Preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead

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EXECUTIVE SUMMARY

This draft report summarizes preliminary scientific conclusions of the NMFS Biological Review Team (BRT) regarding the updated status of 26 ESA-listed Evolutionarily Significant Units (ESUs) 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 decade of the 1990s. The status review updates were undertaken to allow consideration of new data that have accumulated over the various time periods since the last updates and to address issues raised in recent court cases regarding the ESA status of hatchery fish and resident (nonanadromous) populations. The draft BRT conclusions in this report should be considered preliminary for two reasons. First, the BRT will not finalize its conclusions until state, tribal, and other federal comanagers have had an opportunity to review and comment on the draft report. Second, some policy issues regarding the treatment of hatchery fish and resident fish in ESU determinations and risk analyses are not resolved at this time.

When finalized, this draft report would represent 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 take into consideration not only the best scientific information available, but also those efforts being made to protect the species. After receiving the final BRT report and after considering the conservation benefits of such efforts, NMFS will determine what changes, if any, to propose to the listing status of the affected ESUs.

As in the past, the BRT 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 (VSP) document: abundance, growth rate/productivity, spatial structure, and diversity. These criteria are being used as a framework for approaching formal ESA recovery planning for salmon and steelhead. Tabulating mean risk scores for each element allowed the BRT to identify the most important concerns for each ESU as well as make comparisons of relative risk across ESUs and species. These data and other information were considered by the BRT in making their overall risk assessments. Based on provisions in the draft revised NMFS policy on consideration of artificial propagation in salmon listing determinations, the risk analyses presented to the BRT focused on the viability of populations sustained by natural production.

For the following ESUs, the majority BRT conclusion was "in danger of extinction:" Upper Columbia spring-run chinook, Sacramento River winter-run chinook, Upper Columbia steelhead, Southern California steelhead, California Central Valley steelhead, Central California Coast coho, Lower Columbia River coho, Snake River sockeye. 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, Middle Columbia 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, S. Oregon/N. California Coast coho, Lake Ozette sockeye, Hood Canal summer-run chum, and Lower Columbia River chum. In a number of ESUs, adult returns over the last 1-3 years have been significantly higher than have been observed in the recent past, at least in some populations. The BRT found these results, which affected the overall BRT conclusions for some ESUs, to be encouraging. For example, the majority BRT conclusion for Snake River fall chinook salmon was "likely to become endangered," whereas the BRT concluded at the time of the original status review that this ESU was "in danger of extinction." This change reflects the larger adult returns over the past several years, which nevertheless remain well below preliminary targets for ESA recovery. In the Upper Columbia River, the majority BRT conclusions for spring chinook salmon and steelhead were still "in danger of extinction," but a substantial minority of the votes fell in the "likely to become endangered" category. The votes favoring the less severe risk category reflect the fact that recent increases in escapement have at least temporarily somewhat alleviated the immediate concerns for persistence of individual populations, many of which fell to critically low levels in the mid 1990s. Overall, although recent increases in escapement were considered a favorable sign by the BRT, the response was uneven across ESUs and, in some cases, across populations within ESUs. Furthermore, in most instances in which recent increases have occurred, they have not yet been sustained for even a full salmon/steelhead generation. The causes for the increases are not well understood, and in many (perhaps most) cases may be due primarily to unusually favorable conditions in the marine environment rather than more permanent alleviations in the factors that led to widespread declines in abundance over the past century. In general, the BRT felt that ESUs and populations would have to maintain themselves for a longer period of time at levels considered viable before it could be concluded that they are not at significant continuing risk.

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INTRODUCTION

During the 1990s, the National Marine Fisheries Service (NMFS) conducted a series of reviews of the status of West Coast populations of Pacific salmon and steelhead (*Oncorhynchus* spp.) with respect to the United States 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 (Federal Register, Vol. 59, No. 175, September 12, 1994, p. 46808).

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 salmon, NMFS has used the policy developed in 1991 (NMFS 1991; Waples 1991, 1995), which is described in the next section. As a result of these status reviews, NMFS has identified over 50 ESUs of salmon and steelhead from California and the Pacific Northwest, of which 26 are listed as threatened or endangered species under the ESA. A complete list of these evaluations can be found at (http://www.nwr.noaa.gov/1salmon/salmesa/fractlist.htm), and the technical documents representing results of the status reviews can be accessed online at Northwest Fisheries Science Center (http://www.nwfsc.noaa.gov/pubs/), Southwest Regional Office (http://swr.nmfs.noaa.gov/salmon.htm), Santa Cruz Laboratory (http://www.pfeg.noaa.gov/tib/esa/salmonids/esa_docs/index.html), and Northwest Regional Office (http://www.nwr.noaa.gov/1habcon/habweb/listnwr.htm) websites.

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, and regional planners will use this information to help 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/cbd/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 ruling in a lawsuit 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; Alsea decision). That 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 of the other listed ESUs of salmon and steelhead. Second, another lawsuit currently pending that involves the Southern California ESU of steelhead (EDC v. Evans, SACV-00-1212-AHS (EEA), United States District Court, C.D. California) 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 even for the most recently listed 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 (Federal Register Vol. 67, No. 28, February 11, 2002). This report summarizes updated biological information for the 26 listed salmon and steelhead ESUs and one candidate ESU (Lower Columbia coho salmon), and presents preliminary conclusions of the Biological Review Team (BRT) regarding their current risk status. The BRT consisted of a core group of scientists from the NMFS Northwest and Southwest Fisheries Science Centers, supplemented by experts on particular species from NMFS and other federal agencies. The BRT membership is indicated in the sections for each species.

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, 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 salmon, NMFS published a policy describing how the agency will apply the definition of "species" in the ESA to anadromous salmonid species, including sea-run cutthroat trout and steelhead (NMFS 1991). 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) will be considered "distinct" for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. An ESU is defined as a population that: 1) is substantially reproductively isolated from conspecific population, 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 NMFS Biological Review Teams have used a comprehensive approach to defining ESUs that utilized all available scientific information. 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 the BRT 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, that would 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 ESA status reviews conducted since 1993 have been guided by the NMFS ESA policy for artificial propagation of Pacific salmon and steelhead (NMFS 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, the NMFS 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 above, a recent court decision has determined that this approach is inconsistent with the act—an ESU must be listed or not listed in its entirety. At the same time that NMFS announced the status review updates, the agency committed to revising the ESA artificial propagation policy for Pacific salmon and using the revised policy to guide the hatchery ESU determinations and consideration of artificial propagation in the risk analyses (Federal Register Vol. 67, No. 28, February 11, 2002). Although a revised policy has not yet been proposed through formal rulemaking, a draft has been publicly available on the agency's web site since August 2002 (http://www.nwr.noaa.gov/HatcheryListingPolicy/DraftPolicy.pdf). That draft indicates that 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 pending resolution of this issue, the BRT has not attempted to revisit the ESU determinations for hatchery populations in this draft report. However, a working group has updated the stock histories and biological information for every hatchery population associated with each listed ESU, and comanagers and others are currently reviewing that information for accuracy and completeness (SSHAG 2003). This draft report has also provisionally assigned each hatchery population to one of four categories: (listed below). It remains to be determined how these categories relate to ESU membership.

Category 1—The hatchery population was derived from a native, local population; is released within the range of the natural population from which it was derived; and has experienced only relatively minor genetic changes from causes such as founder effects, domestication or non-local introgression. Examples of populations that fall into this category include:

a) A hatchery population that has been recently founded (e.g., within one or two generations) from a representative sample of a native, natural population.

b) A hatchery population that was founded some time in the past (e.g., more than two generations ago) as a representative sample from a native, natural population, and has received regular, substantial, and representative infusions of natural fish from the original founding population into the broodstock since that time.

Category 2—The hatchery population was derived from a local natural population, and is released within the range of the natural population from which it was derived, but is known or suspected to have experienced a moderate level of genetic change from causes such as founder effects, domestication or non-native introgression. Examples of populations that fall into this category include:

a) A hatchery population for which there is direct evidence (e.g., from molecular genetic data or breeding studies) of moderate genetic divergence between the hatchery population and the natural population from which it was derived. In this context, "moderate divergence" would be a level of divergence typical of that observed among natural populations within the same ESU.

b) A hatchery population that was founded from a native, natural population, but 1) the sample was not representative; or 2) the broodstock has received few or no reintroductions of native, natural fish since the time of founding; or 3) the hatchery population is believed to have experienced moderate genetic change (e.g., from domestication or non-local introgression) since the time of founding.

c) A hatchery population that was founded predominantly from a local natural population but has also had a greater level of introgression from non-local stocks than would be expected from natural straying rates.

Category 3—The hatchery population was derived predominantly from other populations that are in the same ESU, but is substantially diverged from the local, natural population(s) in the watershed in which it is released. Examples include:

a) A hatchery population that has been deliberately artificially selected, has experienced substantial unintentional domestication, or both.

b) A hatchery population that was founded in a substantially non-representative way or was founded long ago (many salmon generations) and has received few or no infusions of wild fish into the broodstock since the time of founding.

c) A hatchery population that was founded from a mixture of several natural or hatchery populations from within the ESU, or has experienced substantial introgression from non-local populations (much higher than would be expected from natural straying).

d) A hatchery population that was founded from within the ESU, but is released outside of the historical range of the natural population from which it was founded (but still within the historical range of the ESU).

Category 4—The hatchery population was predominantly derived from populations that are not part of the ESU in question; or there is substantial uncertainty about the origin and history of the hatchery population.

Resident fish

In addition to the anadromous life history, sockeye salmon (*O. nerka*) and steelhead (*O. mykiss*) have nonanadromous or resident forms, generally referred to as kokanee and rainbow trout, respectively. As is the case with hatchery fish, it is important to determine the relationship of these resident fish to anadromous populations in listed ESUs. This issue is complicated by the complexity of jurisdictional responsibilities—NMFS has ESA responsibility for anadromous Pacific salmonids, but the U.S. Fish and Wildlife Service (USFWS) has jurisdiction for resident fish. At the time this report was prepared, the two agencies had not reached agreement on how to determine the ESU/DPS status of resident fish or how to make the listing determinations for the overall ESU/DPSs.

For the purposes of this status review update, the BRT adopted a provisional working framework for determining the ESU/DPS status of resident *O. mykiss* 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. 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 provisional conclusions about the ESU/DPS status of resident fish, NMFS and USFWS have 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 between resident and anadromous forms;
Case 2: long-standing natural barriers (e.g., a waterfall) separate resident and anadromous forms;
Case 3: relatively recent (e.g., within last 100 years) human actions (e.g., construction of a dam without provision for upstream fish passage) separate resident and anadromous forms.

As a provisional framework, NMFS has adopted the following working assumptions about ESU membership of resident fish falling in each of these categories:

Case 1: Resident fish 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 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: resident fish assumed provisionally to be part of the ESU. Rationale: Case 3 populations were, most likely, Case 1 populations (and hence part of the ESU) prior to construction of the artificial barrier.

These default assumptions about ESU membership 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. In addition, some Case 3 populations that historically were part of the ESU may no longer be, as a result of rapid divergence in a novel environment, or displacement by or introgression from non-native hatchery rainbow trout. The BRT reviewed available information about individual resident populations of *O. mykiss* and *O. nerka* to determine which Case each population fits into and whether any information exists to override the default assumption about ESU membership.

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?” The ESA (section 3) defines the term “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 FWS have developed any formal policy guidance about how to interpret the definitions of threatened or endangered species in the act.

A variety of information is considered in evaluating the level of risk faced by an ESU. According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place. In its biological status reviews, the BRT does not evaluate likely or possible effects of conservation measures except to the extent they are reflected in metrics of population or ESU viability; these measures are taken into account in a separate process by the NMFS regional offices prior to making listing determinations. Therefore, the BRT does not make recommendations as to whether identified ESUs should be listed as threatened or endangered species, because that determination requires evaluation of factors not considered by the team. Rather, the BRT draws scientific conclusions about the risk of extinction faced by identified ESUs under the assumption that present conditions will continue into the future (recognizing, of course, that existing trends in factors affecting populations and natural demographic and environmental variability are inherent features of “present conditions”).

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 have focused on "natural" fish (which are defined as the progeny of naturally spawning fish),and whether 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 (Federal Register, Volume 65, Number 114, June 13, 2000, p. 37102) and is consistent with the approach USFWS has used in evaluating captive propagation programs for other species, such as the 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—the risk analysis for listed salmon and steelhead ESUs.

The draft revised hatchery policy reaffirms the interpretation that the purpose of the ESA is to conserve threatened and endangered species in their natural habitats. In its risk evaluations, the BRT therefore used the approach it has in the past—focusing on whether populations and ESUs are self-sustaining in their natural habitat. The draft policy also indicates that the potential conservation benefits of artificial propagation should be considered before a listing determination is made. The potential conservation benefits of artificial propagation, together with other conservation measures, will be considered by NMFS Regional Office and Headquarters staff in developing a listing proposal.

Artificial propagation is also important to consider in ESA evaluations of anadromous Pacific salmonids for several other reasons. First, although natural fish are the focus of ESU determinations, 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 short-term abundance of fish in an ESU, 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 possibly 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 above, the BRT 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, as well as 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. (Although the two listed sockeye salmon ESUs considered in this report [Redfish Lake and Lake Ozette] have associated kokanee populations, in neither case are the kokanee considered to be part of the sockeye salmon ESU, and so the kokanee were not formally considered in the risk analyses.) Information on resident fish is summarized below in the report for steelhead (Section B), where ESU-specific information is discussed in more detail. The steelhead report also contains a more general discussion of how resident fish were considered 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. This makes the assessment of extinction risk difficult. An approach to this problem has been adopted by NMFS for recovery planning, and is outlined in the “Viable Salmonid Populations” (VSP) report by McElhany et al. (2000). In this approach, risk assessment is addressed at two levels: first, the simpler 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. The condition of individual populations is then summarized on the ESU level, and larger-scale issues are considered in evaluating status of the ESU as a whole. These larger-scale issues include total number of viable populations, geographic distribution of these populations (to insure 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). These considerations are detailed in McElhany et al. (2000).

The Risk Matrix

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 (see Appendix 1) integrates the four major VSP criteria (abundance, productivity, spatial structure, 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 scores are tallied and reviewed by the BRT before making its overall risk assessment (see FEMAT method, below). Although this process helps to integrate and quantify a large amount of diverse information, there is not a 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 concerns for any other risk factor.

Scoring VSP criteria. Risks for each of the four VSP factors are ranked on a scale of 1 (very low risk) to 5 (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) *Increasing Risk*. Present risk is Low or Moderate, but is likely to increase to high risk in the foreseeable future if present conditions continue.

5) *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 year(s). 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.

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 above, these evaluations do not consider conservation measures and therefore are not recommendations regarding listing status). The overall risk assessment reflects professional judgment by each BRT member. This assessment is guided by the results of the risk matrix analysis as well as expectations about likely interactions among factors. 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. This method, also referred to as the FEMAT method because it was used by scientific teams evaluating options under President Clinton's Forest Plan (Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team (FEMAT; http://www.or.blm.gov/ForestPlan/NWFPTitl.htm), allows each reviewer to distribute 10 likelihood points among the three ESU risk categories, reflecting their opinion of the likelihood that that category correctly reflects the true ESU status. Thus, if a reviewer were certain that the ESU was in the "not at risk" category; then s/he 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. The FEMAT method has been used in all status review updates for anadromous Pacific salmonids since 1999.

METHODS

Data on adult returns were obtained from a variety of sources, including time series of freshwater spawner surveys, redd counts, and counts of adults migrating past dams/weirs. Time series were assembled at the scale of population where these have been identified by TRTs or quasi-population where population identification is ongoing.

Calculating recruits

Recruits from a give brood year are calculated as

$$C_t = \sum_{i=1}^{MaxAge} N_{t+i} A(i)_{t+i} \ , \qquad \text{(Eq. 1)}$$

where R_t is the number of recruits from brood year 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

$$C(preHarvest)_t = \sum_{i=1}^{MaxAge} P_{t+i} A(i)_{t+i} \ , \qquad \text{(Eq. 2)}$$

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 and simplifying assumptions are often made].

Mean abundance

Recent average abundance of natural-origin spawners is reported as the geometric mean of the most recent data. Five-year geometric means were calculated to represent the recent abundance of natural-origin spawners for each population or quasi-population within an ESU. Five-year geometric means for the most recent 5 years of available data were calculated, as well as the minimum and maximum 5-year geometric means for the entire time series. The equation for a 5-year geometric mean is

$$GM_{N_t} = \sqrt[5]{N_t N_{t-1} N_{t-2} N_{t-3} N_{t-4}}\ , \qquad \text{(Eq. 3)}$$

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

Zero values in the data set were replaced with a value of one, and missing data values within a 5-year range were excluded from geometric mean calculations. For example, if data were available from 1997–2001, with no data for 1998, the geometric mean was calculated as

$$GM_{N_{1997}} = \sqrt[4]{N_{1997} N_{1999} N_{2000} N_{2001}}\ . \qquad \text{(Eq. 4)}$$

Trends in abundance

Short-term and long-term trends were calculated from time series of adult spawners. Short-term was defined as that resulting from data from 1990 to the most recent year of data, with a minimum of 10 data points in the 13-year span. Long-term trend was defined as that resulting from all data in a time series.

Trend was calculated as the slope of the regression of natural-origin spawners (log-transformed); one was added to natural-origin spawners before transforming the data to mediate for zero values. Trend was reported in the original units as exponentiated slope such that a value > 1 indicates a population trending upward, and a value < 1 indicates a population trending downward. The regression was calculated as

$$\ln(N+1) = \beta_0 + \beta_1 X + \varepsilon\ , \qquad \text{(Eq. 5)}$$

where N is the natural-origin 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

$$\exp(\ln(b_1) - t_{0.05(2),df}\, s_{b_1}) \le \beta_1 \le \exp(\ln(b_1) + t_{0.05(2),df}\, s_{b_1})\ , \qquad \text{(Eq. 6)}$$

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. In addition, the probability that the trend value was declining [P(trend < 1)] was calculated.

Lambda calculations

The median growth rate (λ) of natural-origin spawners was calculated in two ways for each population over both short-term and long-term time frames as above (short-term = 1990-most recent year and long-term = all data). 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. However, this parameter can vary considerably across species and populations, and it is very rare that data are available for a particular population of interest.

A multi-step process based on methods developed by Holmes (2001), Holmes and Fagan (2002) and described in McClure et al. (in press) 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

$$R_t = \sum_{i=1}^{4} N_{t-i+1} \ . \qquad \text{(Eq. 7)}$$

where N_t is the number of natural-origin spawners in year t.

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

$$\hat{\mu} = mean\left(\ln\left(\frac{R_{t+1}}{R_t}\right)\right) \qquad \text{(Eq. 8)}$$

—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,

$$\hat{\lambda} = e^{\hat{\mu}} \ . \qquad \text{(Eq. 9)}$$

Confidence intervals (95%) were calculated for $\hat{\lambda}$ to provide a measure of the uncertainty associated with the growth rate point estimate. First, an estimate of variability was determined by calculating an estimate for σ^2 using the slope method (Holmes 2001). An estimate for σ^2, $\hat{\sigma}^2_{slp}$ was calculated for each population in an ESU, after which an arithmetic average of populations was calculated. This average was used as the measurement of variability for calculating confidence intervals for both short-term and long-term time series for all populations in an ESU.

We determined the degrees of freedom for the appropriate *t*-value for use in confidence interval calculations based on the method for adjusting degrees of freedom when variance is calculated using the slope method (Holmes and Fagan 2002). The adjusted degrees of freedom were then summed over all populations in an ESU to obtain the *df* to determine *t*. The degrees of freedom for each population was calculated as

$$df = 0.333 + 0.212n - L, \qquad \text{(Eq. 10)}$$

where n is the length of the time series and L is the number of counts summed to calculate R_t ($L = 4$ in these analyses). Confidence intervals were calculated as

$$\exp\left(\hat{\mu} \pm t_{.05(2),df}\sqrt{\hat{\sigma}_{slp}^{\;2} / \gamma(n-4)}\right), \qquad \text{(Eq. 11)}$$

where $\gamma \cong 1$. In addition, the probability that trend was less than one was calculated utilizing the fact that $\ln(\lambda)$ follows a *t*-distribution. The probability that λ is less than one is calculated by finding the probability that the natural log of the calculated lambda divided by its standard error is less than one, given the degrees of freedom, which is the number of data points used to calculate lambda minus two.

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 produces the most pessimistic view of viability of the natural population. To calculate the median growth rate under this assumption, that hatchery-origin spawners have reproductive success equivalent to that of natural-origin spawners (λ_h), a modified approach to the method developed by Holmes (2001) 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

$$(RN)_t = \sum_{i=1}^{4} N_{t-i+1}\,. \qquad \text{(Eq. 12)}$$

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

$$(RH)_t = \sum_{i=1}^{4} H_{t-i+1}\,, \qquad \text{(Eq. 13)}$$

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

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

$$\psi_t = \frac{(RN)_t + (RH)_t}{(RN)_t}. \qquad \text{(Eq. 14)}$$

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

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

$$A_j = \sum_{j=1}^{\max\text{ age}} \sum_{all\ t} a_j (N+H)_t. \qquad \text{(Eq. 15)}$$

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

$$G = \sum_{j=1}^{\max age} A_j . \qquad \text{(Eq. 16)}$$

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

$$T = \sum_{j=1}^{\max age} \frac{j \times A_j}{G}. \qquad \text{(Eq. 17)}$$

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

$$\hat{\mu} = mean\left(\ln\left(\frac{(RN)_{t+1}}{(RN)_t} \right) - \frac{1}{T} \ln(\psi_t) \right). \qquad \text{(Eq. 18)}$$

The point estimate for λ_h was then calculated as the median annual population growth rate,

$$\hat{\lambda}_h = e^{\hat{\mu}} . \qquad \text{(Eq. 19)}$$

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:

$$\hat{\sigma}^2 = \text{slope of var}\left(\ln\left(\frac{(RN)_{t+\tau}}{(RN)_t} \right) - \frac{1}{T} \ln\left(\prod_{i=0}^{\tau-1} \psi_{t+i} \right) \right) \text{vs. } \tau. \qquad \text{(Eq. 20)}$$

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Appendix 1. A template for the risk matrix used in BRT deliberations. The matrix is divided into five sections: corresponding to the four VSP "parameters" (McElhany et al. 2000) plus a "recent events" category.

[ESU Template]

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)