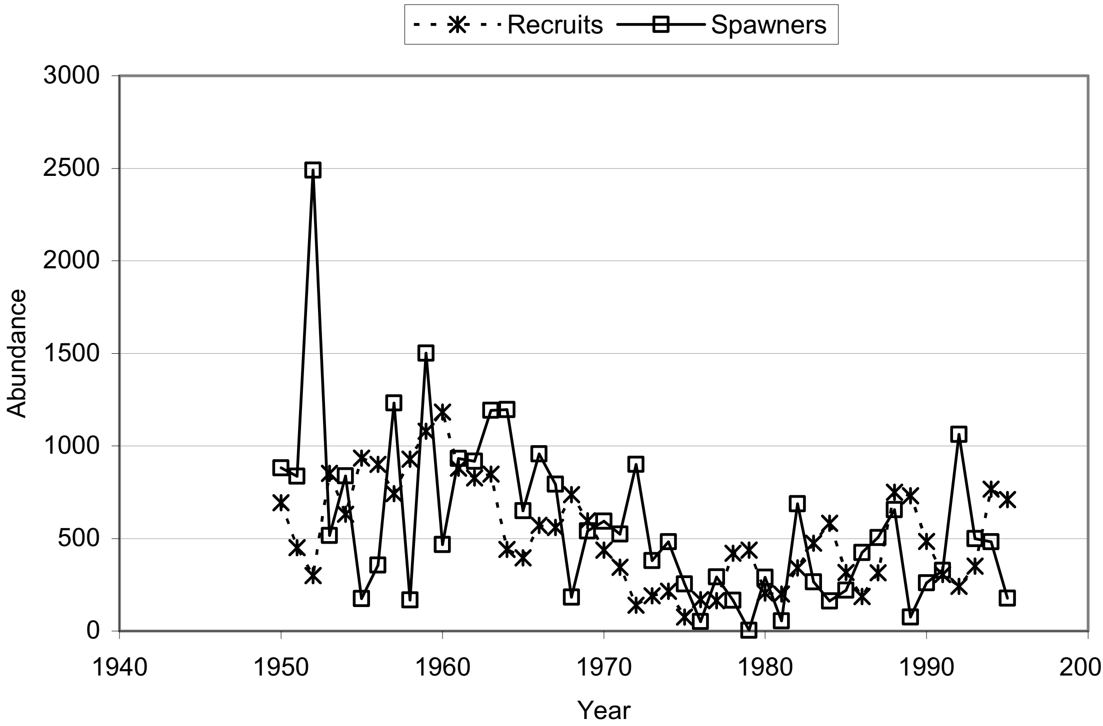

Figure 248. Hamilton and Hardy creeks (lower Columbia Gorge population) chum salmon recruits and spawners, 1950–2000.

of the population to act as poor indicators of total population abundance in any given year. Based on these data, the population showed a downward trend since the 1950s and was at relatively low abundance up to 2000. However, preliminary data indicate that the 2002 abundance showed a substantial increase, estimated to be more than 2,000 chum salmon in Hamilton and Hardy creeks, plus another 8,000 or more in the main stem. There have been no hatchery releases in the lower gorge population, so hatcheries are not responsible for this 2002 increase, unless there was long distance straying from Grays River (>100 km). Potential causes of the 2002 increase are discussed below. No estimate of 2001 abundance was available from WDFW at the time of this report, although the run was described as "large, though not as large as 2002."

Washougal River population

Chum salmon were observed within the last 3–4 years spawning in the mainstem Columbia River on the Washington side, near the I-205 bridge (at Woods Landing and Rivershore). These spawners would be considered part of the WLC-TRT's Washougal population, the nearest tributary mouth, but whether this population is recently established or only recently discovered by WDFW is not clear. Genetic analysis indicates that the fish currently spawning in this area are more closely related to fish in the lower Columbia Gorge than to fish in Grays River (Marshall 2001). In 2000, WDFW estimated 354 spawners at this location (Figure 249). As with the two other Columbia River chum salmon spawning populations, preliminary data indicate a dramatic increase in 2002. Preliminary estimates of this population for 2002 put its abundance in the range of several thousand spawners.

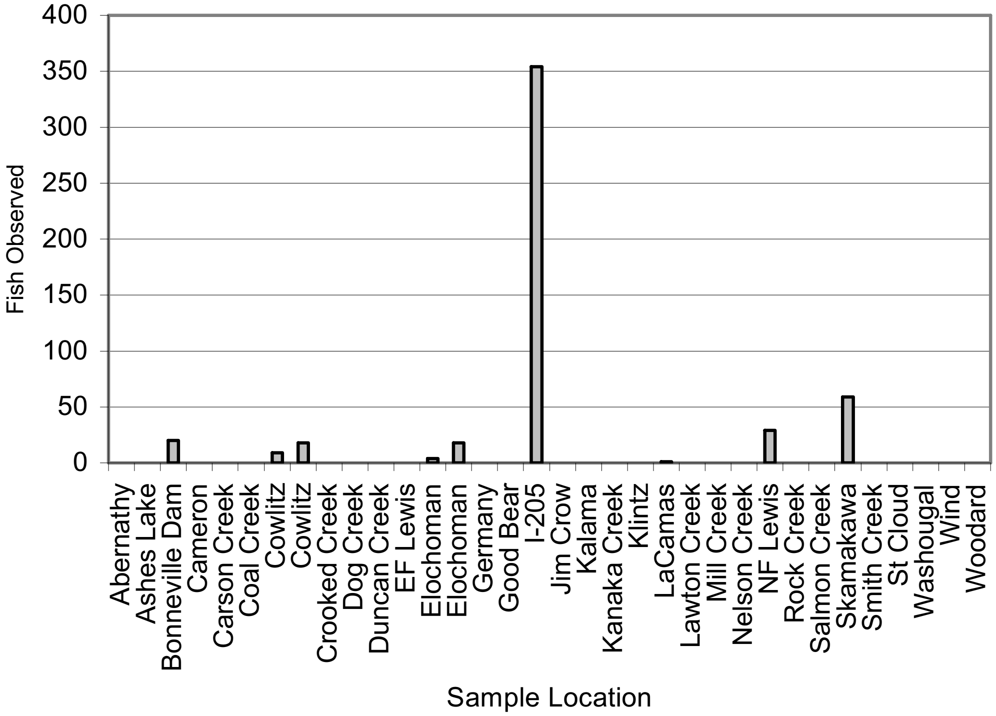

Figure 249. Abundance of chum salmon observed in 2000 Pacific States Marine Fisheries Commission surveys.

Upper Columbia Gorge population

A large portion of the upper gorge population chum salmon habitat is believed to have been inundated by Bonneville Dam. However, small numbers of chum salmon still pass Bonneville Dam (Figure 250). The number of fish passing the dam showed some increase in 2002, but not the dramatic increases estimated in the other three populations.

Other Washington populations

In 2000, the Pacific States Marine Fisheries Commission conducted a study to determine the distribution and abundance of chum salmon on the Washington side of the Columbia River. The results of that survey are shown in Figure 249.[74] Very small numbers of chum salmon were observed in several locations. However, with the possible exception of the Washougal River mainstem (I-205) population (discussed above), none is considered close to self-sustaining abundance.

Oregon populations

Chum salmon spawn on the Oregon side of the lower Columbia Gorge (Multnomah area), but appear to be essentially absent from other populations in the Oregon portion of the Columbia River chum salmon ESU. In 2000, ODFW conducted surveys with a similar purpose to the WDFW 2000 surveys (i.e., to determine the abundance and distribution of chum salmon in the Columbia). Out of 30 sites surveyed, only one chum salmon was observed. With the exception of the lower Columbia Gorge population, Columbia River chum salmon are considered extirpated, or nearly so, in Oregon.

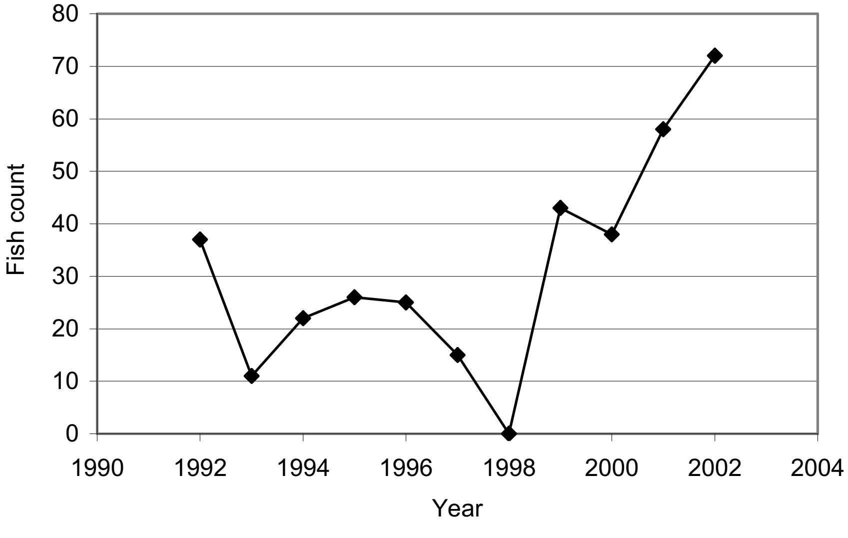

Figure 250. Adult chum salmon passing Bonneville Dam, 1992–2002.

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[74] Pers. commun. from Lynne Krasnow, Northwest Fisheries Science Center, Portland, OR, to P. McElhany, 1 March 2002. Data available from P. McElhany, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112.

Reasons for 2002 Increase in Abundance

It is not known why Columbia River chum salmon dramatically increased in abundance in 2002. As of the writing of this memo, the run had just ended and firm abundance estimates were not available. However, several hypotheses were floated regarding this increase, including:

- improved ocean conditions,
- Grays River and Chinook River hatchery programs,
- Columbia River mainstem flow agreements (the lower Columbia Gorge population is in the tailrace of Bonneville Dam and subject to hydrosystem induced flow fluctuations),
- favorable freshwater conditions, and
- increased sampling effort (since the 2000 survey, effort seems to have increased, though this alone certainly does not explain the apparent increase).

These factors are all possible contributors to the increase, but the reason for the increase is not known. Similarly, why chum salmon were restricted to low abundance and limited distribution for the last 50 years is also not known. It did not appear in 2002 that chum salmon had expanded their range beyond the Grays River, lower Columbia Gorge, and I-205 areas, though not all the 2002 survey data had been reported. Because the cause of the 2002 increase is unknown, it is impossible to know whether it will continue. The 2002 increase in Columbia River chum parallels a recent increase in Puget Sound chum. It is not known whether the reasons for the increase in the two regions are the same.

EDT-Based Estimates of Historical Abundance

The WDFW conducted analyses of Columbia River chum salmon populations using the EDT model (http://www.olympus.net/community/dungenesswc/EDT-primer.pdf), which attempts to predict fish population performance based on information about reach-specific habitat attributes. WDFW populated this model with estimates of historical habitat conditions, which produced the estimates of average historical abundance shown in Table 107. There is a great deal of unquantified uncertainty in the EDT historical abundance estimates, and this uncertainty should be considered when interpreting these data. In addition, the habitat scenarios evaluated as historical may not reflect historical distributions, because some areas that were accessible historically but now are blocked by large dams were omitted from the analyses, and some areas that were historically inaccessible but now made passable by human intervention are included. The EDT outputs are provided here to give a sense of the historical abundance of populations relative to each other and an estimate of the historical abundance relative to the current abundance.

Table 111. Loss of habitat from barriers for the Columbia River chum salmon ESU.

Population	Potential current habitat (%)[a]	Potential historical habitat (km)[b]	Current to historical habitat ratio[c]
Youngs Bay	269	287	94
Grays River[d]	229	230	100
Grays River[e]	229	230	100
Big Creek	369	407	91
Elochoman River	242	242	100
Clatskanie River	160	165	97
Mill, Abernathy, Germany creeks	266	306	87
Scappoose Creek	888	1,048	85
Cowlitz River	114	120	95
Kalama River	382	579	66
Lewis River	319	362	88
Salmon Creek	416	471	88
Clackamas River	148	194	76
Sandy River	125	240	52
Washougal River	81	82	99
Lower Columbia Gorge tributaries	55	77	71
Upper Columbia Gorge tributaries	NA	NA	NA
Total	4,292	5,040	85

[a] The potential current habitat is the kilometers of stream below all currently impassable barriers between a gradient of 0% and 3.5%.

[b] The potential historical habitat is the kilometers of stream below historically impassable barriers with a gradient of between 0% and 3.5%.

[c] The current:historical habitat ratio is the percent of the historical habitat that is currently available. This table does not consider habitat quality.

[d] Hymer (2000).

[e] Rawding (2001c).

Loss of Habitat from Barriers

Steel and Sheer (2003) assessed the number of stream kilometers historically and currently available to salmon populations in the lower Columbia River (Table 111). Stream kilometers usable by salmon are determined based on simple gradient cutoffs and the presence of impassable barriers. This approach overestimates the number of usable stream kilometers, because it does not take into consideration habitat quality (other than gradient). This is likely especially true of chum salmon, which seem to prefer particular microhabitats for spawning.

New ESU Information

Updated information in this report, the information contained in previous lower Columbia River status reviews, and preliminary WLC-TRT analyses suggest that 14 of the 16 historical populations (88%) are extinct or nearly so. The two extant populations have been at low abundance for the last 50 years in the range where stochastic processes could lead to extinction. Encouragingly, the abundance of these two populations has substantially increased. In addition, there are new (or newly discovered) Washougal River mainstem spawning groups. However, whether the increase will continue and whether the abundance is still substantially below the historical levels are not known.

39. Chum Salmon BRT Conclusions

Hood Canal Summer-Run Chum Salmon ESU

Most of the BRT votes for the Hood Canal summer-run chum salmon ESU fell in the "likely to become endangered" category (74%), with a minority in the "danger of extinction" category (21%) and the balance in the "not likely to become endangered" category (Table 112). Mean risk matrix scores were moderately high (3.4–3.7) for each VSP element (Table 113), reflecting ongoing BRT concerns for the major risks identified in previous assessments. An estimated 7 of 16 historical populations in this ESU have been extirpated, with most of the population losses occurring on the eastern side of Hood Canal. Although many of the remaining populations remain at very depressed levels, adult returns in a number of streams increased in 2000–2002. Harvest rates are reduced considerably from their peaks in the 1980s, which should facilitate recovery if other limiting factors are addressed. The BRT felt that the joint state and tribal Summer Chum Salmon Conservation Initiative represented a positive step toward recovery of the Hood Canal ESU. However, although the initiative includes guidelines for habitat restoration, implementation of habitat actions is largely outside its jurisdiction. In particular, the BRT remains concerned that widespread loss of estuary and lower floodplain habitat is an ongoing risk factor for this ESU. A number of supplementation programs have been initiated in recent years to help boost abundance of local populations. Although these programs may help

Table 112. FEMAT votes regarding status of the Hood Canal summer-run and Columbia River chum salmon ESUs. Thirteen BRT members allocated 10 points among the three status categories for the Columbia River population, 12 members for Hood Canal.

ESU	**Danger of extinction**	**Likely to become endangered**	**Not likely to become endangered**
Hood Canal summer-run	25	89	6
Columbia River	44	82	4

Table 113. Summary of risk scores (1 = low to 5 = high) for four viable salmonid population categories* for the Hood Canal summer-run and Columbia River chum salmon ESUs. Data presented are means (range).

ESU	**Abundance**	**Growth rate/productivity**	**Spatial structure and connectivity**	**Diversity**
Hood Canal summer-run	3.7 (3–4)	3.4 (2–4)	3.7 (3–5)	3.5 (2–4)
Columbia River	3.6 (3–4)	3.5 (2–4)	4.4 (4–5)	3.8 (3–5)

*See subsection, Factors Considered in Status Assessments, for a description of the risk categories.

speed recovery of existing populations or reseed vacant habitat, the BRT found it difficult to assess the current effects of these programs because of the inability to distinguish most hatchery and wild fish. More intensive marking programs have been implemented recently, which should make it easier to monitor natural production of summer-run chum salmon in the future.

Columbia River Chum Salmon ESU

Nearly all votes for the Columbia River chum salmon ESU fell in the “likely to become endangered” (63%) or “danger of extinction” (34%) categories (Table 112). The BRT had substantial concerns about every VSP element, as indicated by mean risk matrix scores that ranged from 3.5 for growth rate/productivity to 4.4 for spatial structure (Table 113). 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 populations that remain are small, and overall abundance for the ESU is low. This ESU has shown low productivity for many decades, even though the remaining populations are at low abundance and density-dependent compensation might be expected. The BRT was encouraged that unofficial reports for 2002 suggest a large increase in abundance in some (perhaps many) locations. Whether this large increase is due to any recent management actions or simply reflects unusually good conditions in the marine environment is not known at this time, but the result is encouraging, particularly if it were to be sustained for a number of years.

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Appendix A: Chinook Salmon

Table A-1. SSHAG (2003) categorizations of hatchery stocks of the nine Chinook salmon ESUs reviewed.

ESU/Stock	Run	Basin	SSHAG category*
Snake River fall run			
Lyons Ferry Hatchery	Fall	Snake	2a
Snake River spring/summer run			
McCall (supplementation)	Spring	Salmon	1a
McCall (production)	Spring	Salmon	2a
Rapid River	Spring	Little Salmon	3c
Sawtooth	Spring	Salmon	1a
Pahsimeroi	Summer	Salmon	1a and 2a
Captive broodstock			
Catherine Creek	Summer	Grande Ronde	1a
Upper Grande Ronde	Summer	Grande Ronde	1a
Lostine River	Summer	Grande Ronde	1a
Clearwater	Spring	Clearwater	2b
Imnaha (#29)	Spring/summer	Imnaha	1a
Dworshak	Spring	Clearwater	3b or 4
Kooskia	Spring	Clearwater	3b or 4
Tucannon	Spring	Tucannon	1a
Upper Columbia River spring run			
Leavenworth National Fish Hatchery	Spring	Wenatchee	3c or 4
Entiat National Fish Hatchery	Spring	Entiat	3c, 4, or 2b
Winthrop National Fish Hatchery	Spring	Methow	3c or 4
Chiwawa	Spring	Wenatchee	1a
Methow composite	Spring	Methow	2a/c
Twisp	Spring	Methow	1a
Chewuch	Spring	Methow	1a
Methow	Spring	Methow	3c or 4
Upper Columbia River captive			
Nason	Spring	Wenatchee	1a
White River	Spring	Wenatchee	1a
Twisp	Spring	Methow	1a
Methow	Spring	Methow	1a
Ringold Hatchery	Spring	Upper Columbia River	3c or 4
Carson Hatchery	Spring	Wind	3c or 4
Puget Sound			
Kendall Creek	Spring	Nooksack	2a
Lummi Bay	Fall	Nooksack	3b or 3c
Samish River	Fall	Samish	3b

Table A-1 continued. SSHAG (2003) categorizations of hatchery stocks of the nine Chinook salmon ESUs reviewed.

Stock	Run	Basin	SSHAG category[*]
Puget Sound (continued)			
Marblemount	Spring	Skagit	2c
Marblemount	Summer	Skagit	1a
Marblemount	Fall	Skagit	1a
Tulalip	Spring	Tulalip Bay	3b or 3c
Tulalip	Summer	Tulalip Bay	2b or 2c
Tulalip	Fall	Tulalip Bay	3b or 3c
North Fork Stillaguamish	Summer	Stillaguamish	1a
Wallace River	Summer	Snohomish	2a
Issaquah Hatchery	Fall	Lake Washington	2b
University of Washington Portage Bay	Fall	Lake Washington	3b or 4
Soos Creek	Fall	Green	2a
Keta Creek	Fall	Green	2a
Grover's Creek	Fall	East Kitsap	2b
Garrison Springs	Fall	Chambers Creek	2b
Voights Creek	Fall	Puyallup	2b or 2c
Diru Creek	Fall	Puyallup	2b or 2c
White River	Spring	Puyallup	2a
Clear/Kalama creeks	Fall	Nisqually	2a or 2b
Minter Creek	Fall	South Sound	2b
Tumwater Falls	Fall	Deschutes	2b
George Adams	Fall	Skokomish	2b or 3c
WSC Hood Canal	Fall	Skokomish	2b or 3c
Finch Creek	Fall	South Hood Canal	2b or 3c
Hamma Hamma	Fall	South Hood Canal	2b or 3c
Big Beef Creek	Fall	North Hood Canal	2b
Dungeness	Spring	Dungeness	1a
Elwha	Fall	Elwha	2a
Glenwood Springs	Fall	San Juan Islands	2b
Lower Columbia River			
Sea Resources	Fall	Chinook River	2b
Abernathy National Fish Hatchery	Fall	Abernathy Creek	2b
Grays River	Fall	Grays	2b
Elochoman	Fall	Elochoman	2b
Cowlitz	Fall	Cowlitz	2a
Cowlitz	Spring	Cowlitz	2a
Toutle	Spring	Cowlitz	2c
Kalama	Fall	Kalama	2a
Kalama	Spring	Kalama	2b
Lewis	Spring	Lewis	2a or 2b
Washougal	Fall	Washougal	2a or 2b
Carson	Spring	Wind	4
Little White Salmon Fish Hatchery	Fall	Little White	4

Table A-1 continued. SSHAG (2003) categorizations of hatchery stocks of the nine Chinook salmon ESUs reviewed.

Stock	Run	Basin	SSHAG category[*]
Spring Creek National Fish Hatchery	Fall	Spring Creek	2a
Klickitat	Fall	Klickitat	4
Willamette	Spring	Youngs Bay	4
Big Creek	Fall	Big Creek	3b
Rogue River (#52)	Fall	Youngs Bay	4
Klaskanine (#15)	Fall	Klaskanine	2b
Willamette	Spring	Klaskanine	4
Bonneville (#14)	Fall	Gorge	3a
Bonneville (#95)	Fall	Gorge	4
Hood River	Spring	Hood	4
Upper Willamette River			
North Fork Santiam (#21)	Spring	Santiam	2a and 2b
Willamette Hatchery (#22)	Spring	Middle Fork Willamette	2b or 2c
McKenzie (#24)	Spring	McKenzie	2a
South Fork Santiam (#23)	Spring	Santiam	2b
Clackamas (#19)	Spring	Clackamas	2b or 2c
California Coastal			
Mad River	Fall	Mad River	2q,b,c
Freshwater Creek	Fall	Humboldt Bay	1a
Yaeger Creek	Fall	Van Duzen	1a
Redwood Creek	Fall	Redwood Creek	1a
Hollow Tree Creek	Fall	Eel River	1a
Van Arsdale	Fall	Eel River	2a
Mattole	Fall	Mattole River	1a
Sacramento River winter run			
Livingston Stone National Fish Hatchery	Winter	Sacramento River	1a
California Central Valley spring run			
Feather River	Spring	Feather River	4 or 2b

[*] See the subsection, Artificial Propagation, in Section 1, Introduction, for an explanation of the categories.

Table A-2. Chinook salmon time-series data sources.

Data type	Data source
Snake River Fall-Run Chinook Salmon ESU	
Population	Snake River fall run
Years of data, length of series	1975–2001, 27 years
Abundance type	Dam count
Abundance, hatchery, harvest, age notes, reference	Used run reconstructions spreadsheet to update PATH data set. Yuen (2002), Marmorek et al. (1998).
Snake River Spring/Summer-Run Chinook Salmon ESU	
Population	Snake River spring-run total
Years of data, length of series	1979–2001, 23 years
Abundance type	Dam count
Abundance and hatchery reference	Beamesderfer et al. (1998); recent years from Yuen (2002).
Harvest reference	Yuen (2002)
Age notes, reference	Average from Beamesderfer et al. (1998).
Population	Snake River summer-run total
Years of data, length of series	1979–2001, 23 years
Abundance type	Dam count
Abundance and hatchery notes, reference	Beamesderfer et al. (1998); recent years from Yuen (2002)
Harvest reference	Yuen (2002)
Age notes, reference	Yearly data from Beamesderfer et al. (1998); recent years updated with an average.
Population	Alturas Lake Creek
Years of data, length of series	1957–2001, 45 years
Abundance type, notes, reference	Redd count. Elms-Cockrum (1998); Kiefer (2002) for years 1999–2001.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Aggregate salmon age structure from Beamesderfer et al. (1998).
Population	Bear Valley/Elk Creek
Years of data, length of series	1960–2001, 42 years
Abundance type, notes, reference	Expanded redd count. IDFG updated redd counts from Beamesderfer et al. (1998).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Hatchery reference	Beamesderfer et al. (1998)
Harvest reference	Yuen (2002)
Age notes, reference	Used Middle Fork Salmon River composite to fill in missing years. Beamesderfer et al. (1998)
Population	Big Creek summer run
Years of data, length of series	1957–2001, 45 years
Abundance type, notes, reference	Redd count. StreamNet trend no. 40145 (http://www.streamet.org) for data prior to 1997; Brown (2002) for data years 1998–2001.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Aggregate for Middle Fork age structure from Beamesderfer et al. (1998).
Population	Big Sheep Creek
Years of data, length of series	1957–2001, 39 years
Abundance type, notes, reference	Redd count. StreamNet trend no. 50121 (http://www.streamnet.org) for data prior to 1997; Keniry et al. (2002) for years 1997–2001.
Hatchery notes, reference	Holmes (2002)
Harvest notes, reference	Recent years from Yuen (2002), Beamesderfer et al. (1998).
Age reference	Beamesderfer et al. (1998)
Population	Camas Creek
Years of data, length of series	1972–2001, 29 years
Abundance type, notes, reference	Redd counts. Kiefer (2002)
Hatchery reference	Holmes (2002)
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Aggregate for Middle Fork age structure from Beamesderfer et al. (1998).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Catherine Creek (index area)
Years of data, length of series	1957–2001, 45 years
Abundance type, notes, reference	Redd count. StreamNet (http://www.streamnet.org) for data prior to 1996; Keniry et al. (2002) for 1997–2001.
Hatchery reference	Holmes (2002)
Harvest notes, reference	Beamesderfer et al. (1998); recent years from Yuen (2002).
Age notes, reference	Beamesderfer et al. (1998); used Grande Ronde River aggregate to fill in missing years.
Population	Chamberlain Creek
Years of data, length of series	1952–1997, 22 years
Abundance type, notes, reference	Redds per mile. StreamNet trend no. 41052 (http://www.streamnet.org).
Age notes, reference	Aggregate Salmon River age structure from Beamesderfer et al. (1998).
Population	Grande Ronde River, upper (index area)
Years of data, length of series	1960–2001, 42 years
Abundance type, notes, reference	Redd count. StreamNet (http://www.streamnet.org) for data prior to 1997; Keniry et al. (2002) for 1997–2001.
Hatchery reference	Holmes (2002)
Harvest reference	R. Carmichael[a]
Age notes, reference	Beamesderfer et al. (1998); used Grande Ronde River aggregate to fill in missing years.
Population	Herd Creek
Years of data, length of series	1958–1986, 28 years
Abundance type, notes, reference	Redds per mile. StreamNet trend no. 41018 (http://www.streamnet.org).
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes	Valley Creek age estimates (McClure et al. 2003).
Population	Imnaha River
Years of data, length of series	1953–2001, 49 years

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type	Expanded redd count
Abundance, hatchery, age reference	Beamesderfer et al. (1998)
Harvest reference	R. Carmichael[a]
Population	Johnson Creek
Years of data, length of series	1957–2001, 45 years
Abundance type	Expanded redd count
Abundance and hatchery reference	Beamesderfer et al. (1998)
Harvest notes, reference	Yuen (2002)
Age notes, reference	Beamesderfer et al. (1998); used South Fork Salmon River aggregate data to fill in missing years (McClure et al. 2003).
Population	Lake Creek summer run
Years of data, length of series	1952–2000, 49 years
Abundance type, notes, reference	Redds per mile. StreamNet trend no. 41059 (http://www.streamnet.org).
Hatchery notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Compact disk 1.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Used South Fork Salmon River aggregate data to fill in missing years (McClure et al. 2003).
Population	Lemhi River
Years of data, length of series	1957–2001, 45 years
Abundance type, notes, reference	Redd count. Elms-Cockrum (1998); Kiefer (2002) for 1999–2001.
Hatchery, harvest notes reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Kiefer (2002); used a weighted average to fill in missing years (McClure et al. 2003).
Population	Lick Creek (Imnaha River)
Years of data, length of series	1964–2001, 38 years

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type, notes, reference	Redd count. StreamNet trend no. 50123 (http://www.streamnet.org) for data prior to 1997; Keniry et al. (2002) for 1997–2001.
Hatchery, harvest notes, reference	Beamesderfer et al. (1998); recent years from Yuen (2002).
Age reference	Beamesderfer et al. (1998)
Population	Lookingglass Creek
Years of data, length of series	1957–2001, 44 years
Abundance type, reference	Redd count. StreamNet data (http://www.streamnet.org) prior to 1997; Keniry et al. (2002) for 1997–2001.
Hatchery reference	Holmes (2002)
Age notes, reference	Beamesderfer et al. (1998); used Grande Ronde River aggregate to fill in missing years.
Population	Loon Creek
Years of data, length of series	1957–2001, 43 years
Abundance type, reference	Redd count. Elms-Cockrum (1998); Kiefer (2002) for years 1999–2001.
Hatchery notes	No annual sampling, assumed natural returns.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age reference	Beamesderfer et al. (1998)
Population	Lostine River (index area)
Years of data, length of series	1964–2001, 38 years
Abundance type, reference	Redd count. Abundance database reference no. 52 from ODFW (1997); Keniry et al. (2002) for 1997–2001.
Hatchery reference	Holmes (2002)
Harvest notes, reference	Beamesderfer et al. (1998); recent years from Yuen (2002).
Age notes, reference	Beamesderfer et al. (1998); used Grande Ronde River aggregate to fill in missing years.
Population	Marsh Creek
Years of data, length of series	1957–2001, 45 years
Abundance type, reference	Total live count. Beamesderfer et al. (1998).
Hatchery reference	Beamesderfer et al. (1998)

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Harvest reference	Yuen (2002)
Age notes, reference	Kiefer (2002); used Middle Fork Salmon River composite to fill in missing years.
Population	Minam River
Years of data, length of series	1964–2001, 38 years
Abundance type, reference	Total live count. Beamesderfer et al. (1998).
Hatchery reference	Beamesderfer et al. (1998)
Harvest reference	Data available from Northwest Fisheries Science Center Salmonid Database, 2725 Montlake Blvd. E., Seattle, WA 98112.
Age notes, reference	Beamesderfer et al. (1998); used Grande Ronde River aggregate to fill in missing years.
Population	Pahsimeroi River
Years of data, length of series	1980–2001, 22 years
Abundance type, reference	Total live count. StreamNet trend no. 43002 (http://www.streamnet.org) for 1980–2000; Rogers (2002) for 2001.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes	Kiefer (2002); used a weighted average to fill in missing years (McClure et al. 2003).
Population	Poverty Flat
Years of data, length of series	1957–2001, 45 years
Abundance type, reference	Total live count. Beamesderfer et al. (1998).
Hatchery reference	Beamesderfer et al. (1998)
Harvest notes, reference	Yuen (2002)
Age notes, reference	Kiefer (2002); used South Fork Salmon River aggregate to fill in missing years.
Population	Rapid River (lower Salmon River)
Years of data, length of series	1972–2001, 30 years
Abundance type, reference	Redds per mile. StreamNet trend no. 43002 (http://www.streamnet.org) for 1972–2000; Rogers (2002) for year 2001.

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	East Fork Salmon River summer run
Years of data, length of series	1957–2001, 45 years
Abundance type, reference	Redds per mile. StreamNet trend no. 41016 (http://www.streamnet.org).
Hatchery notes	No annual sampling, assumed natural returns.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Used Poverty Flat summer run from Beamesderfer et al. (1998).
Population	South Fork Salmon River summer run
Years of data, length of series	1957–2001, 45 years
Abundance type, reference	Redd count. Elms-Cockrum (1998); Kiefer (2002) for years 1999–2001.
Hatchery notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Compact disk 1.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	C. Petrosky[b]
Population	North Fork Salmon River spring run
Years of data, length of series	1960–2000, 27 years
Abundance type, reference	Redd count. StreamNet (http://www.streamnet.org) for years 1996–2000.
Population	Upper Salmon River spring run
Years of data, length of series	1954–2001, 48 years
Abundance type, reference	Redd count. Elms-Cockrum (1998); Kiefer (2002) for years 1999–2001.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	C. Petrosky[b]

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Upper Salmon River summer run
Years of data, length of series	1957–1997, 40 years
Abundance type, reference	Redds per mile. StreamNet trend no. 41002 (http://www.streamnet.org)
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Used Poverty Flat age structure from Beamesderfer et al. (1998).
Population	Secesh River summer run
Years of data, length of series	1957–2001, 45 years
Abundance type, reference	Redd count. Elms-Cockrum (1998); Kiefer (2002) for years 1999–2001.
Hatchery notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Compact disk 1.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Kiefer (2002); used South Fork Salmon River aggregate to fill in missing years.
Population	Snake River spring run
Years of data, length of series	1979–2001, 23 years
Abundance type	Total live count
Abundance, hatchery, harvest reference	Yuen (2002)
Age reference	Beamesderfer et al. (1998)
Population	Snake River summer run
Years of data, length of series	1979–2002, 24 years
Abundance type, reference	Dam count. Pacific Salmon Commission CTC Report (2002).
Hatchery reference	Yuen (2002)
Harvest reference	Pacific Salmon Commission CTC Report (2002)
Age reference	Beamesderfer et al. (1998)

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Sulphur Creek
Years of data, length of series	1957–2001, 45 years
Abundance type, notes, reference	Total live count. Kiefer (2002).
Hatchery reference	Beamesderfer et al. (1998)
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	IDFG (Kiefer 2002); used Middle Fork Salmon River composite to fill in missing years.
Population	Tucannon River
Years of data, length of series	1979–2001, 23 years
Abundance type	Total live count
Abundance, hatchery reference	NMFS (2003)
Harvest reference	Yuen (2002)
Age notes, reference	1985–1999 average and 2000 estimate of spring-run Chinook salmon age composition from WDFW (Gallinat et al. 2001).
Population	Upper Valley Creek spring run
Years of data, length of series	1957–2001, 44 years
Abundance type, reference	Redd count. Elms-Cockrum (1998); Kiefer (2002) for years 1999–2001.
Hatchery notes	No annual sampling, assumed natural returns.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	IDFG (Kiefer 2002); used Salmon River aggregate to fill in missing years.
Population	Upper Valley Creek summer run
Years of data, length of series	1952–1997, 49 years
Abundance type, reference	Redds per mile. StreamNet trend no. 41009 (http://www.streamnet.org).
Population	Wallowa River
Years of data, length of series	1963–2001, 39 years

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type, notes, reference	Redd count. StreamNet trend no. 50119 (http://www.streamnet.org) for data prior to 1997; Keniry et al. (2002) for 1997–2001.
Hatchery reference	R. Carmichael[a]
Harvest notes, reference	Beamesderfer et al. (1998); recent years from Yuen (2002).
Age notes, reference	Used Grande Ronde age structure from Beamesderfer et al. (1998)
Population	Wenaha River (index area)
Years of data, length of series	1963–2001, 39 years
Abundance type, notes, reference	Redd count. StreamNet (http://www.streamnet.org) for data prior to 1997; Keniry et al. (2002) for 1997–2001.
Hatchery notes, reference	Used South Fork Wenaha; Holmes (2002)
Harvest notes, reference	Beamesderfer et al. (1998); recent years from Yuen (2002).
Age notes, reference	Used pooled Grande Ronde River age structure values from Beamesderfer et al. (1998).
Population	Yankee Fork River summer run
Years of data, length of series	1960–2001, 42 years
Abundance type, reference	Redd count. Elms-Cockrum (1998) for years 1994–1997; Brown (2002) for data years 1998–2001.
Hatchery notes	No annual sampling; assumed natural returns.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Used Poverty Flat age structure from Beamesderfer et al. (1998).
Population	West Fork Yankee Fork spring run
Years of data, length of series	1960–2001, 41 years
Abundance type, reference	Redd count. StreamNet (http://www.streamnet.org); Brown (2002) for data years 1998–2001.
Harvest notes, reference	Regional Analytical Advisory Committee (Northwest Power Planning Council) run reconstructions, Ecosystem Diagnosis Treatment Validation project. Data summary (compact disk). Formula used: Harvest multiplier = 1 – (1 – Columbia River harvest rate)/(tributary harvest rate).
Age notes, reference	Used aggregate Salmon River age structure from Beamesderfer et al. (1998).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Upper Columbia River Chinook Salmon ESU	
Population	Methow River
Years of data, length of series	1960–2001, 41 years
Abundance type, notes, reference	Estimated total count. Sum of expanded redd counts by area, extended series described in Cooney (2001); 1999–2001 data from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.
Hatchery notes, reference	Beamesderfer et al. (1998), Cooney (2001), assumed equivalent of 25% of the Winthrop NFH returns strayed into natural spawning areas; Yakama Indian Nation carcass sampling for recent years.
Harvest notes, reference	Beamesderfer et al. (1998), Yuen (2002).
Age notes, reference	Yearly. Beamesderfer et al. (1998); update data from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.
Population	Chewack River
Years of data, length of series	1960–2001, 40 years
Abundance type, notes, reference	Redd count. Cooney (2001); 1999–2001 data from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.
Hatchery notes, reference	Beamesderfer et al. (1998), Cooney (2001)
Harvest notes, reference	Beamesderfer et al. (1998), Yuen (2002)
Age notes, reference	Yearly. Used Methow River age data.
Population	Lost River/Early Winters Creek
Years of data, length of series	1958–2001, 42 years
Abundance type, notes, reference	Total live count. Cooney (2001); 1999–2001 data from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.
Hatchery notes, reference	Beamesderfer et al. (1998), Cooney (2001).
Harvest notes, reference	Beamesderfer et al. (1998), Yuen (2002).
Age notes, reference	Yearly. Used Methow River age data.
Population	Methow River (main stem)
Years of data, length of series	1958–2001, 43 years
Abundance type, notes, reference	Redd count. Cooney (2001); 1999–2001 data from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Hatchery notes, reference	Used Methow River estimates for hatchery fraction.
Harvest notes, reference	Beamesderfer et al. (1998), Yuen (2002).
Age notes, reference	Yearly. Beamesderfer et al. (1998); update data from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.
Population	Twisp River
Years of data, length of series	1958–2001, 42 years
Abundance type, notes, reference	Redd count. Cooney (2001); 1999–2001 from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.
Hatchery notes, reference	Cooney (2001)
Harvest notes, reference	Beamesderfer et al. (1998), Yuen (2002).
Age notes, reference	Yearly. Beamesderfer et al. (1998), update data from J. Hubble, Yakama Indian Nation, P.O. Box 151, Toppenish, WA 98948.
Population	Wenatchee River
Years of data, length of series	1960–2001, 42 years
Abundance type, notes, reference	Estimated total count. Sum of expanded redd counts by area, extended series described in Cooney (2001). Mosey and Murphy (2002).
Hatchery notes, reference	Cooney (2001) for prior to 1999; assumed 5% of Icicle Creek (Leavenworth National Fish Hatchery) returns strayed into upriver areas; 1999–2001 data based on annual WDFW carcass surveys (e.g., Mosey and Murphy 2002).
Harvest notes, reference	Beamesderfer et al. (1998), Yuen (2002)
Age notes, reference	Yearly. Beamesderfer et al. (1998); updates from WDFW annual sampling reports (e.g., Mosey and Murphy 2002).
Population	Little Wenatchee River
Years of data, length of series	1958–2001, 42 years
Abundance type, notes, reference	Redd count. Cooney (2001), Mosey and Murphy (2002).
Hatchery notes, reference	Data prior to 1999 (Cooney 2001). Data for 1999–2001 from WDFW annual carcass sampling (e.g., Mosey and Murphy 2002).
Harvest notes, reference	Applied aggregate Wenatchee River estimates.
Age notes, reference	Yearly. Applied aggregate Wenatchee River estimates.
Population	White River
Years of data, length of series	1958–2001, 42 years

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type, notes, reference	Redd count. Cooney (2001), Mosey and Murphy (2002).
Hatchery notes, reference	Data prior to 1999 (Cooney 2001). Data for 1999–2001 from WDFW annual carcass sampling (e.g., Mosey and Murphy 2002).
Age notes, reference	Yearly. Applied aggregate Wenatchee estimates.
Population	Nason Creek
Years of data, length of series	1958–1996, 44 years
Abundance type, notes, reference	Redd count. Cooney (2001), Mosey and Murphy (2002)
Hatchery notes, reference	Data prior to 1999 (Cooney 2001). Data for 1999–2001 from WDFW annual carcass sampling (e.g., Mosey and Murphy 2002).
Harvest notes, reference	Applied aggregate Wenatchee estimates.
Age notes, reference	Yearly. Applied aggregate Wenatchee estimates.
Population	Chiwawa River
Years of data, length of series	1958–2001, 44 years
Abundance type, notes, reference	Redd count. Cooney (2001), Mosey and Murphy (2002).
Hatchery notes, reference	Data prior to 1999 (Cooney 2001). Data for 1999–2001 from WDFW annual carcass sampling (e.g., Mosey and Murphy 2002).
Harvest notes, reference	Applied aggregate Wenatchee estimates.
Age notes, reference	Yearly. Applied aggregate Wenatchee estimates.
Population	Upper mainstem Wenatchee
Years of data, length of series	1959–2001, 40 years
Abundance type, notes, reference	Redd count. Cooney (2001), Mosey and Murphy (2002).
Hatchery notes, reference	Data prior to 1999 (Cooney 2001); 1999–2001, WDFW annual carcass sampling (e.g., Mosey and Murphy 2002).
Harvest notes, reference	Applied aggregate Wenatchee estimates.
Age notes, reference	Yearly. Applied aggregate Wenatchee estimates.
Population	Entiat River
Years of data, length of series	1960–1998, 42 years
Abundance type, notes, reference	Estimated total count. Cooney (2001), Carie (2002).
Hatchery notes, reference	Assumed equivalent of 5% of the rack returns at Entiat NFH strayed up into natural spawning areas each year. Cooney (2001), Carie (2002).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Harvest notes, reference	Cooney (2001), updated using (Yuen 2002).
Age notes, reference	Yearly. Beamesderfer et al. (1998); updated using data from USFWS (e.g., Carie 2002).
Puget Sound Chinook Salmon ESU	
Population	South Fork Nooksack River
Years of data	1984–2001
Abundance type, notes	Carcass/redd counts. Escapements are an expansion of carcass spawning surveys in the upper South Fork and in Huchinson and Skookum creeks prior to 1999 and redd counts × 2.5 from 1999 on. They are designated early spawners; counts stop on 1 October (fish counted after that date are thought to be out-of-basin strays).
Hatchery notes	Contribution rate of hatchery fish to natural spawning only estimated since 1999 (carcass surveys looking for marked fish). It is assumed that the number of hatchery fish on spawning grounds is correlated with number of hatchery fish returning rather than number of fish on spawning grounds. Therefore, the stray rate of hatchery to spawning grounds for years without data is estimated as the average of the 3 years observed, not to exceed 43% of the spawning fish.
Abundance, hatchery reference	Puget Sound Indian Tribes and WDFW (2001, 2003); Castle and Currence (2001); NMFS/Nooksack Comanagers meeting, Point No Point, WA, 29 July 2002; Sanford (2003a).
Harvest notes, reference	Fishing rates are calculated using the method used by the Pacific Salmon Commission (PSC). Coded-wire-tag (CWT) recoveries of indicator hatchery stocks (South Fork fingerlings 1974–1988 and North Fork fingerlings 1988–1998) were used in combination to give the longer time series of estimates. Estimates included both landed and incidental mortalities. PSC (1999, 2000).
Age notes, reference	Scale sampling; n = 213 fish sampled, 3 years (1993–2001, using years with sample sizes >40 fish). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep). Age database, WDFW (2001).
Population	Cedar River
Years of data	1965–2002

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type, notes, reference	Live counts. Escapement estimates are from live count surveys and expanded by area under the curve method. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Seattle, WA, 8 November 2002; Sanford (2003a).
Hatchery notes, reference	There is no estimate of the contribution rate of hatchery fish to natural spawning. Hatchery Chinook salmon are produced at the Issaquah Hatchery primarily for producing fish for harvest.
Harvest notes, reference	Fishing rates are calculated using the method used by the PSC. CWT recoveries of the South Puget Sound index indicator hatchery stock group (1971–1995) were used. Estimates included both landed and incidental mortalities. PSC (1999, 2000).
Age notes, reference	Scale sampling; n = 9 fish sampled in 1988. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.); age database (WDFW 2001).
Population	Dosewallips River
Years of data	1968–2002
Abundance type, notes, reference	Live/dead surveys and redd counts. Three years reported no escapement; the TRT is using one fish each for those years (the surveyors could easily have missed one fish, and it makes calculations easier). Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Point No Point, WA, 8 August 2002; Sanford (2003a).
Hatchery notes, reference	Probably few, if any, hatchery strays in the Dosewallips. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Point No Point, WA, 8 August 2002.
Harvest notes, reference	Fishing rates are calculated using the method used by the PSC. CWT recoveries of George Adams indicator hatchery stock (1972–1994) were used. Estimates included both landed and incidental mortalities. PSC (1999, 2000); D. Simmons.[c]
Age notes, reference	Used average age distribution from Green River Chinook salmon. Age distribution reconstructed for Dosewallips using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.).
Population	Dungeness River
Years of data	1986–2002

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type, notes, reference	Redd counts. Escapements for Dungeness are for spring/summer-run stock with spawning from August to mid-October. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Point No Point, WA, 8 August 2002.
Hatchery notes, reference	There are no estimates of contribution rate of hatchery fish to natural spawners.
Harvest notes, reference	There is assumed to be no harvest in mixed-maturity fishery. The mature fishery (fishing on mature fish or fish on their spawning migration) normally includes all freshwater or terminal fisheries. Terminal fisheries include sport, ceremonial, subsistence, and incidental (in coho fishery). Incidental catch averages 19 fish per year and sport: 34 fish gives a terminal fishing rate of .32, and a very slight randomization with negative trend was added. N. Sands.[d]
Age notes, reference	Scale sampling; n = 159 fish sampled from 1987 to 1998 (9 years with sample sizes >10 fish; all years with sample sizes <40 fish). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database (WDFW 2001).
Population	Elwha River
Years of data	1986–2002
Abundance type, notes, reference	Redd counts. Escapement to natural grounds equals total post-fishery escapement minus broodstock take and rack return, and includes prespawning mortality. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Point No Point, WA, 8 August 2002.
Hatchery notes	There is no estimate of the contribution rate of hatchery fish to natural spawning.
Hatchery reference	WDFW et al. (2001); NMFS and Comanagers meeting, Point No Point, WA, 8 August 2002.
Harvest notes, reference	Fishing rates are calculated using the method used by the PSC. CWT recoveries of Elwha indicator hatchery stock (1982–1994) were used. Estimates included both landed and incidental mortalities. PSC (1999, 2000); D. Simmons.[e]
Age notes, reference	Scale sampling; n = 2,322 fish sampled from 1989 to 1998 (9 years, all with large sample sizes). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Green River
Years of data	1968–2002
Abundance type, notes, reference	Redd counts. Escapements for this population do not include spawning in Newaukum Creek. Escapement estimates are based on redd counts in specified sections of the river and expanded by a factor to reflect the total spawning habitat of the river. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Seattle, WA, 8 November 2002.
Hatchery notes, reference	Hatchery contribution estimates from Soos, Icy, and Keta creeks hatcheries. Alexandersdottir (2001).
Harvest notes, reference	Fishing rates are calculated using the method used by the PSC. CWT recoveries of the South Puget Sound index indicator hatchery stock group (1971–1995) were used. Estimates included both landed and incidental mortalities. PSC (1999, 2000); D. Simmons.[c]
Age notes, reference	Scale sampling; n = 2,454 fish sampled from 1988 to 1998. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	Lower Sauk River
Years of data	1952–2002
Abundance type, reference	Redd counts. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003; B. Hayman.[f]
Hatchery notes, reference	Assume the hatchery releases from the Marblemount Hatchery do not influence the Sauk River populations. NMFS/Comanagers Meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003.
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of an aggregate of fall indicator hatchery stocks (Samish, Stillaguamish, Grovers, Green, Nisqually, and George Adams) 1971–1997 were used for ocean fisheries, and terminal run reconstruction was used for terminal fisheries. Estimates included both landed and incidental mortalities. J. Scott and D. Simmons[g] analysis for TRT after method of PSC (1999).
Age notes, reference	Scale sampling from the upper Skagit River; n = 1,332 fish sampled from 7 years between 1992 to 2000 (where sample sizes were >40 fish). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database, WDFW (2001).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Lower Skagit River
Years of data	1952–2002
Abundance type, reference	Redd counts, Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers Meetings, La Conner, WA, 9 August 2002 and 10 June–3 November; B. Hayman.[f]
Hatchery notes, reference	Marblemount Hatchery rack returns. Some sampling for hatchery contributions to spawning grounds 1998–2001. NMFS/Comanagers Meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003.
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of an aggregate of fall indicator hatchery stocks (Samish, Stillaguamish, Grovers, Green, Nisqually, and George Adams) were used for ocean fisheries, and terminal run reconstruction was used for terminal fisheries. Estimates included both landed and incidental mortalities. J. Scott and D. Simmons[g] analysis for TRT after method of PSC (1999).
Age notes, reference	Scale sampling; n = 392 fish sampled from 4 years between 1992 to 2001 (where sample sizes >40 fish). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	Nisqually River
Years of data	1968–2002
Abundance type, notes, reference	Carcass counts. Escapements are an expansion of spawning surveys in Prairie River/Creek. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers Meeting, Puyallup, WA, 21 November 2002; Sanford (2003b).
Hatchery notes, reference	No estimates of contribution of hatchery fish to natural spawning have been made in past, but these were started in 2002. Puget Sound Indian Tribes and WDFW (2001, 2003).
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of Kalama River fingerling indicator hatchery stock 1979−1995 were used. Estimates included both landed and incidental mortalities. D. Simmons estimates based on method of PSC (1999).[h]
Age notes, reference	Scale sampling from upper Skagit River; n = 1,313 fish sampled from 1992 and 1993. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	North Fork Nooksack River
Years of data	1984–2001
Abundance type, notes, reference	Carcass counts. Total Chinook salmon on the spawning grounds = expanded carcass counts on spawning grounds plus turnback hatchery fish. Puget Sound Indian Tribes and WDFW (2001, 2003); Castle and Currence (2001); NMFS/Nooksack Comanagers meeting, La Conner, WA 29 July 2002; Sanford (2003a).
Hatchery notes, reference	Contribution rate of cultured fish (hatchery and acclimation releases) to natural spawning started in 1988 with significant returns from the hatchery program. Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Nooksack Comanagers meeting, La Conner, WA, 29 July 2002.
Harvest notes, reference	Fishing rates are calculated using the PSC method. Coded-wire-tag recoveries of indicator hatchery stocks (South Fork Nooksack fingerling 1974–1988 and North Fork Nooksack fingerling 1988–1998) were used in combination to give the longer time series of estimates. Estimates included both landed and incidental mortalities. PSC (1999, 2000), Goodman 2002, D. Simmons.[c]
Age notes, reference	Scale sampling; n = 336 fish sampled from 4 years between 1992 to 2000 (where sample sizes >40 fish). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	Lake Washington tributaries
Years of data	1983–2002
Abundance type, notes, reference	Live counts. Escapement estimates are from live counts expanded for area under the curve. Escapement numbers are an index of part of Cottage Creek and all of Bear Creek that represents about 95% of the northern tributaries (not including Issaquah). Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Seattle, WA, 8 November 2002; Sanford (2003a).
Hatchery notes, reference	No estimate of contribution rate of hatchery fish to spawning. There are trapping data that indicate the presence of hatchery strays. NMFS/Comanagers meeting, Seattle, WA, 8 November 2002.
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of the South Puget Sound index indicator hatchery stock group (1971–1995) were used. Estimates included both landed and incidental mortalities. PSC (1999, 2000); D. Simmons.[c]

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Age notes, reference	Scale sampling; n = 75 fish sampled in 1988 (in 1995, only 7 fish were sampled and these were not used). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	North Fork Stillaguamish River
Years of data	1974–2002
Abundance type, notes, reference	Redd counts. Escapement estimates are from foot and boat surveys of the main stem and foot surveys of the tributaries of redd counts. Puget Sound Indian Tribes and WDFW (2001, 2003); Rawson and Kraemer (2001).
Hatchery notes, reference	Stillaguamish Tribal Harvey Creek Hatchery supplementation program does not have rack returns. Return to hatchery is actual broodstock take, which occurs in the North Fork. Hatchery supplementation program began in early 1980s. Returns started in 1986. Puget Sound Indian Tribes and WDFW (2001, 2003), Rawson and Kraemer (2001).
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of the Stillaguamish indicator hatchery stock are used when available; otherwise an aggregate of fall indicator hatchery stocks (Samish, Stillaguamish, Grovers, Green, Nisqually, and George Adams) was used for ocean fisheries, and terminal run reconstruction was used for terminal fisheries. Estimates included both landed and incidental mortalities. Fishing rate estimates derived from D. Simmons and J. Scott[i] after method of PSC (1999).
Age notes, reference	Otolith project; n = 2,772 fish sampled from 12 years between 1987 and 2001 (where sample sizes >40 fish). Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	Puyallup River
Years of data	1968–2002

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type, notes, reference	Redd and live/dead fish counts. Index counts of spawning from South Prairie Creek, which in the past were from a limited area and not a good index of the system. Surveys now are from the entire South Prairie Creek basin. These started in 1992 by float and foot surveys of redds and live/dead fish. However, estimates given here are based on index count only through 1998. Revisions are being made back to 1992 and should be available soon. Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Puyallup, WA, 21 November 2002; Sanford (2003a).
Hatchery notes, reference	There is no estimate of the contribution rate of hatchery fish to natural spawning. Puget Sound Tribes and WDFW (2001, 2003).
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of the south Puget Sound fingerling indicator hatchery stock group, 1971–1995, were used. Estimates included both landed and incidental mortalities. D. Simmons[c] estimates based on method of PSC (1999).
Age notes, reference	Scale sampling; n = 895 fish sampled from 8 years between 1992 and 2000. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database, WDFW (2001).
Population	Skokomish River
Years of data	1987–2002
Abundance type, notes, reference	Various. Escapements are from the co-managers. Estimates should be available from 1976 although there is concern about data prior to 1990 (T. Johnson[j]) (see http://www.nwifc.wa.gov). This population includes index survey sites in both the main river, including the North Fork, and several tributaries; mainly foot, sometimes float. Escapement estimates vary from year to year in survey type and expansion (from 1990 on, no expansion for unsurveyed areas—in other words, all spawning areas are surveyed). Quality of escapement data considered good (WDF, WDW, and WWTIT 1993). Puget Sound Indian Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Point No Point, WA, 8 August 2002; Sanford (2003a).
Hatchery notes, reference	Hatchery strays from the George Adams Hatchery, Hood Canal (Hoodsport Hatchery and Enetai Hatchery) are found on the spawning grounds, but there is no estimate of the contribution rate of hatchery fish to natural spawning. Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Point No Point, WA, 8 August 2002.

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Harvest notes, reference	Fishing rates are calculated using the method used by the PSC. CWT recoveries of the George Adams indicator hatchery stock group (1972–1994) were used. Estimates included both landed and incidental mortalities. PSC (1999, 2000), D. Simmons.[e]
Age notes, reference	Scale sampling; 1999–2001; sample size not given. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Puget Sound Indian Tribes and WDFW (2003).
Population	Skykomish River
Years of data	1965–2002
Abundance type, notes, reference	Aerial surveys, redd counts. Escapements for the Skykomish population were updated by the comanagers[k] for 1979–2001. The Skykomish population includes 10 survey sites in the Skykomish, Wallace, Bridal Veil, Sunset Falls, Pilchuck, and Sultan rivers. Escapement estimates are from aerial surveys of the main stem and foot surveys of the tributaries (redd counts). Escapement estimates for the total Snohomish system are available from 1965. Skykomish estimates for 1965–1978 are made by subtracting Skykomish population escapements from the total system escapements. Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Mill Creek, WA, 18 November 2002; Sanford (2003a).
Hatchery notes, reference	From 1997 to the present, contribution rate of hatchery fish to natural spawning is estimated by sampling spawning grounds for otolith-marked hatchery fish from Tulalip and Wallace hatcheries. Prior to 1997, the hatchery contribution is estimated from "run reconstruction" of hatchery returns (Rawson 2001). Puget Sound Tribes and WDFW (2001, 2003).
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of an aggregate of fall indicator hatchery stocks (Samish, Stillaguamish, Grovers, Green, Nisqually, and George Adams), 1971–1994, were used for ocean fisheries and terminal run reconstruction was used for terminal fisheries. Estimates included both landed and incidental mortalities. Analysis for TRT[l] after method of PSC (1999); Rawson (2001).
Age notes, reference	Scale or otolith sampling; n = 510 fish sampled from 5 years between 1989 and 1999, where sample sizes >40 fish. Age distribution was reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Rawson and Kraemer (2001); age database WDFW (2001).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Snoqualmie River
Years of data	1965–2002
Abundance type, notes	Hatchery straying estimates and otolith sampling. Escapements for the Snoqualmie population were updated from the comanagers for 1979–2000.[k] The Snoqualmie population includes six survey sites in the Snoqualmie River and tributaries of the Snoqualmie River. Escapement for the SASSI Snohomish fall-run stock are available from 1965[m] and, on average, the Snoqualmie portion represented 62% of the Snohomish fall-run escapement. Thus, estimates of Snoqualmie escapement prior to 1979 are estimated as 62% of the Snohomish fall-run escapement. Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Mill Creek, WA, 18 November 2002; Sanford (2003a).
Hatchery notes, reference	From 1997 to the present, contribution rate of hatchery fish to natural spawning is estimated by sampling spawning grounds for otolith-marked hatchery fish from Tulalip and Wallace hatcheries. Prior to 1997, the hatchery contribution is estimated from "run reconstruction" of hatchery returns (Rawson 2001); Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Mill Creek, WA, 18 November 2002.
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of an aggregate of fall indicator hatchery stocks (Samish, Stillaguamish, Grovers, Green, Nisqually, and George Adams), 1971–1994, were used for ocean fisheries, and terminal run reconstruction was used for terminal fisheries. Estimates included both landed and incidental mortalities. Analysis for TRT[l] after method of PSC (1999); Rawson (2001).
Age notes, reference	Scale sampling and scale/otolith sampling; n = 493 fish sampled from 6 years between 1989 and 1999, where samples were >40 fish. Age distribution was reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Otolith sampling on spawning grounds (Rawson and Kraemer 2001). Age database WDFW (2001).
Population	South Fork Stillaguamish River
Years of data	1974–2002
Abundance type, notes, reference	Redd counts. Escapement estimates are from foot and boat surveys of the main stem and from foot surveys of redd counts of the tributaries. Puget Sound Tribes and WDFW (2001, 2003), Rawson and Kraemer (2001).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Hatchery notes, reference	It is assumed that no hatchery fish stray to the spawning grounds of the South Fork Stillaguamish River. Puget Sound Tribes and WDFW (2001, 2003); C. Kraemer and K. Rawson.[n]
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of the Stillaguamish indicator hatchery stock, 1971–1994, were used when available, otherwise an aggregate of fall indicator hatchery stocks (Samish, Stillaguamish, Grovers, Green, Nisqually, and George Adams) was used for ocean fisheries, and terminal run reconstruction was used for terminal fisheries. Estimates included both landed and incidental mortalities. Fishing rate estimates derived after method of PSC (1999).
Age notes, reference	Otolith project; n = 1,516 fish sampled from 9 years between 1987 and 2001, where sample sizes >40 fish. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	Suiattle River
Years of data	1952–2002
Abundance type, notes, reference	Peak live/dead counts/redd counts. Before 1994 escapement estimation method was peak live/dead counts for partial spawning grounds to get fish per mile, then expand by 8.5 for total spawning grounds. From 1994 on, redd counts are used to cover entire spawning area. Puget Sound Tribes and WDFW (2001, 2003); R. Hayman;[f] J. Scott.[l]
Hatchery notes, reference	No hatchery in basin; broodstock take from the Suiattle, 1974–1988, to the Marblemount Hatchery (and fry released at hatchery). Assume no hatchery contribution on spawning grounds. NMFS/Comanagers meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003.
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of Skagit spring-run yearling indicator hatchery stock, 1981–1996, were used. Estimates included both landed and incidental mortalities. PSC (1999); D. Simmons, NMFS provided worksheet of estimates.[o]
Age notes, reference	Scale sampling; n = 536 fish sampled from 8 years between 1986 and 2001, where sample sizes >40 fish. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Upper Cascade River
Years of data	1984–2002
Abundance type, notes, reference	Live/dead counts expanded for area/redd counts. Before 1992, escapement estimation method was peak live/dead counts with expansion for uncovered ground. From 1992 on, redd counts have been used to cover entire spawning area. Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003; R. Hayman.[p]
Hatchery notes, reference	The hatchery is at the mouth of the Cascade River, but releases fish into the Suiattle River. Negligible hatchery contribution assumed on spawning grounds. NMFS/Comanagers meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003.[p]
Harvest notes, reference	Fishing rates are calculated using the PSC method. CWT recoveries of Skagit spring-run yearling indicator hatchery stock, 1981–1996, were used. Estimates included both landed and incidental mortalities.
Age notes, reference	Scale sampling; n = 227 fish sampled from 3 years between 1992 and 2001. Age distribution was reconstructed for other years using an average cohort distribution weighted by the annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	Upper Sauk River
Years of data	1952–2002
Abundance type, notes, reference	Peak live/dead counts/redd counts. Before 1994, escapement estimation method was peak live/dead counts with expansion for uncovered ground. For 1994 and after, used redd counts and cover entire spawning area. Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003.[p]
Hatchery notes, reference	No hatchery in Upper Sauk. Assume the hatchery releases from the Marblemount Hatchery do not influence the Sauk River populations. NMFS/Comanagers meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003.
Harvest notes, reference	Fishing rates are calculated using the method used by the PSC. CWT recoveries of Skagit spring-run yearling indicator hatchery stock were used. Estimates included both landed and incidental mortalities. PSC (1999), D. Simmons.[o]
Age notes, reference	Scale sampling; n = 275 fish sampled from 5 years 1986–2001, where sample sizes >40 fish. Age distribution reconstructed for other years using an average cohort distribution weighted by the annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Upper Skagit River
Years of data	1952–2002
Abundance type, notes, reference	Redd counts. Escapements are based on redd counts and are considered a good measure of relative abundance from year to year. Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003; R. Hayman.[p]
Hatchery notes, reference	Marblemount Hatchery rack returns. The Marblemount Hatchery is situated at the mouth of the Cascade River, such that returns pass through the lower and upper Skagit River. Some samples for hatchery contribution, 1995–2001. NMFS/Comanagers Meetings, La Conner, WA, 9 August 2002 and 10–11 June 2003.
Harvest notes, reference	Fishing rates calculated using the PSC method. CWT recoveries of an aggregate of fall indicator hatchery stocks (Samish, Stillaguamish, Grovers, Green, Nisqually, and George Adams) were used for ocean fisheries, and terminal run reconstruction was used for terminal fisheries. Estimates included both landed and incidental mortalities. Analysis for TRT[g] after method of PSC (1999).
Age notes, reference	Scale sampling; n = 1,691 fish sampled from 8 years between 1992 and 2001, where sample sizes > 40 fish. Age distribution was reconstructed for other years using an average cohort distribution weighted by the annual abundance of contributing years (Sands 2002, in prep.). Age database WDFW (2001).
Population	White River
Years of data	1970–2002
Abundance type, notes, reference	Trap counts. Chinook counts from 1970 to present are from Buckley trap for the entire season (year round). Counts do not include spawners below the dam, which may be about 25% of total spawning (21 November 2002). Spawning ground surveys are difficult due to it being a glacial system. Starting 2003, rejecting (not passing upstream) tagged or marked fish (except acclimated fish). Earlier years may include fall-run hatchery fish. WDF et al. (1993); C. Phinney;[q] Puget Sound Tribes and WDFW (2001, 2003); NMFS/Comanagers meeting, Puyallup, WA, 21 November 2002.
Hatchery notes, reference	There is a program to put acclimated hatchery fish on the spawning grounds; we will begin to estimate this. No estimates of hatchery contribution prior to 2001. Assume no contribution of hatchery fish to natural spawning. Puget Sound Tribes and WDFW (2001, 2003).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Harvest notes, reference	Fishing rates are calculated using the method used by the PSC. CWT recoveries of the White River yearling indicator hatchery stock, 1974–1994, were used. Estimates include both landed and incidental mortalities. Estimates based on method of PSC (1999).[h]
Age notes, reference	Scale sampling; n = 1,327 fish sampled from 1993 to 1998. Age distribution was reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW (2001).
Lower Columbia River Chinook Salmon ESU	
Population	Big White Salmon River fall run
Years of data, length of series	1967–2001, 38 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Data for 1980–2000 from Rawding (2001a). Data for 1964–1979 from Norman (1982). Rawding (2001a); Sanford (2003b)
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).
Harvest reference stock	Spring Creek
Harvest notes, reference	Estimated exploitation rate on hatchery stocks applied to natural stocks. PSC (2002).
Age notes, reference	Age distribution for 1982–1990 based on an average of 1991–2000. Rawding (2001a).
Population	Clackamas River fall run
Years of data, length of series	1967–2001, 35 years
Abundance type, reference	Peak count. ODFW (1998a).
Hatchery notes, reference	No hatchery data
Harvest reference	No harvest data available
Age notes, reference	Generic fall-run age structure. Myers et al. (1998).
Population	Coweeman River fall run
Years of data, length of series	1964–2001, 38 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates extrapolated from peak count data and marking rate. Years 1964–1979 spawning data from are from Kreitman (1981); 1980–2000 data from Rawding (2001a).
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Harvest reference stock	Coweeman
Harvest notes, reference	Harvest data based on Pacific Fisheries Management Council (PFMC) models provided by D. Simmons.[r]
Age notes, reference	Age distribution for 1980–1990 and estimate based on average for 1991–2000. Rawding (2001a).
Population	East Fork Lewis River fall run
Years of data, length of series	1980–2001, 22 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Rawding (2001a); Sanford (2003b).
Harvest reference stock, reference	Lewis River wild. Rawding (2001a).
Harvest notes, reference	Adult equivalent exploitation rate for Lewis River from D. Simmons.[r] Rawding (2001a).
Age notes, reference	Age distribution for 1980–1983 based on an average for 1984–2000. Rawding (2001a).
Population	Lewis River (brights) fall run
Years of data, length of series	1964–2001, 38 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Spawning data for 1964–1979 from Kreitman (1981); 1980–2000 from Rawding (2001a).
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).
Harvest reference stock	Lewis River wild
Harvest notes, reference	Adult equivalent exploitation rate for Lewis River from D. Simmons.
Age notes, reference	Age distribution for 1980–1990 and estimate based on average from 1991 to 2000. Rawding (2001a).
Population	Middle Columbia Gorge tributaries fall run
Years of data, length of series	1964–2001, 38 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Data for 1980–2000 are from Rawding (2001a); 1964–1979 data are from Norman (1982); Sanford (2003b).
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Harvest reference	No harvest data available.
Age notes, reference	Age distribution for 1980–1990 and estimate based on average from 1991 to 2000. Age distribution data missing for 1993. Rawding (2001a).
Population	Mill Creek fall run
Years of data, length of series	1980–2000, 21 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Rawding (2001a).
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).
Harvest reference	Coweeman River. PSC (2002).
Age notes, reference	Age distribution for 1982–1990 based on an average of years 1991–2000. Rawding (2001a)
Population	Sandy River fall run
Years of data, length of series	1988–2001, 14 years
Abundance type, notes, reference	Total from redd count. The estimate of spawning abundance is based on a one-time peak count of live fish on the Sandy River. The index area is 10 miles from the mouth of Gordon Creek to Lewis and Clark ramp. The number of fish is then multiplied by 2.5 to get the estimate (StreamNet, trend no. 50070, http://www.streamet.org). Fish counts are provided in StreamNet (trend no. 57517). Surveys were not conducted prior to 1988. ODFW (1998a).
Hatchery notes, reference	McClure et al. (2003) reference ODFW (1998a) for proportion of natural spawners.
Harvest notes, reference	No harvest data available.
Age notes, reference	Generic fall-run age structure. Myers et al. (1998).
Population	Sandy River late fall run
Years of data, length of series	1984–2001, 18 years
Abundance type, reference	Total from redd count (ODFW 1990a, 2002); Murtagh et al. (1997).
Hatchery notes, reference	McClure et al. (2003), reference ODFW (1998a) for proportion of natural spawners.
Harvest notes, reference	No harvest data available.
Age notes, reference	Generic fall-run age structure. Myers et al. (1998).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Population	Washougal River fall run
Years of data, length of series	1964–2001, 38 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Spawning data for 1964–1979 are from Kreitman (1981); 1980–2000 are from Rawding (2001a); Sanford (2003b).
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).
Harvest reference stock	Cowlitz Hatchery
Harvest notes, reference	Adult equivalent exploitation rate for Lewis River from D. Simmons.[r]
Age notes, reference	Age distribution for 1982–1990 based on an average for 1991–2000. Rawding (2001a)
Population	Kalama River spring run
Years of data, length of series	1980–2001, 22 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Rawding (2001a); Sanford (2003b).
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).
Harvest reference	No harvest data available.
Age reference	No age data available.
Population	Lewis River spring run
Years of data, length of series	1980–2001, 22 years
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Rawding (2001a); Sanford (2003b)
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).
Harvest reference	No harvest data available.
Age reference	No age data available.
Population	Upper Cowlitz River spring run
Years of data, length of series	1980–2001, 22 years

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Abundance type, notes, reference	Peak count. Abundance data are for adults and jacks. Estimates of spawner abundance are extrapolations made using peak count data and marking rate. Rawding (2001a); Sanford (2003b).
Hatchery notes, reference	Hatchery data are part of the escapement data from Rawding (2001a).
Harvest reference	No harvest data available.
Age reference	Myers et al. (1998).
Population	Youngs Bay fall run
Years of data, length of series	1950–2001, 52 years
Abundance type, reference	Fish per mile. Fulop (2002, 2003).
Population	Big Creek fall run
Years of data, length of series	1970–2001, 32 years
Abundance type, reference	Fish per mile. Fulop (2003).
Population	Clatskanie River fall run
Years of data, length of series	1970–2001, 32 years
Abundance type, reference	Fish per mile. Fulop (2003).
Upper Willamette River Chinook Salmon ESU	
Population	Clackamas River spring run
Years of data, length of series	1958–2002, 45 years
Abundance type, notes, reference	Dam/weir count. Data are dam counts for North Fork Dam; adults only, production is mixed. Cramer (2002b).
Hatchery notes, reference	Counts of hatchery vs. wild fish are for 2001–2002; the number of marked hatchery fish is estimated to be 50% (Cramer 2002a).
Harvest reference	No harvest data available.
Age notes, reference	Age distribution is taken from the upper Willamette Chinook salmon totals, not specific to Clackamas River spring-run Chinook. McClure et al. (2003).
Population	McKenzie River spring run
Years of data, length of series	1970–2001, 32 years
Abundance type, notes, reference	Dam/weir count. Data come from dam counts at Leaburg Dam. Spawning also occurs below the dam. Kostow (2002).

Table A-2 continued. Chinook salmon time-series data sources.

Data type	Data source
Hatchery notes, reference	Hatchery fish have only been 100% marked in recent years. The hatchery marks are not 100% detectable at the dam because a portion of the hatchery fish is double index marked to evaluate the fishery impact to wild fish. Double index marked means that the hatchery fish has a coded-wire tag but it is not externally marked (that is, no fin clip). Therefore, the fish "looks wild" both to the fisherman (who must release the fish) and in the raw dam count. The McKenzie fish managers therefore do several expansions to deal with these issues. Kostow (2002).
Harvest notes	No harvest data available.
Age notes, reference	Age distribution is taken from the Upper Willamette Chinook salmon ESU totals, not specific to McKenzie River spring-run Chinook salmon. McClure et al. (2003).
Population	Sandy River spring run
Years of data, length of series	1977–2001, 25 years
Abundance type, notes, reference	Dam/weir count. Abundance estimates only. Cramer (2002a).
Hatchery reference	No hatchery data.
Harvest reference	No harvest data available.
Age reference	No age data available.
Years of data, length of series	1946–2001, 56 years
Abundance type, notes, reference	Dam/weir count. Data are for adults and jacks. Two additional references are Foster (2000, 2002). Howell (1986), Bennett (1986), Bennett and Foster (1990, 1994, 1995), Foster (1998).
Population	Willamette Falls spring run
Years of data, length of series	1946–2001, 56 years
Abundance type, notes, reference	Dam/weir count. Data are for adults and jacks. ODFW (1998b), Foster (1998, 2000).

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[a] R. Carmichael, ODFW, La Grande, OR. Pers. commun., January 2003.

[b] C. Petrosky, IDFG, Fish Division, Boise, ID. Pers. commun., November 2002.

[c] D. Simmons, NMFS, Lacey, WA. Pers. commun., 3 July 2003.

[d] N. Sands, Northwest Fisheries Science Center, Seattle, WA. Pers. commun., 7 January 2002.

[e] D. Simmons, NMFS, Lacey, WA. Pers. commun., 7 January 2002.

[f] R. Hayman, Skagit Coop. BRT/Comanagers meeting to review draft ESU status report, NWFSC, Seattle, WA. Pers. commun. 28 March 2003.

[g] J. Scott, WDFW, and D. Simmons, NMFS, Lacey, WA. Pers. commun., 12 March 2001.

[h] D. Simmons, NMFS, Lacey, WA. Pers. commun., 31 July 2001.

[i] D. Simmons, NMFS, and J. Scott, WDFW, Lacey, WA. Pers. commun., 12 March 2002.

[j] T. Johnson, WDFW, Olympia, WA. Pers. commun., 27 March 2003.

[k] C. Kraemer, WDFW, Olympia, WA, and K. Rawson, Tulalip Tribal Nation, Tulalip, WA. Pers. commun., 19 November 2002.

[l] J. Scott, WDFW, and D. Simmons, NMFS, Lacey, WA. Pers. commun., 7 February 2002.

[m] J. Scott, WDFW, Olympia, WA. Pers. commun. January 2002.

[n] C. Kraemer, WDFW, Olympia, WA, and K. Rawson, Tulalip Tribal Nation, Tulalip, WA. Pers. commun., 9 January 2002.

[o] D. Simmons, NMFS, Lacey, WA. Pers. commun., 12 June 2003.

[p] R. Hayman, Skagit River System Cooperative, La Conner, WA. Pers. commun., January 2002.

[q] C. Phinney, Puyallup Indian Fisheries, Tacoma, WA. Pers. commun., 25 January 2001.

[r] D. Simmons, NMFS, Lacey, WA. Pers. commun., 9 January 2002.

Table A-3. Lower Columbia River hatchery releases.

Watershed	Years	Hatchery	Stock	Release site	Total
Lower Columbia River Fall-Run Chinook Salmon (Washington)					
Chinook River	1990–1994	Sea Resources	Chinook River	Chinook River	2,598,400
	1990	Sea Resources	Washougal	Chinook River	629,500
	1997–2000	Sea Resources	Chinook River	Chinook River	820,627
	1993	Lower Columbia	Kalama Falls	Deep River	49,400
Grays River	1990–1994	Grays River	Grays River	Grays River	2,767,900
	1991, 1993	Grays River	Kalama Falls	Grays River	1,332,380
	1992	Grays River	Spring Creek	Grays River	1,107,000
	1995–1997	Grays River	Kalama	Grays River	764,550
	1996, 1997	Grays River	Washougal	Grays River	1,745,500
Elochoman River	1990–1994	Elochoman	Elochoman	Elochoman River	17,809,719
	1991	Elochoman	Kalama Falls	Elochoman River	1,046,700
	1995	Beaver Creek	Abernathy	Beaver Creek	377,252
	1997	Beaver Creek	Big Creek	Beaver Creek	1,096,198
	1996–1999	Beaver Creek	Elochoman	Elochoman River	2,081,670
	1995	Beaver Creek	Kalama	Beaver Creek	760,039
	1995–2001	Elochoman	Elochoman	Elochoman River	15,280,038
	1999	Elochoman	Grays River	Elochoman River	174,500
	1997–1998	Elochoman	Washougal	Elochoman River	1,633,200
Lower Columbia River	1996–1998	Cathlamet FFA	Washougal	Columbia River	1,132,500
Cowlitz River	1990–1994	Cowlitz	Cowlitz	Cowlitz River	28,757,600
	1995–2001	Cowlitz	Cowlitz	Cowlitz River	42,322,920
Toutle River	1990–1993	Toutle	Kalama Falls	Green River	5,718,000
	1991–1993	Toutle	Toutle	Green River	2,941,000
	1994	Toutle	Tule	Green River	2,044,500
	1990–1993	Toutle	Washougal	Green River	2,693,400
	2000	North Toutle	Elochoman	Green River	618,266
	1996	North Toutle	Kalama	Green River	1,588,937
	1996–2001	North Toutle	Toutle	Green River	10,584,543
	1996	North Toutle	Washougal	Green River	633,414
Kalama River	1991–1994	Lower Kalama	Kalama	Kalama River	10,701,203
	1990–1994	Kalama Falls	Kalama Falls	Kalama River	17,600,800
	1996–2001	Fallert Creek	Kalama	Fallert Creek	13,998,602
	1995–2001	Kalama Falls	Kalama	Kalama River	20,198,653
Washougal River	1994	Washougal	Kalama Falls	Washougal	2,443,100
	1992	Washougal	Spring Creek	Washougal	1,409,300
	1991–1994	Washougal	Washougal	Washougal	27,002,103
	2000	Washougal	Elochoman	Washougal	1,312,680
	1995–2001	Washougal	Washougal	Washougal	32,878,694
Spring Creek	1992	Ringold	Little White Salmon	Spring Creek	82,511

Table A-3 continued. Lower Columbia River hatchery releases.

Watershed	Years	Hatchery	Stock	Release site	Total
Lower Columbia River Fall-Run Chinook Salmon (Oregon)					
	1991–1995	Astoria H.S.	Big Creek	Youngs Bay	15,500
	1991–1994	CEDC	Rogue River	Youngs Bay	394,382
	1991, 1992	STEP	Big Creek	Youngs Bay	13,758
	1992, 1993	STEP	Klaskanine	Youngs Bay	15,700
	1996–1998	STEP	Big Creek	Youngs Bay	63,050
	1997, 1998	STEP	Unknown	Youngs Bay	16,500
	1995–2002	Youngs Bay	Rogue River	Youngs Bay	4,248,147
	1996–1998	Youngs Bay	URB	Youngs Bay	828,884
Lower Columbia River	1991	STEP	Unknown	Lower Columbia	25,000
	1996, 1997	Tongue Point	Rogue River	Tongue Point	54,274
	1996, 1997	Tongue Point	URB	Tongue Point	299,715
	1995–1997	Blind Slough	Rogue River	Blind Slough	54,793
Skipanon River	1992–1993	STEP	Klaskanine	Skipanon	3,550
	1996–1999	STEP	Big Creek	Skipanon	15,193
Plympton Creek	1991	Big Creek	Big Creek	Plympton Creek	50,278
Big Creek	1991–1994	Big Creek	Big Creek	Big Creek	34,675,446
	1991–1994	Big Creek	Rogue River	Big Creek	2,798,710
	1993	Big Creek	Kalama Falls	Big Creek	886,471
	1995–2002	Big Creek	Big Creek	Big Creek	40,633,091
	1995–1996	Big Creek	Rogue River	Big Creek	1,530,550
Klaskanine River	1995	CEDC	Rogue River	Klaskanine	15,758
	1996–1999	Klaskanine	Rogue River	Klaskanine	3,694,245
Wahkeena Pond	1991–1993	Bonneville	URB	Columbia River	1,183,764
Johnson Creek	1994, 1995	Step	Tanner Creek	Johnson Creek	99,008
Tanner Creek	1991	Bonneville	Big Creek	Tanner Creek	2,580,763
	1991–1994	Bonneville	Tanner Creek	Tanner Creek	32,862,338
	1991	Bonneville	WA Tule	Tanner Creek	1,534,122
	1991–1994	Bonneville	URB	Tanner Creek	26,877,822
	1993	Bonneville	Kalama Falls	Tanner Creek	1,505,421
	1995–1996	Bonneville	Tanner Creek	Tanner Creek	15,369,642
	1995–1996	Bonneville	WA Tule	Tanner Creek	10,922,745
	1995–2002	Bonneville	URB	Tanner Creek	43,729,497
	2000–2001	Bonneville	WA URB	Tanner Creek	328,426
Lower Columbia River Spring-Run Chinook Salmon (Washington)					
Deep River	1999–2001	Deep River	Cowlitz	Deep Creek	255,657
Abernathy Creek	1991–1996	Abernathy NFH	Abernathy Creek	Abernathy Creek	6,853,504
	1997–1999	Abernathy NFH	Abernathy Creek	Abernathy Creek	1,223,647
Cowlitz River	1990–1994	Cowlitz	Cowlitz	Cowlitz River	9,016,451
	1992–1994	Friends of Cowlitz	Cowlitz	Cowlitz River	115,800
	1995–2001	Cowlitz	Cowlitz	Cowlitz River	8,870,002
	1995, 1997	Cowlitz	Cowlitz	Tilton River	3,074 adults
	1996, 1999	Friends of Cowlitz	Cowlitz	Cowlitz River	53,800

Table A-3 continued. Lower Columbia River hatchery releases.

Watershed	Years	Hatchery	Stock	Release site	Total
Toutle River	1991, 1993	Toutle	Cowlitz	Green River	641,382
	1995	North Toutle	Toutle	Green River	1,412,100
	1995	North Toutle	Washougal	Green River	1,086,100
	1995–2001	North Toutle	Cowlitz	Green River	766,740
Lewis River	1990–1993	Speelyai	Lewis	Lewis River	1,229,262
	1994	Lewis River	Kalama	North Fork Lewis River	975,700
	1991, 1992	Lewis River	Lewis	Lewis River	1,885,900
	1990–1994	Lewis River	North Fork Lewis	North Fork Lewis River	1,801,800
	1996	Fish First NP	Lewis	Lewis River	55,872
	1997–2000	Fish First NP	Lewis	Lewis River	570,857
	1996, 1998	Lewis River	Lewis	Lewis River	2,074,841
	2001	Lewis River	Lewis	Lewis River	34 adults
	1995–2001	Lewis River	Lewis	Lewis River	4,692,781
	2001	Speelyai	Lewis	Lewis River	566,373
Kalama River	1990–1994	Lower Kalama	Kalama	Hatchery Creek	2,455,252
	1995–2001	Fallert Creek	Kalama	Fallert Creek	2,129,550
	1998, 2000	Fallert Creek	Lewis	Fallert Creek	615,463
	1999	Gobar Pond	Kalama	Gobar Creek	87,500
	1997, 2001	Kalama Falls	Kalama	Gobar Creek	332,281
Spring Creek	1993	Ringold	Carson	Spring Creek	68,900
	1993	Ringold	Kalama	Spring Creek	462,700
	1990	Ringold	Klickitat	Spring Creek	40,264
	1994	Ringold	Little White Salmon	Spring Creek	336,268
	1993–1994	Ringold	Ringold	Spring Creek	596,274
	1992–1994	Ringold	Wind River	Spring Creek	2,250,000
Wind River	1991–1996	Carson NFH	Carson	Wind River	13,350,658
	1997–2001	Carson NFH	Carson	Wind River	7,096,346
Little White Salmon River	1991–1994	Little White Salmon NFH	Spring Creek	Little White Salmon River	2,757,539
	1992	Willard NFH	Carson	Little White Salmon River	869,952
	1991–1994	Little White Salmon NFH	Carson	Little White Salmon River	4,780,148
	1997	Little White Salmon NFH	Carson	Little White Salmon River	2,835,741
	1998–2001	Little White Salmon NFH	Little White Salmon	Little White Salmon River	4,272,833
	1998–2001	Little White Salmon NFH	URB-Mixed	Little White Salmon River	8,057,188
Drano Lake		Abernathy NFH	Spring Creek	Drano Lake	40,756
Spring Creek	1991	Spring Creek NFH	URB-Bonn Dam	Spring Creek	14,348,604
	1991	Spring Creek NFH	Clackamas	Spring Creek	3,292,304
	1992–1996	Spring Creek NFH	Spring Creek	Spring Creek	89,083,822

Table A-3 continued. Lower Columbia River hatchery releases.

Watershed	Years	Hatchery	Stock	Release site	Total
	1997–2001	Spring Creek NFH	Spring Creek	Spring Creek	70,435,986
Big White Salmon River	1991–1996	Big White Salmon NFH	Carson	Big White Salmon River	3,581,536
	1997–1999	Big White Salmon NFH	Carson	Big White Salmon River	2,795,464
	2001	Big White Salmon NFH	Methow	Big White Salmon River	1,238,764
	1997	Spring Creek NFH	Carson	Big White Salmon River	543,270
Deep River	1999–2001	Deep River	Cowlitz	Deep River	255,657
Abernathy Creek	1991–1996	Abernathy NFH	Abernathy Creek	Abernathy Creek	6,853,504
	1997–1999	Abernathy NFH	Abernathy Creek	Abernathy Creek	1,223,647
Cowlitz River	1990–1994	Cowlitz	Cowlitz	Cowlitz River	9,016,451
	1992–1994	Friends of Cowlitz	Cowlitz	Cowlitz River	115,800
	1995–2001	Cowlitz	Cowlitz	Cowlitz River	8,870,002
	1995, 1997	Cowlitz	Cowlitz	Tilton River	3,074 adults
	1996, 1999	Friends of Cowlitz	Cowlitz	Cowlitz River	53,800
Toutle River	1991, 1993	Toutle	Cowlitz	Green River	641,382
	1995	North Toutle	Toutle	Green River	1,412,100
	1995	North Toutle	Washougal	Green River	1,086,100
	1995– 2001	North Toutle	Cowlitz	Green River	766,740
Lewis River	1990–1993	Speelyai	Lewis	Lewis River	1,229,262
	1994	Lewis River	Kalama	North Fork Lewis River	975,700
	1991, 1992	Lewis River	Lewis	Lewis River	1,885,900
	1990–1994	Lewis River	North Fork Lewis	North Fork Lewis River	1,801,800
	1996	Fish First NP	Lewis	Lewis River	55,872
	1997–2000	Fish First NP	Lewis	Lewis River	570,857
	1996, 1998	Lewis River	Lewis	Lewis River	2,074,841
	2001	Lewis River	Lewis	Lewis River	34 Adults
	1995–2001	Lewis River	Lewis	Lewis River	4,692,781
	2001	Speelyai	Lewis	Lewis River	566,373
Kalama River	1990–1994	Lower Kalama	Kalama	Hatchery Creek	2,455,252
	1995–2001	Fallert Creek	Kalama	Fallert Creek	2,129,550
	1998, 2000	Fallert Creek	Lewis	Fallert Creek	615,463
	1999	Gobar Pond	Kalama	Gobar Creek	87,500
	1997, 2001	Kalama Falls	Kalama	Gobar Creek	332,281
Spring Creek	1993	Ringold	Carson	Spring Creek	68,900
	1993	Ringold	Kalama	Spring Creek	462,700
	1990	Ringold	Klickitat	Spring Creek	40,264
	1994	Ringold	Little White Salmon	Spring Creek	336,268
	1993–1994	Ringold	Ringold	Spring Creek	596,274
	1992–1994	Ringold	Wind River	Spring Creek	2,250,000

Table A-3 continued. Lower Columbia River hatchery releases.

Watershed	Years	Hatchery	Stock	Release site	Total
Wind River	1991–1996	Carson NFH	Carson	Wind River	13,350,658
	1997–2001	Carson NFH	Carson	Wind River	7,096,346
Little White Salmon River	1991–1994	Little White Salmon NFH	Spring Creek	Little White Salmon River	2,757,539
	1992	Willard NFH	Carson	Little White Salmon River	869,952
	1991–1994	Little White Salmon NFH	Carson	Little White Salmon River	4,780,148
	1997	Little White Salmon NFH	Carson	Little White Salmon River	2,835,741
	1998–2001	Little White Salmon NFH	Little White Salmon	Little White Salmon River	4,272,833
	1998–2001	Little White Salmon NFH	URB-Mixed	Little White Salmon River	8,057,188
Drano Lake		Abernathy NFH	Spring Creek	Drano Lake	40,756
Spring Creek	1991	Spring Creek NFH	URB-Bonneville Dam	Spring Creek	14,348,604
	1991	Spring Creek NFH	Clackamas	Spring Creek	3,292,304
	1992–1996	Spring Creek NFH	Spring Creek	Spring Creek	89,083,822
	1997–2001	Spring Creek NFH	Spring Creek	Spring Creek	70,435,986
Big White Salmon River	1991–1996	Big White Salmon NFH	Carson	Big White Salmon River	3,581,536
	1997–1999	Big White Salmon NFH	Carson	Big White Salmon River	2,795,464
	2001	Big White Salmon NFH	Methow	Big White Salmon River	1,238,764
	1997	Spring Creek NFH	Carson	Big White Salmon River	543,270
Lower Columbia River Spring-Run Chinook Salmon (Oregon)					
Youngs Bay	1991–1992	CEDC	Clackamas	Youngs Bay	242,534
	1994	CEDC	North Santiam	Youngs Bay	301,361
	1992	CEDC	Willamette	Youngs Bay	301,786
	1996	Youngs Bay	Clackamas	Youngs Bay	97,945
	1995–1999	Youngs Bay	Willamette	Youngs Bay	3,114,060
	1996	Youngs Bay	South Santiam	Youngs Bay	276,493
Lower Columbia River	1996	Blind Slough	South Santiam	Blind Slough	199,389
	1995–2002	Blind Slough	Willamette	Blind Slough	1,457,655
	1996	Tongue Point	South Santiam	Tongue Point	242,319
	1997–2000	Tongue Point	Willamette	Tongue Point	1,029,850

Table A-3 continued. Lower Columbia River hatchery releases.

Watershed	Years	Hatchery	Stock	Release site	Total
Klaskanine River	1991	CEDC	Clackamas	South Fork Klaskanine	119,627
	1994	CEDC	North Santiam	South Fork Klaskanine	109,974
	1992, 1997	CEDC	Willamette	South Fork Klaskanine	238,316
	1996	CEDC	South Santiam	South Fork Klaskanine	76,618
Multnomah Channel	1997–1998	STEP	McKenzie	Little Willamette	123,134
Sandy River	1991–1994	Clackamas	Clackamas	Sandy River	1,316,973
	1991–1993	Clackamas	Clackamas	Salmon River	594,656
	1995–2002	Clackamas	Clackamas	Sandy River	3,539,458
Hood River	1991–1992	Bonneville	Lookingglass	Hood River	288,727
	1993–1995	Bonneville	Deschutes	Hood River	245,209
	1996–2001	Various (3)	Deschutes	Hood River	677,652
	2000–2002	Parkdale	Wild origin	Hood River	101,883
	2000	Parkdale	Hood River	Hood River	4,126
Lower Columbia River Upriver Bright Chinook Salmon (Washington) Note: Upriver bright Chinook salmon are not in the Lower Columbia River Chinook salmon ESU.					
Little White Salmon River	1991–1993	Little White Salmon NFH	URB-Eggbank	Little White Salmon River	8,758,842
	1994–1996	Little White Salmon NFH	Carson	Little White Salmon River	8,453,502
	1994–1996	Little White Salmon NFH	Carson	Little White Salmon River	1,225 Adults
Spring Creek	1994	Ringold	URB-Bonneville Dam	Spring Creek	4,217,491

Appendix B: Steelhead

Table B-1. Distribution of *O. mykiss* trout by category in the Columbia Basin steelhead ESUs. Only major barriers are noted; numerous small barriers, both natural and artificial, also exist. Many other natural barriers are present but have *O. clarki* trout, rather than *O. mykiss* trout, above them. *O. mykiss* trout distribution in areas of sympatry with steelhead may be restricted in some areas if native *O. clarki* trout are also in the basin. The generalized listing of basins and subbasins does not imply that these constitute single trout populations or that trout distribution is continuous throughout the areas listed. Detailed trout distribution is usually unknown and actual demographically independent trout populations have not been described. All current trout distributions are decreased from historical distributions. In particular, many mainstem and lower basin tributaries are no longer used but probably were historically. Many current trout populations are only in upper basins and are highly fragmented (from Kostow 2003).

ESU	Category 1 trout populations (sympatric)	Category 2 trout populations (major natural barriers)	Category 3 trout populations (major artificial barriers)
Willamette River	Pudding/Molalla Lower Santiam Calapooia Tualatin (Gales Creek)	All populations upstream of Calapooia McKenzie Middle Fork Willamette	North Fork Santiam (Big Cliff/Detroit Dams) South Fork Santiam (Green Peter Dam)
Lower Columbia River	Historical use of lower basins by trout may have been greater Wind Clackamas: Callowash Other areas * Hood: West Fork Middle Fork Sandy* Upper Cowlitz Upper Kalama Upper Lewis Upper Washougal	Clackamas: Roaring River North Fork South Fork Memaloose* Sandy: Little Sandy Salmon* Some of the Columbia Gorge small tributaries	Cowlitz (Mayfield Dam) Lewis (Merwin Dam) Sandy (Bull Run Dams)
Middle Columbia River	Historically all areas where steelhead are/were present. Trout distributions currently more restricted. Fifteenmile Eightmile Deschutes Klickitat Umatilla Upper Umatilla	All natural barriers upstream of Klickitat and Deschutes basins Deschutes: White River Upper Deschutes (Big Falls) Upper North Fork Crooked River John Day: Upper South Fork John Day	Trout distributions currently more restricted than historically Little White Salmon (Conduit Dam) Deschutes (Pelton/Round Butte dams) Metolius Squaw Creek

Table B-1 continued. Distribution of *O. mykiss* trout by category in the Columbia Basin steelhead ESUs.

ESU	Category 1 trout populations (sympatric)	Category 2 trout populations (major natural barriers)	Category 3 trout populations (major artificial barriers)
	John Day		Crooked River
	Upper tributaries		
	Walla Walla		Umatilla (Irrigation dams)
	Upper tributaries		Willow Creek
	Yakima		Butter Creek
	Upper Yakima		McKay Creek
	Naches		
	Some other small tributaries		
Snake River			
	Potentially all areas that are/were used by steelhead.	Palouse River Malad River	Trout distributions currently more restricted than historically
	Tucannon	Several Hells Canyon tributaries	North Fork Clearwater (Dworshak Dam)
	Asotin		
	Grande Ronde Imnaha	Upper Malheur basin “recent” disconnect from lower Malheur Lakes basin	Mainstem Snake (Hells Canyon Dam) Powder
	Salmon found in about 43% of streams		Burnt Malheur
	Clearwater		Owhyee
	Selway		Weiser
	Other areas*		Payette
			Boise
			Burneau
			Salmon Falls Creek
			Several small tributaries
Upper Columbia River			
	Potentially all areas that are/were used by steelhead	Upper Entiat Upper Kootenay	Trout distributions currently more restricted than historically
	Wenatchee	Okanogan:	Okanogan Basin:
	Lower Entiat	Enlow Falls*	Conconully Dam/Enlow Dam*
	Methow	Methow:	
	Okanogan	Chewuch*	Chief Joseph Dam
		Lost	Lower Spokane to Post Falls
			Sanpoil
			Several small tributaries
			Lower Pend Oreille to Z Canyon
			Columbia headwaters in Canada

*Expected presence of *O. mykiss* trout, but not confirmed by reliable sources.

Distribution, Abundance, and Stocking in Five California Steelhead ESUs

Overview

Table B-2 summarizes available information on the distribution, abundance, and stocking of *O. mykiss* above recent barriers (case 3) within the five listed steelhead ESUs in California. Populations above longstanding natural barriers (case 2) and below barriers (case 1) are not listed. Historically, coastal *O. mykiss* were broadly distributed in coastal watersheds and within the Central Valley (Behnke 1992, McEwan and Jackson 1996). Hatchery-produced *O. mykiss* have been stocked for over 100 years (Behnke 1992) into streams and lakes throughout California by numerous state and federal agencies, private groups, and individuals. Given their broad historical range and widespread stocking over the last century, *O. mykiss* probably occur above all major recent barriers in California. However, little specific information is available on their distribution and abundance above these barriers, and stocking records are incomplete and not centralized. Because of these limitations, this table is necessarily incomplete and is intended to provide information at the level of the ESU.

Methods and Scope

Data were obtained from several sources. Barrier data were derived primarily from the California Department of Water Resources (DWR 1993) and the National Inventory of Dams (NID) compiled by the U.S. Army Corps of Engineers. Data for a few dams were missing from these databases and were obtained from other sources. These databases list over 1,400 unique dams on rivers and streams in California. Of these, fewer than 200 were classified as major barriers. A major barrier was arbitrarily defined as one that blocks or restricts access to greater than or equal to 100 sqaure miles of a watershed. Keystone barriers are the lowermost complete barrier to upstream migration in a watershed. For brevity, major barriers upstream of keystone barriers are not shown for the Central Valley ESU if there is no associated data on *O. mykiss.* A few minor barriers were included if information was available.

Stream lengths were derived from the National Hydrography Dataset (NHD) produced by the U.S. Geological Survey and U.S. Environmental Protection Agency. Total stream length for a watershed (or ESU) is the sum for all streams within the watershed (or ESU), not just streams or watersheds that are listed. Above barrier totals are the sum for all streams above the barrier (watershed) or above listed keystone barriers (ESU). The above barrier totals include sections of streams that may be above longstanding natural barriers and exclude streams above smaller keystone barriers that are not listed in the table.

Data on the distribution, abundance, and stocking of *O. mykiss* were obtained from the literature and from interviews with regional fish biologists with the CDFG, NMFS, and other agencies and academic institutions. Data on *O. mykiss* refer to fish that occur above the associated barrier but below the next upstream barrier, if it exists. Fish densities were converted from number per mile, but were not rounded to reflect true precision of estimate.

Table B-2. Distribution, abundance, and stocking of *O. mykiss* above major recent barriers (case 3 situations) within five steelhead ESUs in California, listed by ESU and watershed. A major barrier blocks or restricts access to greater thanor equal to 100 square miles of a watershed. Names of keystone (lowermost complete) barriers are shown in bold; partial or seasonal barriers are in italics. SH = steelhead, RT = rainbow trout (usually means resident), ? = unknown. Blanks indicate no data.

ESU	**Stream length**		***O. mykiss* above barrier**		
Basin Subbasin dam name /year built	**Total km**	**Above barrier km (%)**	**Distribution and abundance**	**Hatchery stocking notes**	**Source[a]**
Northern California steelhead ESU					
Mad River	1,188				
Mad River: Robert W. Matthews Dam, 1962		282 (24)	Present above barrier. Low abundance (gets warm in summer).	Stocking is ongoing, 18,000/year, using stock from various hatcheries.	3
Eel River	8,654		No data		
Eel River					
Van Arsdale Dam, 1907		1,106 (13)	Steelhead, rainbow trout present		
Scott Dam, 1921		963 (11)	Steelhead present		15, 4
South Fork Eel River					
Benbow Dam, 1932		949 (11)	Steelhead present		
ESU Total	15,496	1,245 (8)			
Central California Coast steelhead ESU					
Russian River	3,129				
Russian River					
Russian R. No 1, 1963		2,878 (92)	No data		
Healdsburg Rec, 1953		2,591 (83)	No data		
Dry Creek, Warm Springs Dam, 1982		271 (9)	Present in all tributaries.	Stocked ≈1984–1987 by private hatchery (Warm Springs), Russian River steelhead from Warm Springs Hatchery released above Warm Springs Dam.	5
East Fork Russian River Coyote Valley, 1959		269 (9)	Present	Stocked	
Lagunitas Creek	202				
Seeger, 1961		100 (50)	Present in headwaters of Halleck Creek, probably in western portion of Nicasio Creek.		5
Peters, 1954		61 (30)	Present	Ongoing stocking from Silverado Fisheries Base.	5
Alameda Creek	1,658		No data		
Alameda Creek					
Rubber Dam 1		1,578 (95)	Present	Stocked	
Rubber Dam 3, 1990		1,578 (95)	No data		
Calaveras Creek Calaveras, 1925		283 (17)	No data		
Arroyo Valle Del Valle, 1968		413 (25)	No data	Stocked	
Coyote Creek	757		No data		
Coyote					
Standish, 1994		747 (99)	No data		
Coyote Creek					
Coyote Percol, 1934		532 (70)	No data		

Table B-2 continued. Distribution, abundance, and stocking of *O. mykiss* above major recent barriers (case 3 situations) within five steelhead ESUs in California, listed by ESU and watershed. A major barrier blocks or restricts access to greater thanor equal to 100 square miles of a watershed. Names of keystone (lowermost complete) barriers are shown in bold; partial or seasonal barriers are in italics. SH = steelhead, RT = rainbow trout (usually means resident), ? = unknown. Blanks indicate no data.

ESU	**Stream length**		***O. mykiss* above barrier**		
Basin **Subbasin** **dam name /year built**	**Total km**	**Above barrier km (%)**	**Distribution and abundance**	**Hatchery stocking notes**	**Source[a]**
Coyote River					
Leroy Anderson, 1950		487 (64)	No data		
Coyote Creek					
Coyote, 1936		278 (37)	No data		
ESU total	11,447	3,026 (26)			
South-Central California Coast steelhead ESU					
Salinas River	9,966				
San Antonio River San Antonio, 1965		1,102 (11)	Present in reservoir, unknown if in stream.	Stocking ongoing from Silverado Fisheries Base	1, 6
Nacimiento River Nacimiento, 1957		761 (8)	Present; density is 330–390 per km.	Stocking ongoing from Silverado Fisheries Base	6, 7
Salinas River Salinas, 1942		293 (3)	Present	Stocking ongoing from Silverado Fisheries Base. Hatchery stock released at Lake Margarita marina.	1, 6
Carmel River	656				
San Clemente, 1921		337 (51)	Steelhead present		1, 6
Los Padres, 1949		128 (20)	Steelhead, rainbow trout present.	No hatchery stocking. Trap and truck of steelhead around Los Padres Dam for 20 years.	1, 6
Big Sur Coastal	711		No data		
Estero Bay Coastal	1,521		No data		
Old Creek Whale Rock, 1960	44	42 (95)	Present	Stocking from Whale Rock Hatchery; 55,000 total 1992–2002; broodfish taken from Whale Rock Reservoir.	26
Arroyo Grande Creek Lopez, 1969	282	143 (51)	Present	Stocking ongoing from Silverado Fisheries Base	1
ESU Total	19,213	2,469 (13)			
Southern California steelhead ESU					
Santa Maria River	5,775				
Cuyama River Twitchell, 1958		4,088 (71)	Present in all tributaries	Stocked 10–15 years ago (≈1987–1992)	2
Santa Ynez River	2,619		No data		
Santa Ynez River Bradbury, 1953		1,517 (58)	Present in all tributaries	Stocking ongoing from Fillmore Hatchery into Lake Cachuma.	2, 8, 9
Gibraltar, 1920		721 (28)	Present in all tributaries	Stocking ongoing from Fillmore Hatchery. Not open to fishing?	2, 9
Juncal, 1930		49 (2)	Present in all tributaries. A lot of rainbow trout, up to 26".	No stocking in last 30 years.	2, 9, 25

Table B-2 continued. Distribution, abundance, and stocking of *O. mykiss* above major recent barriers (case 3 situations) within five steelhead ESUs in California, listed by ESU and watershed. A major barrier blocks or restricts access to greater thanor equal to 100 square miles of a watershed. Names of keystone (lowermost complete) barriers are shown in bold; partial or seasonal barriers are in italics. SH = steelhead, RT = rainbow trout (usually means resident), ? = unknown. Blanks indicate no data.

ESU	**Stream length**		***O. mykiss* above barrier**		
Basin **Subbasin** **dam name /year built**	**Total km**	**Above barrier km (%)**	**Distribution and abundance**	**Hatchery stocking notes**	**Source[a]**
Ventura River	644				
Coyote Creek Casitas, 1959		131 (20)	Present where water present, note seasonal streams.	Stocking ongoing from Fillmore Hatchery; 32,000 pounds in 2002.	2
Matilija Creek Robles Diversion, 1958		224 (35)	Present		
Matilija, 1949		157 (24)	Present	Stocked 5–6 years ago (≈1996–1997) from Fillmore Hatchery.	2, 10
Santa Clara River	3,851				
Santa Clara River *Vern Freeman Diversion,* 1991		3,830 (99)	Present		2, 16
Piru Creek Santa Felicia, 1955		1,192 (31)	Present in all tributaries; 2,371–2,940 per km; 107–143 (>8") per km; 0 (>12") per km	Stocking ongoing from Fillmore Hatchery, Hot Creek strain, into Lake Piru and Frenchman's Flat.	2
Pyramid, 1973		825 (21)	Present in all tributaries	Stocking ongoing from Fillmore Hatchery.	2
Castaic Creek Castaic, 1973		378 (10)	Present in reservoir and where water present, note seasonal streams.	Stocking ongoing into Castaic Lake and Castaic Lagoon (below dam).	2
Malibu Creek	269				
Rindge		264 (98)	No data		
Subtotal	15,490	7,463 (48)			
Los Angeles River	1,220				
Los Angeles River Sepulveda[b,] 1941		215 (18)	No data		2
Tujunga Wash Hansen, 1940		408 (33	Present ≈5 miles or where water present. Few fish.	Stocking ongoing from Fillmore Hatchery.	2
San Gabriel River	1,270		No data		
San Gabriel River Whittier Narrows,[b] 1957		1,192 (94)	Present in reservoir, but probably not far upstream.	Stocking ongoing from Fillmore Hatchery.	2
Santa Fe, 1949		692 (54)	Present in reservoir, but probably not far upstream.	Stocking ongoing from Fillmore Hatchery.	2
Morris, 1935		626 (49)	Present in reservoir.	No, washdown from above	2
San Gabriel No 1, 1938		577 (45)	Present in all tributaries where there is water, East Fork usually perennial. Density is 1,550–2,706 per km; 129–198 (>8") per km; 0 (>12") per km.	Stocking ongoing from Fillmore Hatchery. In West Fork below Cogswell, North Fork, and East Fork of San Gabriel River.	2, 19
Cogswell, 1935		121 (10)	Present		2
Santa Ana River	4,620				
Santa Ana River Prado,[b] 1941		3,158 (68)	Present		

Table B-2 continued. Distribution, abundance, and stocking of *O. mykiss* above major recent barriers (case 3 situations) within five steelhead ESUs in California, listed by ESU and watershed. A major barrier blocks or restricts access to greater thanor equal to 100 square miles of a watershed. Names of keystone (lowermost complete) barriers are shown in bold; partial or seasonal barriers are in italics. SH = steelhead, RT = rainbow trout (usually means resident), ? = unknown. Blanks indicate no data.

ESU	**Stream length**		***O. mykiss* above barrier**		
Basin **Subbasin** **dam name /year built**	**Total km**	**Above barrier km (%)**	**Distribution and abundance**	**Hatchery stocking notes**	**Source[a]**
Bear Creek			Present at density 96–732 per km; 14–15 (>8") per km; 0 (>12") per km.		18, 19
Upper Santa Ana River			Present at density 29–43 per km; 0–14 (>8") per km; 0 (>12") per km.		19
San Antonio Creek San Antonio, 1956		73 (2)			
Santa Ana River Seven Oaks, under construction		594 (13)			
Cajalco Creek Mathews, 1938		95 (2)			
Santa Margarita River	1,604				
Temecula Creek Vail, 1949		655 (41)	Present	Private stocking	2
San Luis Rey River Henshaw, 1923	1,184	447 (38)		Stocking is ongoing from Mojave Hatchery into West Fork of San Luis Rey River.	2
San Dieguito River Lake Hodges, 1918	693	618 (89)	None	Not stocked. Bass and catfish in Lake Hodges	2
San Diego River El Capitan, 1934	1,013	558 (55)	Present in reservoir: few fish.	No hatchery stocking.	2
Sweetwater River Sweetwater Main, 1888	440	367 (83)		Stocking is ongoing	2
Otay River Savage, 1919	410	333 (81)			
Tijuana River[d]	734				
Cottonwood Creek Barrett, 1922		506			
Morena, 1912		210			
ESU total	31,964	15,414 (48)			
Central Valley steelhead ESU					
Sacramento River	52,206				
Red Bluff Diversion, 1964		14,261 (27)	SH		
Anderson Cottonwood, 1917		9,224 (18)	SH		
Keswick, 1950		9,189 (18)	Present	Steelhead from below dam are transported above dam.	
Shasta, 1945		9,106 (17)	Present	See below.	
Upper Sacramento	568				

Table B-2 continued. Distribution, abundance, and stocking of *O. mykiss* above major recent barriers (case 3 situations) within five steelhead ESUs in California, listed by ESU and watershed. A major barrier blocks or restricts access to greater thanor equal to 100 square miles of a watershed. Names of keystone (lowermost complete) barriers are shown in bold; partial or seasonal barriers are in italics. SH = steelhead, RT = rainbow trout (usually means resident), ? = unknown. Blanks indicate no data.

ESU	**Stream length**		***O. mykiss* above barrier**		
Basin **Subbasin** **dam name /year built**	**Total km**	**Above barrier km (%)**	**Distribution and abundance**	**Hatchery stocking notes**	**Source[a]**
Shasta, 1945			Present population is 4,163–5,468 (fish kill); 420–1,670 (>4")	Stocking from Mt. Shasta; Sacramento and McCloud River stocks. Average was 15,000 from 1994 to 1998; stocked at least since 1930, average of ≈80,000/year; maximum of 4M RT planted in 1936.	14
Box Canyon, 1969		127 (22)	Yes		
McCloud River	949				
Shasta, 1945			Present density is 2,361 (>5")		3
McCloud, 1965		474 (50)	Present in all tributaries; 1,864 in Squaw Valley Creek.	Stocking is ongoing below McCloud Falls, ≈7 years ago (≈1994) above falls; 15,000/year into McCloud reservoir	3
Pit River	6,979				
Shasta, 1945			Present		
Fall River			Present density is 1,021–2,541 (>6")		20
Pit No 1 Diversion, 1922					
Pit No 1 Forebay, 1947			Present		
Hat Creek			Present density is 159–2,539 (>8"); 32–1,335 (>12")		17
Burney					
Hat Cr. No 2 Diversion, 1942					
Clear Creek	462	377 (82)	Present in Whiskey and Clear Creeks. Density is 1,553–3,107 per km.	Stocking is ongoing from private hatchery.	
Whiskeytown, 1963					
Stony Creek	2,707				
Stony Creek					
Stony Creek Gravel, 1906					
Black Butte, 1963		2,427 (90)	Presently migrate through Stony and Grindstone creeks, too warm in summer.		12
Stony Gorge, 1928			Present in all tributaries.	Stocking is ongoing.	12
Little Stony Creek			Present seasonally in Trout and Stony creeks.	Stocked	12
East Park, 1910					
Cache Creek	3,362				
Cache Creek		3,362 (100)			
Cache Creek Settling Basin					
Putah Creek	1,200				
Putah Creek		1,087 (91)			
Putah Diversion, 1957					
Monticello		1,010 (84)			
Feather River 1957	9,094				

Table B-2 continued. Distribution, abundance, and stocking of *O. mykiss* above major recent barriers (case 3 situations) within five steelhead ESUs in California, listed by ESU and watershed. A major barrier blocks or restricts access to greater thanor equal to 100 square miles of a watershed. Names of keystone (lowermost complete) barriers are shown in bold; partial or seasonal barriers are in italics. SH = steelhead, RT = rainbow trout (usually means resident), ? = unknown. Blanks indicate no data.

ESU	**Stream length**		***O. mykiss* above barrier**		
Basin **Subbasin** **dam name /year built**	**Total km**	**Above barrier km (%)**	**Distribution and abundance**	**Hatchery stocking notes**	**Source**[a]
Feather River					
Thermalito Diversion, 1967					
Feather River Hatchery, 1964					
Oroville, 1968		7,702 (85)			
North Fork Feather River			Present	Stocked at North Fork below Lake Almanor; rotenoned at least 3 times.	11
Poe, 1959					
Lake Almanor, 1927			Present	Stocking is ongoing; Eagle Lake strain 80,000/year during last 15 years.	11
Bucks Creek			Present	Stocking is ongoing at 15,000–30,000/year.	11
Bucks Storage, 1928					
Middle Fork Feather River			Present	Stocked above wild trout section of Middle Fork.	11
Nelson Creek			Present density is 155–621 (>6").		13
Yuba River	3,510				
Yuba River		2,923 (83)			
Englebright1941					
Bear River	1,180				
Camp Far West1963		719 (61)			
American River	4,480				
American River		4,351 (97)			
Nimbus, 1955					
Rubicon River			Yes		
Cosumnes River	2,426	1,322 (54)			22
Granlees,[c] 1921					
Mokelumne River	1,877				
Mokelumne River		1,858 (99)			
Woodbridge Diversion, 1910					
Camanche, 1963		1,800 (96)			
Calaveras River	1,740	1,277 (73)			
New Hogan, 1963					
Stanislaus River	3,269				
Stanislaus River		3,074 (94)			
Goodwin, 1912					
Tuolumne River	3,362				
Tuolumne River		3,170 (94)			
La Grange, 1894					
Clavey River			Present density is 1,317 per km.		21
Merced River	2,574				
Merced River		2,129 (83)			
Crocker Diversion, 1910					
Subtotal	73,558	43,587 (59)			

Table B-2 continued. Distribution, abundance, and stocking of *O. mykiss* above major recent barriers (case 3 situations) within five steelhead ESUs in California, listed by ESU and watershed. A major barrier blocks or restricts access to greater thanor equal to 100 square miles of a watershed. Names of keystone (lowermost complete) barriers are shown in bold; partial or seasonal barriers are in italics. SH = steelhead, RT = rainbow trout (usually means resident), ? = unknown. Blanks indicate no data.

ESU	**Stream length**		***O. mykiss* above barrier**		
Basin **Subbasin** **dam name /year built**	**Total km**	**Above barrier km (%)**	**Distribution and abundance**	**Hatchery stocking notes**	**Source[a]**
San Joaquin River	3,238				
San Joaquin River					
Mendota Diversion, 1917					
Friant, 1942		2,876 (89)			
Upper Middle Fork San Joaquin			Present density is 273–2,985 per km; 119–695 (>6") per km.	Stocked; RT probably not native	23
Kings River	3,570				
Kings River		2,819 (79)			
Pine Flat 1954					
Kern River	4,467				
Kern River		3,952 (88)			
Diversion No. 11906					
Isabella, 1953		3,547 (79)	Present density is 43–620.	Stocked; Kern River Planting Base; 50,500 lb/year above Isabella.	24
ESU total	103,504	53,234 (51)			

[a] Sources:

[1] Jennifer Nelson, CDFG, Yountville, CA. Pers. commun., 12 November 2002.

[2] Dwayne Maxwell, CDFG, Los Alamitos, CA. Pers. commun., 15 January 2003.

[3] CDFG Region 1 biologists (Mike Dean, Mike Berry, Randy Benthin, Bob McAllister, Bill Jong, Phil Bairrington), Redding, CA. Pers. commun., 2 December 2002.

[4] Scott Downie, CDFG, Fortuna, CA. Pers. commun., 25 January 2003.

[5] Bill Cox, CDFG, Yountville, CA. Pers. commun., 12 December 2002.

[6] Mike Hill, CDFG, Monterey, CA. Pers. commun., 1 June 2003.

[7] Joel Casagrande, Watershed Institute, CSUMB, Seaside, CA. Pers. commun., 2 March 2003.

[8] Mauricio Cardenas, CDFG, Ojai, CA. Pers. commun., 16 November 2002.

[9] Scott Engblom, Cachuma Operation and Maintenance Board, Santa Barbara, CA. Pers. commun., 2 April 2003.

[10] Rick Rogers, NMFS, Arcata, CA. Pers. commun., 3 February 2003.

[11] Ken Kundargi, CDFG, Chico, CA. Pers. commun., 18 November 2002.

[12] Emil Ekman, USFS, Mendocino National Forest, Willows, CA. Pers. commun., 12 December 2002.

[13] CDFG (1979).

[14] CDFG (2000b.

[15] Jones (2001).

[16] McEwan and Jackson (1996).

[17] Deinstadt and Berry (1999).

[18] Deinstadt et al. (1993).

[19] Deinstadt et al. (1990).

[20] Rode and Weidlein (1986).

[21] Robertson (1985).

[22] Yoshiyama et al. (2001).

[23] Deinstadt et al. (1995).

[24] Stephens et al. (1995).

[b] Extensive portions of river below dam are channelized or concrete apron.

[c] Granlees Dam is not considered a keystone barrier for steelhead, impassable natural falls below dam.

[d] Portion in California.

Table B-3. SSHAG (2003) categorizations of hatchery populations of nine steelhead ESUs reviewed.

ESU	Stock	Run	Basin	SSHAG category*
Snake River	Wallowa	Summer	Wallowa	3c
	Cottonwood	Summer	Grande Ronde	3c
	Little Sheep Creek	Summer	Imnaha	2a
	Oxbow	Summer	Snake	3c
	Sawtooth	Summer	Salmon	3c
	Pahsimeroi	Summer	Salmon	3c
	Dworshak	Summer	Clearwater	2a
	Lyons Ferry	Summer	Snake	3c or 4
	Tucannon (Lyons Ferry)	Summer	Tucannon	3c or 4
	Tucannon (new)	Summer	Tucannon	1a
	Curl Lake	Summer	Snake	3 or 4
Upper Columbia River	Wells	Summer	Upper Columbia	2b
	Wenatchee	Summer	Wenatchee	1b
Middle Columbia River	Deschutes (#66)	Summer	Deschutes	2a or 2c
	Umatilla (#91)	Summer	Umatilla	1a
	Dayton Pond	Summer	Touchet	4
	Dayton Pond (new)	Summer	Touchet	1a
Lower Columbia River	Skamania	Summer	Washougal	4
	Sandy (ODFW #11)	Winter	Sandy	1a
	Clackamas (#122)	Winter	Clackamas	1a
	Hood (ODFW #50)	Winter	Hood	1a
	Hood (ODFW #50)	Summer	Hood	1a
	Big Creek/Eagle Creek	Winter	Clackamas	4
	Chambers Creek	Winter	various	4
	Cowlitz	Late-winter	Cowlitz	2a
	Kalama	Winter	Kalama	1a
	Kalama	Summer	Kalama	1a
Upper Willamette River	Skamania (#24)	Summer	Santiam	4
Northern California	Mad River	Winter	Mad	3c
	Yager Creek	Winter	Yager	1a
	North Fork Gualala	Winter	Gualala	1a
Central California Coast	Don Clausen	Winter	Russian	2a
	Monterey Bay	Winter	Scott Creek	1a
South-Central California Coast	Whale Rock	Winter	Old Creek	1a or 2a
California Central Valley	Coleman NFH	Winter	Sacramento	2a
	Feather River	Winter	Feather	2a
	Nimbus Hatchery	Winter	American	4
	Mokelumne Hatchery	Winter	Mokelumne	4

[*] See subsection, Artificial Propagation, in Section 1, Introduction, for explanation of the categories.

Table B-4. Steelhead time-series references.

Data type	Data source
Snake River Steelhead ESU	
Population	Snake River Steelhead (total)
Years of data, length of series	1980–2001, 22 years
Abundance type	Total live count
Abundance and hatchery reference	E. Holmes, unpublished data (available from E. Holmes, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112)
Harvest reference	Yuen (2002)
Age notes, reference	E. Holmes, unpublished data (available from E. Holmes, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112)
Population	Imnaha River (Zumwalt/Camp Creek)
Years of data, length of series	1974–2000, 27 years
Abundance type, reference	Redds per mile. Chilcote (2002).
Hatchery and harvest reference	Chilcote (2001)
Age notes, reference	Average. Chilcote (2001).
Population	Camp Creek (Imnaha)
Years of data, length of series	1974–2002, 29 years
Abundance type	Total live count
Abundance, hatchery, and harvest reference	Chilcote (2002)
Age notes, reference	Average. Used Grande Ronde River aggregate.
Population	Upper Grande Ronde River
Years of data, length of series	1967–2000, 34 years
Abundance type	Redds per mile
Abundance, hatchery, and harvest reference	Chilcote (2001)
Age notes, reference	Average. Chilcote (2001)
Population	Joseph Creek
Years of data, length of series	1974–2002, 29 years
Abundance type	Total live count
Abundance, hatchery, and harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2002).
Population	Little Sheep Creek (Imnaha River) hatchery
Years of data, length of series	1985–2002, 18 years
Abundance type, reference	Total live count, Chilcote (2002).
Hatchery reference	Chilcote (2002)
Population	Little Sheep Creek (Imnaha River) wild
Years of data, length of series	1985–2002, 18 years
Abundance type, reference	Total live count. Chilcote (2002).
Hatchery and harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2002).

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Population	Snake River A-run total
Years of data, length of series	1985–2001, 17 years
Abundance type	Total live count
Abundance and hatchery reference	Yuen (2002)
Harvest and age reference	Yuen (2002)
Age notes	Yearly
Population	Snake River B-run total
Years of data, length of series	1985–2001, 17 years
Abundance type	Total live count
Abundance and hatchery reference	Yuen (2002)
Harvest and age reference	Yuen (2002)
Age notes	Yearly
Population	Tucannon River
Years of data, length of series	1987–2001, 13 years
Abundance type	Total live count
Abundance reference	Gallinat et al. (2001); 2001 estimate from M. Shuck.[a]
Hatchery reference	Gallinat et al. (2001)
Harvest reference	Yuen (2002)
Age notes, reference	Average. Gallinat et al. (2001)
Population	Wallowa River (Grande Ronde River)
Years of data, length of series	1965–1996, 31 years
Abundance type	Redds per mile
Population	Asotin Creek
Years of data, length of series	1986–2001, 13 years
Abundance type	Expanded redd count
Abundance reference	M. Schuck[a]
Upper Columbia Steelhead	
Population	Above Wells Dam
Years of data, length of series	1976–2001, 26 years
Abundance type, reference	Total live count (Cooney 2001)
Hatchery reference	Douglas PUD, Wells Dam broodstock sampling
Harvest reference	Cooney (2001); mainstem harvest rates from Yuen (2002); tributary rates from Brown (1995).
Age notes, reference	Yearly. Cooney (2001); Brown (1995); annual update memos for Priest Rapids steelhead sampling program from WDFW (Fish Program, 600 Capitol Way N., Olympia, WA 98501).
Population	Wenatchee and Entiat rivers
Years of data, length of series	1976–2001, 26 years
Abundance type, reference	Total live count (Cooney 2001)

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Hatchery reference	Cooney (2001); Brown (1995); annual update memos for Priest Rapids steelhead sampling program from WDFW (Fish Program, 600 Capitol Way N., Olympia, WA 98501).
Harvest reference	Cooney (2001); mainstem harvest rates from Yuen (2002); tributary rates from Brown (1995).
Age notes, reference	Yearly. Cooney (2001); WDFW, Priest Rapids steelhead sampling program
Population	Methow River
Years of data, length of series	1976–2001, 26 years
Abundance type, reference	Total live count for years 1999–2001. Cooney (2001).
Hatchery reference	Douglas County PUD, Wells Dam broodstock sampling
Harvest reference	Cooney (2001); mainstem harvest rates from Yuen (2002); tributary rates from Brown (1995).
Age notes, reference	Yearly. Cooney (2001); Brown (1995); annual update memos for Priest Rapids steelhead sampling program from WDFW (Fish Program, 600 Capitol Way N., Olympia, WA).
Population	John Day River, upper north fork
Years of data, length of series	1977–2002, 26 years
Abundance type, notes, reference	Redds per mile. Chilcote (2001, 2002)
Hatchery reference	E. Holmes, unpublished data (available from E. Holmes, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112)
Harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2001).
Population	John Day River, middle fork
Years of data, length of series	1974–2001, 28 years
Abundance type, notes, reference	Redds per mile. Chilcote (2001, 2002)
Hatchery reference	E. Holmes, unpublished data (available from E. Holmes, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112).
Harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2001).
Population	Deschutes River
Years of data, length of series	1978–2002, 25 years
Abundance type, reference	Dam count (Sherars Dam). Chilcote (2002).
Hatchery and harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2001).
Population	Fifteenmile Creek (winter)
Years of data, length of series	1964–2001, 24 years
Abundance type, reference	Redds per mile. StreamNet (http://www.streamet.org).
Hatchery reference	No annual sampling, assumed natural returns
Harvest reference	Chilcote (2001)
Age notes, reference	Average. Chilcote (2001).

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Population	John Day River, lower main stem
Years of data, length of series	1965–2002, 37 years
Abundance type, notes, reference	Redds per mile. Chilcote (2001, 2002).
Hatchery reference	Chilcote (2001)
Harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2001).
Population	John Day River, upper main stem
Years of data, length of series	1974–2002, 29 years
Abundance type, reference	Total live count. Chilcote (2002).
Hatchery and harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2001).
Population	Shitike Creek (Deschutes)
Years of data, length of series	1976–2002, 26 years
Abundance type, reference	Redds per mile. Chilcote (2002, 2001).
Age notes, reference	Average. Used Deschutes River ages.
Population	South Fork John Day River
Years of data, length of series	1974–2002, 29 years
Abundance type, notes, reference	Redds per mile. Chilcote (2002, 2001)
Hatchery reference	Chilcote (2001)
Harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2001).
Population	Touchet River
Years of data, length of series	1987–2001, 13 years
Abundance type, reference	Total live count. Leland (2003); Bumgarner (2002) for data years 1996–2001,
Hatchery reference	StreamNet (http://www.streamet.org) : Touchet River natural (180,065) divided by total (180,065 + 180,002)
Harvest reference	Mainstem harvest rates from Yuen (2002); tributary rates from Brown 1995.
Age notes	Average
Population	Umatilla River
Years of data, length of series	1966–2002, 35 years
Abundance type, reference	Total live count. StreamNet (1966–2000, available online at http://www.streamnet.org); M. Chilcote.[b]
Hatchery and harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2002).
Population	Lower North Fork John Day River
Years of data, length of series	1976–2002, 27 years
Abundance type	Redds per mile
Abundance notes, reference	Updated spreadsheets. Chilcote (2002, 2001).

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Hatchery and harvest reference	Chilcote (2002)
Age notes, reference	Average. Chilcote (2002).
Population	Walla Walla River
Years of data, length of series	1993–2000, 8 years
Abundance type, reference	Total live count. M. Chilcote.[b]
Hatchery and harvest reference	Chilcote (2001)
Age notes, reference	Average. Chilcote (2001).
Population	Warm Springs National Fish Hatchery
Years of data, length of series	1980–1999, 20 years
Abundance type, reference	Total live count. Chilcote (2001).
Hatchery and harvest reference	Chilcote (2001)
Age notes, reference	Average. Chilcote (2001).
Population	Yakima River
Years of data, length of series	1980–2001, 23 years
Abundance type	Total live count
Abundance and hatchery reference	Leland (2002)
Harvest reference	Table 4-3 in U.S. Bureau of Reclamation (2000)
Age notes, reference	Average (Leland 2003)
Years of data, length of series	1990–2002, 9 years
Abundance type, reference	Redd count[c]
Hatchery notes, reference	No recent year data available
Lower Columbia River Steelhead ESU	
Population	Hood River summer run
Years of data, length of series	1992–2000, 9 years
Abundance type, notes, reference	Dam/weir count. Dam counts at Powerdale Dam. Gorman (unpublished data).
Hatchery reference	Gorman (unpublished data)
Harvest reference	No harvest data available.
Age notes, reference	Repeat % total ranged from 2% to 10%. Gorman (unpublished data).
Population	Kalama River summer run
Years of data, length of series	1977–2003, 27 years
Abundance type, notes, reference	Trap count. Trap count plus correction estimate for jumpers. Rawding (2002).
Hatchery notes, reference	Work done at River Mile 10 above the two hatcheries to minimize handling of hatchery fish. Substantial rearing may occur below; trapping takes place during spring. Rawding (2002).
Harvest reference	Rawding (2002)
Age notes, reference	From 1998 on, no scales have been aged, and mean ages are used for these years. Rawding (2002).

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Population	Washougal River summer run
Years of data, length of series	1986–2003, 18 years
Abundance type, reference	Index. WDFW (1997); Rawding (2002).
Hatchery reference	No hatchery data
Harvest reference	No harvest data available
Age notes, reference	Generic sum age structure. Busby et al. (1996), Chilcote (2001), Hulett et al. (1995).
Population	Wind River summer run
Years of data, length of series	1989–2003, 15 years
Abundance type, notes, reference	Mark-recapture. Estimates made from mark-recapture from trap efficiency method. Adult trap at Shipherd Falls, but adult population is estimated by mark-recapture, since fish jump the falls. Not able to differentiate winter- and summer-run steelhead smolts. Rawding (2001b, 2002).
Hatchery, harvest, age reference	Rawding (2001b)
Population	Clackamas River winter run
Years of data, length of series	1958–2001, 44 years
Abundance type, notes, reference	Dam/weir count. Cramer (2002a, 2002c).
Hatchery notes, reference	Pre-1997 wild fraction determined by run timing; all fish counted on or after March 1 assumed to be wild. Additional reference for 1997–2001 from D. Cramer;[d] PGE has numbers for wild and hatchery fish as of 1996–1997 run; all winter-run steelhead trapped and identified as wild or hatchery. Cramer (2002a).
Harvest notes, reference	Reconstructed run year estimates from punch cards for steelhead from M. Chilcote.[e]
Age notes, reference	Generic sum age structure. Busby et al. (1996), Chilcote (2001), Hulett et al. (1995)
Population	Upper Cowlitz, Cispus, and Tilton winter run
Years of data, length of series	2002, 1 year
Abundance type, notes, reference	Dam/weir count. Cramer (2002c), Serl and Morrill (2002).
Population	East Fork Lewis River winter run
Years of data, length of series	1985–1994, 10 years
Abundance type, notes, reference	Peak count. Natural population only; East Fork Lewis River, tributary to Lewis River from river mile 0.0 to 41.8. Johnson and Cooper (1995).
Hatchery reference	Busby et al. (1996)
Harvest reference	No harvest data available.
Age reference	Busby et al. (1996), Chilcote (2001), Hulett et al. (1995)
Population	Hood River summer run
Years of data, length of series	1992–2000, 9 years

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Abundance type, notes, reference	Dam/weir count. Dam counts at Powerdale Dam. Gorman (unpublished data).
Hatchery reference	Gorman (unpublished data)
Harvest reference	No harvest data available.
Age reference	Gorman (unpublished data)
Population	Kalama River winter run
Years of data, length of series	1977–2002, 26 years
Abundance type, notes, reference	Trap count. Trap count plus correction estimate for jumpers. Rawding (2001b, 2002).
Hatchery notes, reference	Work done at river mile 10 above the two hatcheries to minimize handling of hatchery fish. Substantial rearing may occur below; trapping takes place during spring. Rawding (2001b).
Harvest reference	Leland (2003)
Age notes, reference	From 1998 on no scales have been aged, and mean ages are used for these years. Rawding (2001b).
Population	North Fork Toutle River winter run
Years of data, length of series	1989–2002, 14 years
Abundance type, notes, reference	Total from redd count; 100% trap count. Rawding (2001b, 2002).
Hatchery and age reference	Rawding (2001b)
Harvest reference	Rawding (2002)
Population	Sandy River winter run
Years of data, length of series	1978–2001, 24 years
Abundance type, notes, reference	Dam/weir count. Dam counts made at Marmot Dam. Cramer (2002d).
Hatchery notes, reference	Used average hatchery fraction from 1978 to 1997 for years 1998–2001. Chilcote (1998).
Harvest notes, reference	Natural population catch is determined by multiplying harvest by wild fraction. Berry (1978).
Age notes, reference	Generic winter age structure. Busby et al. (1996), Chilcote (1998), Hulett et al. (1995).
Population	South Fork Toutle River winter run
Years of data, length of series	1981–2002, 19 years
Abundance type, notes, reference	Redd surveys. Winter-run steelhead in South Fork Toutle River are by redd surveys from 15 March to 31 May. Redd surveys assume 100% of the redds are seen; only wild steelhead spawn after March 15, sex ratio is 1:1, and each redd represents 0.8 females. Assumed stray rate is 2%. Leland (2003), Rawding (2001b, 2002).
Hatchery and harvest reference	Rawding (2001b)

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Age notes, reference	Applied Kalama estimates to South Fork Toutle River. Pooled ages 6 and 7 into age 6 to increase redd survey sample size. Rawding (2001b).
Population	Washougal River winter run
Years of data, length of series	1991–2002, 5 years
Abundance type, reference	Redd index. Leland (2003), WDF and WDW (1993).
Hatchery notes, reference	Reports little hatchery impact. Leland (2003), WDF and WDW (1993).
Harvest reference	No harvest data available.
Age notes, reference	Generic winter age structure. Busby et al. (1996), Chilcote (2001), Hulett et al. 1995.
Population	Coweeman River winter run
Years of data, length of series	1987–2002, 16 years
Abundance type, notes, reference	Redd surveys. Winter-run steelhead estimates in the Coweeman River are by redd surveys from March 15 to May 31. Redd surveys assume 100% of redds are seen; only wild steelhead spawn after March 15, sex ratio is 1:1, and each redd represents 0.8 females. Leland (2003), Rawding (2001b, 2002).
Hatchery notes, reference	Data on hatchery fraction for 1987–1989 were provided by Leland (2003). Estimate for 1990–2002 based on estimate from Rawding (2001b) of 50% hatchery fish. Leland (2003), Rawding (2001b).
Harvest reference	Leland (2003), Rawding (2001b)
Age notes, reference	Only age structure data is for winter run in North Fork Toutle and Kalama, and summer run in the Kalama. Age structure is very similar in Toutle and Kalama river winter run. Toutle River has fewer repeats 5.3% to 8.9%, possibly because kelts must pass through PVC tubes on the sediment dam, which negatively impacts their survival. Rawding (2001b) applied the Kalama River winter run to the Coweeman and South Forth Toutle rivers populations. Rawding (2001b).
Population	East Fork Lewis River summer run
Years of data, length of series	1996–2003, 8 years
Abundance type, reference	Snorkel survey. Rawding (2002).
Hatchery, harvest, and age reference	Rawding (2002)
Upper Willamette River Steelhead ESU	
Population	Calapooia River winter run
Years of data, length of series	1980–2000, 21 years
Abundance type, notes, reference	Redd count. Data from StreamNet (http://www.streamnet.org). ODFW (1994), Hunt (1999).
Harvest and hatchery reference	Chilcote (2001)

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Population	South Santiam River winter run
Years of data, length of series	1983–2000, 18 years
Abundance type, notes, reference	Redd count. Data from StreamNet (http://www.streamnet.org). StreamNet (1995, 1997).
Harvest and hatchery reference	Chilcote (2001)
Population	North Santiam River winter run
Years of data, length of series	1983–2000, 18 years
Abundance type, notes, reference	Redd count. Data from StreamNet (http://www.streamnet.org). StreamNet (1998), ODFW (1998b).
Harvest and hatchery reference	Chilcote (2001)
Population	Molalla River winter run
Years of data, length of series	1980–2000, 21 years
Abundance type, reference	Redd count. StreamNet (1997), Hunt (1999).
Harvest and hatchery reference	Chilcote (2001)
Population	South Santiam (Foster Dam)
Years of data, length of series	1973–2000, 28 years
Abundance type, reference	Total live fish. ODFW (1990b), StreamNet (1997), Hunt (1999).
Harvest reference	Chilcote (2001)
Population	Willamette Falls Dam winter run
Years of data, length of series	1971–2002, 32 years
Abundance type, reference	Dam/weir count. Serl and Merrill (2002)
Northern California Steelhead ESU	
Population	South Fork Eel River winter run above Benbow
Years of data, length of series	1938–1975, 38 years
Abundance type	Dam count
Abundance notes, reference	CDFG (1994b)
Population	Mad River, winter run, above Sweasy
Years of data, length of series	1938–1963, 26 years (some years no data)
Abundance type	Dam count
Abundance notes, reference	StreamNet (1964)
Population	Middle Fork Eel River, summer run
Years of data, length of series	1966–2002, 37 years (some years no data)
Abundance type	Reach surveys, adult
Abundance notes, reference	Harris (2002c)
Population	Mad River, summer run
Years of data, length of series	1994–2002, 9 years
Abundance type	Reach surveys, adult
Abundance notes, reference	Sparkman (2002); CDFG (2002c), M. House.[f]

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Population	Freshwater Creek, winter run
Years of data, length of series	1994–2001, 8 years
Abundance type	Upstream trap
Abundance notes, reference	Humboldt Fish Action Council (2002)
Population	Redwood Creek, summer run
Years of data, length of series	1981–2002, 22 years
Abundance type	Reach surveys, adult
Abundance notes, reference	Anderson (2000, 2002)
Population	Abalobadiah Creek, one reach
Years of data, length of series	1993–2002, 10 years (one year no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	Usal Creek, three reaches
Years of data, length of series	1993–2002, 10 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	South Fork Tenmile Creek, nine reaches
Years of data, length of series	1993–2002, 10 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	North Fork Tenmile Creek, eight reaches
Years of data, length of series	1993–2002, 10 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	Middle Fork Tenmile Creek, seven reaches
Years of data, length of series	1993–2002, 10 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	Pudding Creek, two reaches
Years of data, length of series	1993–2002, 10 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	North Fork Noyo River, seven reaches
Years of data, length of series	1993–2002, 10 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	Big River, two reaches
Years of data, length of series	1993–2002, 10 years (some years no data)

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	Big Salmon River, five reaches
Years of data, length of series	1993–2002, 10 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Population	South Fork Eel Creek, five reaches
Years of data, length of series	1994–2002, 9 years (some years no data)
Abundance type	Reach surveys, juveniles per sq. mi.
Abundance notes, reference	NMFS (2002g)
Central California Coast Steelhead ESU	
Population	San Lorenzo River, various reaches
Years of data, length of series	1996–2001, 6 years
Abundance type	Reach surveys, juveniles per 30 m
Abundance notes, reference	Data from D. W. Alley & Associates, Brookdale, Calif.; see NMFS (2002g).
Population	Scott Creek, various reaches
Years of data, length of series	1994–2001, 8 years (some years, some reaches no data)
Abundance type	Reach surveys, juveniles per 30 m
Abundance notes, reference	Data from J. Smith, San Jose State University, San Jose; see NMFS (2002g).
Population	Waddell Creek, various reaches
Years of data, length of series	1992–2001, 10 years (some years, some reaches no data)
Abundance type	Reach surveys, juveniles per 30 m
Abundance notes, reference	Data from J. Smith, San Jose State University, San Jose; see NMFS (2002g).
Population	Gazos Creek, various reaches
Years of data, length of series	1994–2001, 8 years (some years, some reaches no data)
Abundance type	Reach surveys, juveniles per 30 m
Abundance notes, reference	Data from J. Smith, San Jose State University, San Jose; see NMFS (2002g).
Population	Redwood Creek, various reaches
Years of data, length of series	1992–2001, 10 years (some years, some reaches no data)
Abundance type	Reach surveys, juveniles per 30 m.
Abundance notes, reference	Data from J. Smith, San Jose State University, San Jose; see NMFS (2002g).
South-Central California Coast Steelhead ESU	
Population	Carmel River, winter run, above San Clemente Dam
Years of data, length of series	1964–2002, 39 years (significant gaps in the time series)

Table B-4 continued. Steelhead time-series references.

Data type	Data source
Abundance type	Dam count
Abundance notes, reference	Data from Monterey Peninsula Water Management District (2002)

[a] M. Schuck, WDFW. Pers. commun., 1 April 2003.

[b] M. Chilcote, ODFW, Fish Division, Salem, OR. Pers. commun., December 2002.

[c] R. Evenson, Confederated Tribes of the Yakama Nation, Fisheries Resource Management, Toppenish, WA. Pers. commun., November 2002.

[d] D. Cramer, Portland General Electric, Portland, OR. Pers. commun., 6 November 2002.

[e] M. Chilcote, ODFW, Fish Division, Salem, OR. Pers. commun., 27 November 2002.

[f] M. House, Simpson Resource Company, Korbel, CA, and A. Bundschuh, Six Rivers National Forest, Eureka, CA. Pers. commun., October 2002.

Appendix C: Coho Salmon

Table C-1. Preliminary SSHAG (2003) categorizations of hatchery populations of the four coho salmon ESUs reviewed.*

	Stock	Run	Basin	SSHAG category*
Oregon Coast	North Fork Nehalem	(#32)	Nehalem	2c
	Fishhawk Lake	(#99)	Nehalem	2a or 3a
	Trask River	(#34)	Trask	2c or 3c
	Siletz	(#33)	Siletz	2a or 3a
	Umpqua	(#55)	Umpqua	2a
	Cow Creek	(#18)	Umpqua	2a
	Woahink		Siltcoos	1a
	Coos	(#37)	Coos	2a
	Coquille	(#44)	Coquille	2a
Southern Oregon/Northern California Coast	Rogue River	(#52)	Rogue River	2a
	Iron Gate		Klamath	2c
	Trinity River		Trinity	2b
	Mad River		Mad River	4
Central California	Noyo River		Noyo River	2a
	Don Clausen		Russian	1a
	Monterey Bay		Scott Creek	1a
Lower Columbia River	Big Creek		Big Creek	2a
	Klaskanine		Klaskanine	4
	Tanner Creek		Lower gorge	2b
	Sandy River	Late	Sandy	2a
	Eagle Creek		Clackamas	2c
	Little White Salmon		Upper gorge	3c
	Toutle	Type S	Cowlitz	2a
	Type S complex	Type S	Various	2c or 3c
	Cowlitz	Type N	Cowlitz	2a
	Type N complex	Type N	Various	2b or 2c

*See subsection, Artificial Propagation, in Section 1, Introduction, for an explanation of the categories.

Table C-2. Coho salmon time-series data sources.

Data type	Data source
Oregon Coast Coho Salmon ESU	
Population	Oregon Coast
Years of data, length of series	1970–2002, 33 years
Abundance type, notes, reference	Rivers: 1970–1989 index live spawner surveys expanded by stream miles; 1990–2002 stratified random sample (SRS) survey design. Pre-1990 calibrated to SRS estimates. Lakes: index surveys expanded by historical mark-recapture data. Jacobs et al. (2000, 2001, 2002), PFMC (2002a, 2003b).
Southern Oregon/Northern California Coast (SONCC) Coho Salmon ESU	
Population	Rogue River
Years of data, length of series	1980–2002
Abundance type, notes, reference	Adult fish. Abundance estimates based on expansion of beach seine abundance index based on hatchery fraction and returns of hatchery fish to Cole Rivers Hatchery; Jacobs et al. (2002)
Population	Hollow Tree Creek (Mendocino County)
Years of data; length of series	1986–2002 (1983 included for one site; 1992 excluded from one site); 16–18 years
Abundance type, notes, reference	Juvenile density estimates (index reaches). Juvenile density estimates are derived based on multiple-pass depletion estimates at index reaches established by CDFG. Harris (2002a).
Population	South Fork Eel River basin (5 sites) (Mendocino County)
Years of data; length of series	1994–2002 for one site, 1995–2002 for all others; 8–9 years
Abundance type, notes, reference	Juvenile density estimates (index reaches). Juvenile density estimates are derived based on multiple-pass depletion estimates (Wright and Levesque 2002) at index reaches established by Campbell Timberland Management, Fort Bragg, CA. Most index reaches range from approximately 30 to 60 m in length.
Population	Numerous throughout SONCC ESU
Years of data; length of series	Variable, extending back to 1987
Abundance type, notes, reference	Presence-absence observations. Database contains information on coho salmon occurrence in streams throughout the SONCC ESU. Original sources include a variety of surveys, reports, and other documents produced by CDFG, NMFS, tribes, private landowners, academic institutions, and others doing research or monitoring of coho salmon or other salmonids in streams believed to have historically supported coho salmon. Original sources are documented in databases housed at SWFSC. Spence (2001).

Table C-2 continued. Coho salmon time-series data sources.

Data type	Data source
Central California Coast Coho Salmon ESU	
Population	Caspar Creek and Little River (Mendocino County)
Years of data, length of series	1987–2002; 16 years
Abundance type, notes, reference	Smolt counts (partial). Smolt counts are partial counts made at downstream migrant traps and are not corrected for trap efficiency; numbers should be viewed as indices of abundance rather than population estimates. Harris (2002b).
Population	Noyo River Egg Collecting Station (Mendocino County)
Years of data, length of series	1962–2001; 40 years
Abundance type, notes, reference	Adult counts (partial). Counts of adult coho salmon are partial counts made at the Noyo Egg Collecting Station on the South Fork Noyo River. In most years, the trap was not operated continuously during the spawning season. Furthermore, trapping usually ceased when egg take goals were met. Thus, counts should be viewed as indices of abundance rather than population estimates. Grass (2002).
Population	Pudding Creek, Caspar Creek, and Little River (Mendocino County)
Years of data; length of series	Pudding Creek, 1983–2002 (except 1990), 19 years. Caspar Creek (two sites), 1986–2002, 17 years. Little River (two sites), 1986–2002 (except 2000), 16 years.
Abundance type, notes, reference	Juvenile density estimates (index reaches). Juvenile density estimates are derived based on multiple-pass depletion estimates at index reaches established by CDFG. Pudding Creek site has been sampled in recent years by Campbell Timberland Management. Harris (2002a).
Population	Noyo River, Big River, and Big Salmon Creek (Mendocino County)
Years of data; length of series	Noyo River (eight sites), generally 1993–2002 (variable among sites), 6–10 years. Big River (two sites), 1993–2002, 10 years. Big Salmon Creek (5 sites), generally 1993–2002 (variable among sites), 7–10 years.
Abundance type, notes, reference	Juvenile density estimates (index reaches). Juvenile density estimates are derived based on multiple-pass depletion estimates at index reaches established by Campbell Timberland Management. Most index reaches range from approximately 30 to 60 m in length Wright and Levesque (2002).
Population	Lagunitas Creek (Marin County)
Years of data; length of series	1995–2001; 7 years

Table C-2 continued. Coho salmon time-series data sources.

Data type	**Data source**
Abundance type, notes, reference	Juvenile population estimates (expanded from index reaches). Juvenile density estimates for different habitat unit types are derived based on multiple-pass depletion estimates at index reaches. Unit-specific density estimates are then used in conjunction with habitat typing for the entire stream reach to obtain an overall population estimate for juveniles within the stream. Ettlinger (2002).
Population	Redwood Creek (Marin County)
Years of data; length of series	1994–2001 (excluding 1999); 7 years
Abundance type, notes, reference	Juvenile population index. Juvenile counts are made annually at multiple index sites in Redwood Creek using single-pass electro-fishing. Mean numbers of fish per linear distance of stream were calculated based only on sites that were sampled each year during the period of record (i.e., sites sampled sporadically were not included in the overall estimate). Smith (1994a, 1996a, 1997, 1998a, 2000b, 2001b).
Population	Waddell and Scott Creeks (Santa Cruz County), and Gazos Creek (San Mateo County)
Years of data; length of series	Waddell Creek and Scott Creek, 1992–2001; 10 years Gazos Creek, 1993-2001 (excluding 1994); 8 years
Abundance type, notes, reference	Juvenile population index. Juvenile counts are made annually at multiple index sites in each creek using single-pass electro-fishing. Mean numbers of fish per linear distance of stream were calculated based only on sites that were sampled each year during the period of record (i.e., sites sampled sporadically were not included in the overall estimate). Smith (1992, 1994b, 1994c, 1996b, 1996c, 1997, 1998b, 1998c, 1999, 2000a, 2001a)
Population	Numerous throughout Central California Coast ESU
Years of data; length of series	Variable, extending back to 1987
Abundance type, notes, reference	Presence-absence observations. Database contains information on coho salmon occurrence in streams throughout the Central California Coast ESU. Original sources include a variety of surveys, reports, and other documents produced by CDFG, NMFS, private landowners, water districts, academic institutions, and others doing research or monitoring of coho salmon or other salmonids in streams believed to have historically supported coho salmon. Original sources are documented in databases housed at the NMFS SWFSC. Spence (2001).

Table C-2 continued. Coho salmon time-series data sources.

Data type	Data source
Lower Columbia River Coho Salmon ESU	
Population	Clatskanie River
Years of data, length of series	1949–2001, 53 years
Abundance type, notes, reference	Fish per mile. Data from StreamNet (available online at http://www.streamet.org). Fulop et al. (1998a, 1998b), White et al. (1999), Ollerenshaw (2002).
Population	Scappoose Creek
Years of data, length of series	1949–2001, 53 years
Abundance type, notes, reference	Fish per mile. Data from StreamNet (available online at http://www.streamet.org). Fulop et al. (1998a, 1998b), White et al. (1999), Ollerenshaw (2002).
Population	Big Creek
Years of data, length of series	1950–2001, 52 years
Abundance type, notes, reference	Fish per mile. Data from StreamNet (available online at http://www.streamet.org). Fulop et al. (1998a, 1998b), White et al. (1999), Ollerenshaw (2002)
Population	Clackamas River
Years of data, length of series	1950–2001, 52 years
Abundance type, notes, reference	Fish per mile. Data from StreamNet (available online at http://www.streamet.org). Fulop et al. (1998a, 1998b), White et al. (1999), Ollerenshaw (2002).
Population	Youngs Bay
Years of data, length of series	1949–2001, 53 years
Abundance type, notes, reference	Fish per mile. Data from StreamNet (available online at http://www.streamet.org). Fulop et al. (1998a); Fulop et al. (1998b); White et al. (1999), Ollerenshaw (2002).
Population	Sandy River (Marmot Dam)
Years of data, length of series	1977–2001, 25 years
Abundance type, reference	Dam count. Cramer (2002b).
Population	Clackamas River (North Fork Dam)
Years of data, length of series	1957–2001, 45 years
Abundance type, reference	Dam count. Cramer (2002a).

Appendix D: Sockeye Salmon

Table D-1. Preliminary SSHAG (2003) categorizations of hatchery populations of the Ozette Lake sockeye ESU.

ESU	Stock	Run	Basin	SSHAG category[*]
Ozette Lake	Umbrella Creek		Ozette	1a or 2a, or 1b or 2b

[*] See subsection, Artificial Propagation, in Section 1, Introduction, for an explanation of the categories.

Appendix E: Chum Salmon

Table E-1. Preliminary SSHAG (2003) categorizations of hatchery populations of chum salmon of the Hood Canal summer-run and Columbia River chum salmon ESUs.

ESU	**Stock**	**Run**	**Basin**	**SSHAG category**[*]
Hood Canal summer run	Big Quilcene	Summer	Quilcene River	1a
	Lilliwaup Creek	Summer	South Hood Canal	1a
	Hamma Hamma River	Summer	South Hood Canal	1a
	Big Beef Creek	Summer	North Hood Canal	1b
	Salmon Creek	Summer	Dungeness River	1a
	Chimacum Creek	Summer	Dungeness River	1b
	Union River	Summer	Union River	1a
	Jimmycomelately Creek	Summer	Dungeness River	1a
Columbia River	Sea Resources	Fall	Chinook River	1a
	Gorley Creek	Fall	Grays River	1a
	Hamilton Creek	Fall	Columbia Gorge	1a
	Washougal/Duncan Creek	Fall	Washougal River	1a

[*] See subsection, Artificial Propagation, in Section 1, Introduction, for an explanation of the categories.

Table E-2. Chum salmon time-series data sources.

Data type	Data source
Hood Canal Summer-Run Chum Salmon ESU	
Population	Anderson Creek
Years of data, length of series	1970–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male to female ratio). Counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	No supplemental hatchery program.
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Anderson is that from the areas 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001); Lampsakis (2003).
Age notes, reference	Spawner survey; n = 10 fish sampled from 2001 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Johnson (2003a, 2003b).
Population	Big Beef Creek
Years of data, length of series	1968–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap. Includes all ages.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male female ratio). Counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001); Johnson (2003b).
Hatchery notes, reference	Supplementation program was started with releases in basin in 1996. No sampling for hatchery marks on escapement grounds, but assume that all returns after 1996 are from hatchery plants since there had been no returns for several years prior. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Big Beef is from areas 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001); Lampsakis (2003).

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Age notes, reference	Trap, spawner survey; n = 396 fish sampled from 2000 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Big Quilcene River
Years of data, length of series	1968–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male female ratio) Method—area under the curve, 10-day stream life. Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	Supplementation program started in 1992 in the Big Quilcene River. Broodstock is taken from returning fish; eggs are incubated, and fry released into the Big Quilcene. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Big Quilcene is from areas 82F, 12A, 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	From bay fisheries, spawner surveys; n = 3,770 fish sampled from 1992 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2000, 2001), Johnson (2003a, 2003b).
Population	Chimacum River
Years of data, length of series	1999–2002
Abundance notes, reference	Returns come from recent hatchery plants to system. Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Johnson (2003b).
Hatchery notes, reference	Reintroduction program started in 1996 when eyed eggs were transferred in from Salmon Creek. WDFW and Point No Point Treaty Tribes (2001).

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). There is no terminal catch area for Chimacum. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 537 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2000, 2001), Johnson (2003a, 2003b).
Population	Combined Quilcene River
Years of data, length of series	1974–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	Coded-wire-tag otolith sampling for hatchery marks. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Quilcene is from areas 82F, 12A, 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	From bay fisheries, trap, spawner surveys; n = 4,076 fish sampled from 1992 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2000, 2001), Johnson (2003a, 2003b).
Population	Dewatto River
Years of data, length of series	1968–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	No broodstock take. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Dewatto is that from the areas 12C, 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Spawner survey; n = 5 fish sampled from 2000 to 2001. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). Johnson (2003a, 2003b).
Population	Dosewallips River
Years of data, length of series	1972–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	There are no hatchery releases in basin. There may be some from nearby hatchery summer-run chum releases, but the basin is not sampled. Hatchery impact on natural spawners is assumed to be zero. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Dosewallips is from the areas 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 500 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).

Table E-2 continued. Chum salmon time-series data sources.

Data type	**Data source**
Population	Duckabush River
Years of data, length of series	1968–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	No hatchery releases or broodstock take in the Duckabush. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Duckabush is that from fishing areas 12B, 12, 9A. WDFW and Point No Point Treaty Tribes (2000, 2001); Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 326 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Hamma Hamma River
Years of data, length of series	1968–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	Supplementation program was started with broodstock takes in 1998; assumed that there was no hatchery straying into basin prior to hatchery releases in basin. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Hamma Hamma is from the areas 12B, 12, 9A. WDFW and Point No Point Treaty Tribes (2000, 2001); Lampsakis (2003).

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Age notes, reference	Trap, seine, spawner survey; n = 386 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Jimmycomelately Creek
Years of data, length of series	1974–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Johnson (2003b).
Hatchery notes, reference	Supplementation program started with 1999 broodyear. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Jimmycomelately is from the Sequim area. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 233 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Lilliwaup River
Years of data, length of series	1971–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male to female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	Supplementation program was started with broodstock take in 1992. WDFW and Point No Point Treaty Tribes (2001).

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Lilliwaup is from the areas 12C, 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 233 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001) Johnson (2003a, 2003b).
Population	Little Quilcene River
Years of data, length of series	1968–2002
Abundance type	Method—area under the curve, 10-day stream life.
Abundance notes, reference	Redd counts expanded by 2 (assumes 1:1 male to female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	Supplementation program started in 1992 in the Big Quilcene River. Broodstock is taken from Big Quilcene and fry released into the Big Quilcene. Some return to Little Quilcene. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Little Quilcene is that from the areas 12A, 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001); Lampsakis (2003).
Age notes, reference	From bay fisheries, spawner survey, seine in bay, rack; n = 2,599 fish sampled from 1992 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Salmon River
Years of data, length of series	1971–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male to female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Johnson (2003b).
Hatchery notes, reference	Supplementation program was started in 1992. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Salmon is that from the Discovery Bay. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 1,087 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Salmon/Snow
Years of data, length of series	1974–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male to female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery reference	WDFW and Point No Point Treaty Tribes (2001)
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Salmon and Snow is that from Discovery Bay. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 1,227 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Snow River
Years of data, length of series	1972–2002

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male to female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Johnson (2003).
Hatchery notes, reference	No estimate of hatchery fish contribution to spawners. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Salmon and Snow is that from Discovery Bay. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes, reference	Trap, spawner survey; n = 140 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Population	Tahuya River
Years of data, length of series	1972–2002
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male to female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001); T. Johnson (WDFW, pers. commun., 28 March 2003); Johnson (2003b).
Hatchery notes, reference	No estimate of hatchery contribution to spawners. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Tahuya is from areas 12D, 12C, 12B, 12, and 9A. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Age notes	No surveys
Population	Union River
Years of data, length of series	1974–2002

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Abundance type	Trap counts (excluding broodstock take adjustment) plus redd counts downstream of trap.
Abundance notes, reference	Redd count expanded by 2 (assumes 1:1 male to female ratio). Escapement counts include all ages. WDFW and Point No Point Treaty Tribes (2000, 2001), Lampsakis (2003).
Hatchery notes, reference	Supplementation program was started with broodstock take in 2000. WDFW and Point No Point Treaty Tribes (2001).
Harvest notes, reference	The offshore catch includes marine catch from Seattle Area 10, Admiralty Area 9, U.S. Convention Areas, and Canadian Area 20. For summer-run chum these are assumed to be mature fish returning to spawning grounds. Catches by population/stock are determined from the run reconstruction tables given in WDFW and Point No Point Treaty Tribes (2001). The terminal catch for Union is that from the Sequim area. WDFW and Point No Point Treaty Tribes (2000, 2001).
Age notes, reference	Trap, spawner survey; n = 317 fish sampled from 1999 to 2002. Age distribution reconstructed for other years using average cohort distribution weighted by annual abundance of contributing years (Sands 2002, in prep.). WDFW and Point No Point Treaty Tribes (2001), Johnson (2003a, 2003b).
Columbia River Chum Salmon ESU	
Population	Grays River
Years of data, length of series	1951–2000, 50 years
Abundance type	Live/dead index
Abundance notes, reference	1999 and 2000 data from Keller (2001) and Keller and Bruce (2001). Hymer (2000).
Hatchery notes, reference	There has been no significant contribution of hatchery fish to the Grays River chum salmon population. Rawding (2001c).
Harvest notes, reference	There has been no significant directed harvest on Columbia chum salmon for the duration of the time series. Indirect harvest is believed to be negligible. Rawding (2001c).
Age reference	Salo (1991)
Age notes, reference	McClure et al. (2003)
Population	Grays River
Years of data, length of series	1967–1998, 32 years
Abundance type, reference	Live/dead index. Rawding (2003).
Hatchery notes, reference	There has been no significant contribution of hatchery fish to the Grays River chum salmon population. Rawding (2001c).

Table E-2 continued. Chum salmon time-series data sources.

Data type	Data source
Harvest notes, reference	There has been no significant directed harvest on Columbia chum salmon for the duration of the time series. Indirect harvest is believed to be negligible. Rawding (2001c).
Age notes, reference	McClure et al. (2003), Salo (1991).
Population	Lower gorge tributaries (Hamilton Creek, Hamilton Springs, and Hardy Creek)
Years of data, length of series	1944–2000, 57 years
Abundance type	Live/dead index
Abundance notes, reference	Separate time series for each subpopulation were combined for analysis (Rawding 2001c, 2003).
Hatchery notes, reference	There has been no (or extremely little) hatchery impact on Hardy Creek chum salmon. Rawding (2001c).
Harvest notes, reference	There has been no significant directed harvest on Columbia chum salmon for the duration of the time series. Indirect harvest is believed to be negligible. Rawding (2001c).
Age notes, reference	McClure et al. (2003), Salo (1991).

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NMFS-NWFSC-

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