UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, WA 98112-2097

February 3, 2004

MEMORANDUM FOR: D. Robert Lohn, Regional Administrator, Northwest Region; Rod McInnis, Acting Regional Administrator, Southwest Region

FROM: Usha Varanasi
Science and Research Director
Northwest Fisheries Science Center

SUBJECT: Extinction Risk Assessments for Evolutionarily Significant Units (ESUs) of West Coast *Oncorhynchus mykiss*

This document is a response to your request (November 13, 2003 memorandum from D. Robert Lohn and Rod McInnis) for clarification of extinction risk assessments by the Biological Review Team (BRT; NMFS 2003) for Evolutionarily Significant Units (ESUs) of *Oncorhynchus mykiss*. The BRT concluded that, below natural barriers to upstream migration by anadromous salmonids, resident fish are part of *O. mykiss* ESUs that include anadromous fish. The specific question addressed in this document is: "For each *O. mykiss* ESU in the Northwest and Southwest Regions, is the ESU in-total likely to persist into the foreseeable future in the geographic range presently occupied below impassable natural and man-made barriers?" In responding to this question, we begin by making three observations:

1) None of these ESUs is likely to persist in-total into the foreseeable future because substantial parts of the ESUs are at risk of extinction. Therefore, the anadromous life history may be considered a significant portion of the species "range," such that its loss is a direct threat to the ESU.
2) In many of these ESUs, remnant resident populations might persist indefinitely even if anadromous populations were lost. These ESUs might therefore persist in part, but (as discussed below) this is uncertain.
3) Although a resident-only population structure might ensure persistence of *O. mykiss* in the area, it is not likely to preserve the ESU as defined unless the genetic basis of anadromy is maintained in residents.

In light of these observations, our interpretation of the question posed above leads us to put it in another way, which highlights the key scientific issue considered here: *Is the resident component of an* O. mykiss *ESU composed of both anadromous and resident life-history forms sufficient for long-term persistence of the ESU*?

We know that some populations of *O. mykiss* composed of resident fish below long-standing migration barriers have persisted for several decades in the interior Columbia River Basin since major impediments to anadromous migration were established by the mid-20th century. The apparent numerical dominance of the resident form in these populations indicates that residents provide some protection against imminent extinction from this class of threats.

However, although we conclude that abundant resident populations can significantly reduce one component of the risk to an ESU by increasing overall abundance, there is considerable scientific uncertainty as to how the resident form affects extinction risk through its influence on ESU productivity, spatial structure, and diversity. The threats to *O. mykiss* ESUs extend beyond low population size and include declining productivity, reduced resilience of productivity to environmental variation, curtailed range of distribution, impediments to population connectivity and reproductive exchange, depleted diversity stemming from loss or blockage of habitat and associated erosion of local adaptation, and erosion of the diversity of expressed migratory behaviors. Thus, we conclude that, despite the reduced risk to abundance for certain *O. mykiss* ESUs due to numerically abundant residents, the collective contribution of the resident life-history form to the viability of an ESU as a whole is unknown and may not substantially reduce extinction risks to an ESU in-total. Based on present scientific understanding, we cannot exclude the possibility that complete loss of anadromous forms from within an ESU may be irreversible.

The rationale for this conclusion follows. In providing the scientific basis for these conclusions, we provide a summary of the BRT's consideration of resident fish and the scientific uncertainty regarding their ecological relationships. A draft of one independent report on Columbia River Basin *O. mykiss* (Kostow 2003) provided valuable information to the BRT. Another recent report focusing on *O. mykiss* in the mid-Columbia River ESU (Cramer et al. 2003) was published after the BRT reached its findings. We consider the conclusions of these reports in light of Viable Salmonid Populations (VSP; McElhany *et al.* 2000) criteria and current information on the relationship between resident and anadromous forms of *O. mykiss*. In an appendix, we summarize the BRT's risk assessments for the ten *O. mykiss* ESUs reviewed, with attention on the relationship of anadromous and resident forms to VSP criteria.

SUMMARY OF BRT APPROACH

Determining ESU Membership

The *O. mykiss* BRT final report (NMFS 2003) is summarized here with emphasis on the relationship between anadromous and resident *O. mykiss.* We provide no new analyses or information beyond considering how independent analyses have evaluated this relationship and its effect on extinction risk, and in reviewing several recent publications on *O. mykiss*. In its report the BRT noted that this relationship is not well understood and that the ESU status of many resident populations remains uncertain. The BRT considered information and analyses made available in an earlier draft of the Kostow (2003) report, which addressed Columbia River Basin *O. mykiss* ESUs, in evaluating the level of reproductive isolation between the resident and anadromous populations and determining the membership of a given *O. mykiss* ESU. The BRT relied heavily on the information in the Kostow draft for the abundance and distribution of resident fish. The BRT generally considered co-occurring resident and anadromous fish to be part of the same ESU. Where they co-occur the two life-history forms may interbreed, or produce offspring of the alternate life-history form, at least in some cases (Burgner *et al.* 1992; Shapovalov and Taft 1954; Mullan *et al*. 1992; Zimmerman and Reeves 2000; F. Thrower, Alaska Fisheries Science Center, unpubl. data). Patterns of genetic relationship among populations often correlate more strongly with geography than life history, and there is growing evidence for multiple origins and parallel evolution of anadromy and residency in *O. mykiss* (e.g., McCusker *et al.* 2000, Docker and Heath 2003). Where long-standing natural barriers separate the resident and anadromous forms, resident populations were not regarded as part of the ESU. Many populations in this category have been isolated from contact with anadromous populations for thousands of years and often exhibit substantial genetic and life-history divergence from the nearest downstream anadromous populations.

On the issue of ESU status of resident populations above relatively recent man-made barriers, the BRT recognized the need for case-by-case decisions but found relevant information only for a few populations. Although the two life-history forms most likely existed without any barriers to interbreeding prior to the establishment of the manmade barrier(s), given the paucity of available information the current ESU relationship of these resident populations is uncertain. Resident populations above man-made barriers may no longer represent the evolutionary legacy of an *O. mykiss* ESU due to rapid divergence in a novel environment, or displacement by or introgression from non-native hatchery rainbow trout. Indeed, the stocking of hatchery-origin *O. mykiss* into reservoirs for recreational fishing has been pervasive throughout the western United States, including areas inhabited previously by anadromous salmonids. Because of the widespread lack of information on the relationship between particular

anadromous and resident populations, the BRT concluded it could not categorically determine whether these resident populations should or should not be included in an *O. mykiss* ESU.

Assessing ESU Viability

The BRT assessed ESU-level extinction risk at two levels: first, at the population level; then, at the overall ESU level. The BRT used VSP criteria to guide their risk analyses. The VSP criteria were developed to provide a consistent and transparent reference for making viability determinations and are based on a review and synthesis of the conservation biology and salmon literature. Individual populations were evaluated according to the four VSP criteria: abundance, growth rate/productivity, spatial structure, and diversity. These four parameters are important indicators of species status and together represent reasonable predictors of extinction risk. These parameters are also the same criteria being used by the agency's Technical Recovery Teams, therefore providing some continuity with salmon and steelhead recovery planning. After reviewing all relevant biological information for the populations in a particular ESU, the BRT estimated an ESU-level risk score for each of the four VSP criteria.

Factors considered in relating the population-level VSP criteria to ESU-level extinction risk include: the total number of viable populations; the geographic distribution of these populations; the connectivity among populations; and the genetic, behavioral, and ecological diversity among populations. ESUs with fewer populations are more likely to become extinct due to catastrophic events, and have a lower likelihood that the necessary phenotypic and genotypic diversity will exist to maintain future viability. ESUs with limited geographic range are similarly considered to be at increased extinction risk due to catastrophic events and anthropogenic factors. ESUs with populations that are geographically distant from each other, or are separated by severely degraded habitat, may lack the connectivity to function as metapopulations and are more likely to become extinct. ESUs with limited diversity are more likely to go extinct as the result of correlated environmental catastrophes or environmental change that occurs too rapidly for an evolutionary response. ESUs comprised of a small proportion of populations meeting or exceeding VSP criteria may lack the "source" populations to sustain the non-viable "sink" populations during environmental downturns. These considerations are described in the BRT's report (NMFS 2003), and further detailed in McElhany *et al*. (2000). In short, a viable ESU by definition has a negligible risk of going extinct as a result of normal environmental variation, genetic change, catastrophic events or human activity. A viable ESU typically has multiple viable populations that have sufficient abundance and growth rates, possess a variation in traits, and are spatially well distributed to survive environmental variation and natural or anthropogenic catastrophes (however, it should be recognized that some ESUs may historically only have had a single population).

Assessing Viability of O. mykiss *ESUs*

Despite concerted efforts to collect and synthesize available information on resident forms of *O. mykiss*, existing data regarding interactions between resident and anadromous forms are meager (NMFS 2003). This uncertainty about the relationship between the resident and anadromous forms complicates the evaluation of individual VSP parameters, and thus extinction risk analysis for an *O. mykiss* ESU in-total. In its risk assessments for *O. mykiss* ESUs, the BRT focused primarily on information for anadromous populations, which often represented the only quantitative data available. As discussed in the BRT report, the presence of relatively numerous, native resident fish was considered to be a mitigating risk factor for some ESUs; however, the scientific uncertainty about the contribution of resident *O. mykiss* to ESU productivity, spatial structure, and diversity makes it difficult to determine the degree to which extinction risk is reduced by the resident life-history form. Below we summarize the BRT's consideration of resident fish for each of the VSP parameters.

Abundance – Abundance data are much more sparse for the resident than the anadromous form. Were such information generally available, abundance estimates might increase substantially in some populations and ESUs. Relatively abundant resident fish contribute to the total abundance of *O. mykiss* in the Snake River, Upper Columbia River, Middle Columbia River, Central California Coast, South-Central California Coast, Southern California, and California Central Valley ESUs. Resident fish do not greatly affect abundance in the Lower Columbia River, Upper Willamette River, and Northern California *O. mykiss* ESUs.

Productivity – It is unclear how resident fish contribute to ESU growth rate/ productivity. Life-history characteristics that influence productivity (e.g., fecundity, age at first reproduction, survival) differ between resident and anadromous *O. mykiss*, and the relative productivity of the two life-history forms is not well understood, even

though lifetime fecundities of anadromous females may be an order of magnitude higher than those of residents (therefore, anadromous forms may be substantially more productive per capita than residents). Nevertheless, in many areas above human-caused barriers to migration, natural resident populations have persisted for decades, a fact that demonstrates the ability of these isolated populations to persist without anadromy (Kostow 2003). However, the benefits of maintaining an anadromous life-history form include: 1) protection against catastrophic events that destroy natal freshwater habitat, and 2) a means of increasing ESU productivity by utilizing the marine environment and suitable freshwater habitat elsewhere, particularly when conditions in natal freshwater habitat are unfavorable (e.g., due to land-use practices in watersheds). It is unclear how long an *O. mykiss* ESU that historically produced anadromous migrants can persist if dependent entirely upon the productivity of resident fish. The ability of residents to contribute to anadromy may quickly diminish if the fitness of their anadromous progeny is low, an issue that remains a key scientific uncertainty.

Spatial Structure & Connectivity – Spatial structure is an important component of *O. mykiss* viability because it fosters opportunities for development of local adaptations, protects an ESU against catastrophic events impacting individual populations, and supports connectivity among populations (McElhany *et al.* 2000). The BRT noted the critical role that anadromous *O. mykiss* play in providing linkages among different spawning populations within an ESU. Whether resident forms of *O. mykiss* alone are able to maintain sufficient connectivity among populations is not known. Resident populations are more prone to population fragmentation than anadromous ones. Resident populations can become isolated and vulnerable to local extinctions if habitat downstream becomes inhospitable, and natural recolonization can be difficult. Whether extensive river migrations are an important behavior generally for resident *O. mykiss* is not clear, although there is some evidence for in-river migrations of tens of kilometers for resident trout. Connectivity among populations greatly reduces the risk that populations at low abundance will be extirpated; reductions in population connectivity can increase ESU extinction risk. Zimmerman and Reeves (2000) provide data indicating that connectivity between sympatric and resident populations varies greatly among rivers.

Diversity – Diversity is important to viability in a spatially and temporally variable environment. Phenotypic (expressed) diversity allows a species to use a wider array of environments than it could without this variability. Variation in spawn timing, for example, permits *O. mykiss* to utilize habitats with distinct hydrologic and thermal regimes for both spawning and rearing. Diversity also protects a species against short-term spatial and temporal changes in the environment. The variable age structure of *O. mykiss* helps buffer populations from unpredictable environmental threats and year-class failures. Diversity also enables a species to cope with longer-term environmental changes. Salmonids, including *O. mykiss*, regularly face cyclic or directional changes in their freshwater, estuarine, and ocean environments, and genetic diversity underlying life-history variation allows them to adapt to these changes. The increase in diversity when resident and anadromous fish co-occur is evident in morphology, physiology, and life-history strategies, as well as in molecular genetic diversity. Indeed, there is little doubt that the range of variation in migratory propensity present in *O. mykiss* is a key component of an evolutionary strategy to persist in an environment that varies substantially in space and time. The resident form increases, to an uncertain degree, the ability of a population to endure physical, environmental, or ecological changes that restrict anadromous migration. As noted above, we consider the anadromous form to represent a critical component of the species' evolutionary "bet-hedging" strategy for coping with environmental and ecological challenges, as well as an opportunistic means of increasing scope for growth and reproductive potential. The prevalence of a mixed migratory strategy (resident and anadromous forms) in interior ESUs, where threats to viability are often highest, likely reflects the importance of both forms to sustainable production in these ESUs.

Summary of Consideration of VSP Parameters – The ability of the resident form alone to maintain an *O. mykiss* ESU's viability in a deteriorating or unpredictable environment is not known. Although abundant resident populations can reduce risks to ESU abundance, their contribution to ESU productivity, spatial structure, and diversity is unclear. The above discussion underscores the importance of the anadromous life-history form in reducing risks to these latter three VSP parameters, and thus in contributing to a viable *O. mykiss* ESU in-total. The extent to which adult residents can produce anadromous offspring, thereby reducing risks to all VSP parameters, is not known for most populations; in those for which it has been documented, this propensity appears to be quite variable. In some populations residents produce few or no anadromous progeny.

The genetic and environmental factors that influence expression of these different life-history forms are not well understood, but empirical evidence indicates that both genetic diversity and phenotypic plasticity (the capacity of particular genetic types to produce different life-history forms in different environments) are probably involved in the maintenance of anadromy and freshwater residency. There is evidence for substantial genetic variability underlying migratory tendency in some resident *O. mykiss* (F. Thrower and J. Hard, unpubl. data; see also Boula *et al*. 2002 for evidence from brook charr). Even so, in full sympatry resident and anadromous life histories maintain distinct phenotypes. Furthermore, the inheritance and expression of anadromy in wild *O. mykiss* may be substantially lower than that measured in hatchery populations due to large environmental effects on expression. Collectively, these observations indicate the potential for resident populations historically connected to anadromous populations to generate anadromous migrants. This potential may, however, be short-lived if the reproductive success of anadromous individuals migrating from the resident population is low. In this case, natural selection may quickly erode a population's ability to produce the anadromous phenotype. This prospect raises significant questions regarding the ability of resident forms to "recover" anadromous populations of *O. mykiss.*

EVALUATION OF TWO INDEPENDENT RISK ASSESSMENTS

There have been other attempts at risk analysis for some *O. mykiss* ESUs. In addition to the BRT report (NMFS 2003), Kostow (2003) summarized approaches and considerations for ESUs in the Columbia River Basin, and Cramer *et al.* (2003) summarized approaches and considerations for the Middle Columbia River ESU. Although the information presented in a draft of the Kostow (2003) report was considered by the BRT in its determinations of ESU membership and assessments of ESU viability, the BRT met before the final Kostow report and the Cramer *et al.* (2003) report were available. These reports are noteworthy for two reasons: 1) although they considered diversity, neither evaluated the effects of parameters other than abundance and productivity (e.g., spatial structure/connectivity and diversity) on viability, and 2) both took resident fish into account in assessing risk. As a result, they concluded that extinction risk in corresponding ESUs was lower than the risk estimated by the BRT.

These reports differ substantively in approach and scope from the BRT's risk assessments. Kostow (2003) considered several approaches to evaluating ESU productivity. However, her assessments were based heavily on data that are readily quantified: abundance (of residents as well as anadromous fish, if that information was available) and productivity. Kostow argued that despite the loss of anadromy in several interior Columbia River basin *O. mykiss* ESUs, it is highly probable that the species would persist into the foreseeable future without anadromous steelhead (Middle Columbia River, Upper Columbia River and Snake River ESUs). Indeed, she emphasizes the point that the conclusion for persistence depends critically on the question; if the question is whether any form of *O. mykiss* in an ESU currently dominated by residents is likely to persist for the foreseeable future, the answer is affirmative. We believe the more appropriate question is whether the diversity of life-history strategies historically present in an ESU is critical for persistence into the foreseeable future.

Her argument hinges on the observation that several populations of *O. mykiss* have already persisted for several decades above barriers in interior ESUs, in the face of declines of anadromous populations. She included above-barrier resident populations in her assessments, while the BRT considered only below-barrier resident populations co-occurring with anadromous fish. Kostow's consideration of risk represented primarily an abundance-centered approach, focusing on overall abundance (and, where available, productivity) information but not explicitly considering the contributions of resident fish to ESU spatial structure, and diversity. Hence, her approach focused on the persistence of *O. mykiss* in any form in these ESUs. The BRT's approach underestimated overall abundance in some ESUs by ignoring residents above barriers, but they gave considerable consideration to threats to diversity and connectivity when anadromous fish are absent.

Cramer *et al.* (2003) concluded that extinction risk for the Middle Columbia River ESU is low. Cramer *et al.* (2003) argued that resident fish in the Middle Columbia River will produce anadromous migrants into the foreseeable future, while providing little direct evidence to support this claim. At the same time, these authors' population viability analyses considered residents primarily as competitors with anadromous fish for space. The Cramer *et al.* (2003) study was not intended as a synoptic assessment of ESU-level risk. Their modeling efforts focused on the Deschutes River population. Cramer *et al.* (2003) specifically investigated competitive interactions among the life-history forms, as well as the influence of hatchery-origin fish on natural spawners.

In the above reports, the authors recognized the ecological and evolutionary importance of the diversity of life-history types in interior populations of *O. mykiss*. However, we believe their analyses give inadequate consideration to the contribution that anadromous fish make to long-term productivity, spatial structure, and diversity in these populations, particularly given the cataclysmic environmental history of this region over the past several millennia (due to, e.g., glaciation, massive flooding, and volcanism). Indeed, the 1980 eruption of Mt. St. Helens clearly revealed the value of increased population resiliency associated with anadromous behavior, factors that may be critically important for long-term persistence. Although the BRT in its report did not account quantitatively for the abundance of resident fish in evaluating risk, it did attempt to apply some credit for the abundance of resident fish as a factor mitigating risk (and it was considered a mitigating factor for some ESUs. Moreover, the BRT did attempt to consider all VSP parameters. We believe that failing to consider all four VSP factors underestimates long-term risk by ignoring the contribution that anadromous fish make to productivity, connectivity, and diversity in these populations.

CONCLUSIONS

The BRT report (NMFS 2003) concluded that several interior ESUs of *O. mykiss* were at risk of extinction; independent evaluations by Kostow (2003) and Cramer *et al.* (2003) came to different conclusions. This disparity in conclusions arose primarily because the BRT felt that the information available on the interactions between anadromous and resident forms is still insufficient to adequately evaluate the contribution of resident fish to overall ESU viability; thus, the BRT's conclusions were influenced substantially by an evaluation of the status of the anadromous form only. We believe that the presence of resident forms in a mixed ESU can reduce extinction risk only when they contribute to spatial structure and diversity by maintaining connectivity among populations and the ability to produce anadromous progeny. The other reports shed no new insight on this essential problem.

The factors that affect viability of *O. mykiss* in ESUs with historical connections to the ocean are complex, and evaluating extinction risk in these ESUs cannot rely on a simple formula. The wide range of variation in the migratory mechanisms that *O. mykiss* employs to cope with environmental challenges, when coupled with iteroparity (ability to survive spawning), is unparalleled among Pacific salmonids. A mixed migratory strategy may represent an important evolutionary strategy in interior ESUs, where threats to viability can often be very high. The uncertainty surrounding these factors and the risk they reflect will not be resolved by more accurate estimates of abundance of resident fish, or even solely by greater knowledge of their relative productivities. What is needed is a better understanding of the factors that influence expression and success of the alternate life histories and of the range of variability in migratory propensity itself. Work on this problem has seldom been attempted because it requires considerable resources and time to accomplish.

We conclude that the BRT's risk evaluations for these *O. mykiss* ESUs remain the most comprehensive assessments available, and that most of the ESUs with steeply declining anadromous populations are at some risk of extinction, particularly when one examines the overall declines in abundance over the past century. Furthermore, because of the lack of substantive empirical data on the relationship between resident and anadromous *O. mykiss*, we conclude that at present there is a high likelihood that ESU viability will not be secure unless there is an adequate opportunity for continued expression of anadromy and other migratory strategies.

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APPENDIX

What follows is a brief summary of the BRT's risk assessments for ten *O. mykiss* ESUs from NMFS (2003).

Brief Summary of BRT Risk Assessments for Ten O. mykiss *ESUs*

The BRT quantified extinction risk using a matrix that integrated abundance, productivity, spatial structure, and diversity. In its deliberations, the BRT considered information on presence of resident forms in areas where they co-occur with the anadromous form. For some BRT members, reports of abundant populations of the resident form were considered to be a mitigating factor in the assessment of extinction risk. For others, the paucity of information concerning the potential contribution of the resident form to ESU productivity, spatial structure, and diversity rendered reports of the presence of resident form unpersuasive in the overall extinction risk assessment of the *O. mykiss* ESUs. Below we clarify the BRT's risk assessments for the 10 *O. mykiss* ESUs reviewed by more clearly articulating the contribution of resident populations to the individual VSP risk scores, and collectively to ESU viability.

Snake River Basin ESU

Resident fish below historical barriers were assumed to be part of the ESU, while those above long-standing natural barriers (e.g., Palouse and Malad rivers) were not. Recent genetic data suggested 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 introduced to that and other areas should not. The BRT did not attempt to resolve the ESU status of resident fish residing above the Hell's Canyon Dam complex, as little new relevant information was available.

The BRT assigned moderate risk scores for all VSP categories. For many BRT members, the presence of relatively numerous resident fish reduced risks to ESU abundance, but provided an uncertain contribution to ESU productivity, spatial structure, and diversity. The majority opinion of the BRT was that the naturally spawned component of the Snake River Basin *O. mykiss* ESU is "likely to become endangered within the foreseeable future." The minority BRT opinion was split between the "in danger of extinction" and "not in danger or extinction or likely to become endangered within the foreseeable future" extinction risk categories.

Upper Columbia River ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers (e.g., in Entiat, Methow, and perhaps Okanogan basins) were not. Resident fish above Conconully Dam are of uncertain ESU affinity. Similarly, the BRT did not attempt to resolve the ESU status of resident fish residing above Grand Coulee Dam, as little new relevant information was available.

The BRT assigned high-risk scores for all VSP categories, particularly growth rate/ productivity. For many BRT members, the presence of relatively numerous resident fish reduces risks to ESU abundance, but provides an uncertain contribution to ESU productivity, spatial structure, and diversity. The BRT opinion for the Upper Columbia River *O. mykiss* ESU was split between the "in danger of extinction" and "likely to become endangered within the foreseeable future" categories.

Middle Columbia River ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers (e.g., Deschutes and John Day basins) were not. 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 River were of uncertain ESU status.

The BRT assigned moderate risk scores for all VSP categories. The BRT noted that resident fish are very common in this ESU and may greatly outnumber anadromous fish. Historically, resident fish are believed to have occurred in all areas in the ESU used by anadromous fish, although current distribution is more restricted. The BRT concluded that the relatively abundant and widely distributed resident fish reduce risks to ESU abundance, but provide an uncertain contribution to ESU productivity, spatial structure, and diversity. The opinion of the BRT was

split between the “likely to become endangered within the foreseeable future” and “not in danger or extinction or likely to become endangered within the foreseeable future” extinction risk categories.

Lower Columbia River ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers (e.g., upper Clackamas and Sandy rivers, and some of the small tributaries of the Columbia River Gorge) were not. Resident fish above dams on the Cowlitz, Lewis, and Sandy rivers were of uncertain ESU status.

The BRT assigned moderate risk scores for all VSP categories. 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. The Willamette Lower Columbia River TRT has estimated that at least four historical populations are now extinct. The hatchery contribution to natural spawning remains high in many populations. Resident fish are not as abundant in this ESU as they are in the inland *O. mykiss* ESUs. The BRT did not consider resident fish to reduce risks to ESU abundance, and their contribution to ESU productivity, spatial structure, and diversity is uncertain. The majority opinion of the BRT was that the Lower Columbia River *O. mykiss* ESU is “likely to become endangered within the foreseeable future.” The minority opinion was that the ESU is “not in danger or extinction or likely to become endangered within the foreseeable future.”

Upper Willamette River ESU

Resident fish below barriers in the Pudding/Molalla, Lower Santiam, Calapooia, and Tualatin drainages were assumed to be part of the ESU. 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 ESU.

The BRT assigned moderate risk scores for all VSP categories. Because coastal cutthroat trout is dominant in the basin, resident *O. mykiss* are not as abundant or widespread here as in the inland *O. mykiss* ESUs. The BRT did not consider resident fish to reduce risks to ESU abundance, and their contribution to ESU productivity, spatial structure, and diversity is uncertain. The majority opinion of the BRT was that the Upper Willamette River *O. mykiss* ESU is “likely to become endangered within the foreseeable future.” The minority BRT opinion was that the ESU is “not in danger or extinction or likely to become endangered within the foreseeable future.”

Northern California ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers were not. Resident fish above recent (usually man-made) barriers (e.g., 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.

The BRT assigned moderate-high risk scores for abundance and productivity and low-moderate scores for spatial structure and diversity, although at least one BRT member gave a score of 4 for the latter metrics. Historically, resident fish are believed to have occurred in all areas in the ESU used by anadromous fish, although current distribution is more restricted. In this ESU, resident fish do not substantially increase the total ESU abundance. The BRT did not consider resident fish to reduce risks to ESU abundance, and their contribution to ESU productivity, spatial structure, and diversity is uncertain. The majority opinion of the BRT was that the Northern California *O. mykiss* ESU is “likely to become endangered within the foreseeable future.” The minority BRT opinion was split between the “in danger of extinction” and “not in danger or extinction or likely to become endangered within the foreseeable future.”

Central California Coast ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers were not. Resident fish above recent (usually man-made) barriers (e.g., 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. An estimated 22% of historical habitat is behind recent barriers; the only relevant information about the populations above these barriers pertains to Alameda Creek, which suggests that some but not all populations above Dam 1 are genetically similar to populations within the ESU.

The BRT assigned moderate-high risk scores for abundance, growth rate/productivity, and spatial structure, and moderate risk for the diversity category. Historically, resident fish are believed to have occurred in all areas in the ESU used by anadromous fish, although current distribution is more restricted. For some BRT members, the presence of relatively numerous resident fish reduces risks to ESU abundance, but provides an uncertain contribution to ESU productivity, spatial structure, and diversity. The majority opinion of the BRT was that the Central California Coast *O. mykiss* ESU is "likely to become endangered within the foreseeable future;" the minority opinion was that the ESU is "in danger of extinction."

South-Central California Coast ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers were not. Resident fish above recent (usually man-made) barriers (e.g., 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.

The BRT found high risks for each of the four VSP categories, particularly for spatial structure. Historically, resident fish are believed to have occurred in all areas in the ESU used by anadromous fish, although current distribution is more restricted. For some BRT members, presence of relatively numerous resident fish reduces risks to ESU abundance, but provides an uncertain contribution to ESU productivity, spatial structure, and diversity. The strong majority opinion of the BRT was that the South-Central Coast *O. mykiss* ESU is "likely to become endangered within the foreseeable future." The minority opinion was that the ESU is "in danger of extinction."

California Central Valley ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers were not. Resident fish above recent (usually man-made) barriers (e.g., 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 anadromous fish habitat.

The BRT assigned high-risk scores for abundance, productivity and spatial structure and moderate risk scores for diversity. Historically, resident fish are believed to have occurred in all areas in the ESU used by anadromous fish, although current distribution is more restricted. For some BRT members, the presence of relatively numerous resident fish reduces risks to ESU abundance, but provides an uncertain contribution to ESU productivity, spatial structure, and diversity. The majority opinion of the BRT was that the naturally spawned component of the California Central Valley *O. mykiss* ESU is "in danger of extinction." The minority opinion was that the ESU is "likely to become endangered within the foreseeable future."

Southern California ESU

Resident fish below historical barriers were assumed to be part of this ESU, while those above long-standing natural barriers were not. Resident fish above recent (usually man-made) barriers (e.g., Twitchell Dam on the Cuyama River; Bradbury Dam on the Santa Ynez River; Casitas Dam on Coyote Creek, Ventura River; Matilija Dam on Matilija Creek, Ventura River; Santa Felicia Dam on Piru Creek, Santa Clara River; and Casitac Dam on Casitac Creek, Santa Clara River) but below natural barriers are of uncertain ESU affinity.

The BRT found extremely high risks for each of the four VSP categories. Historically, resident fish are believed to have occurred in all areas in the ESU used by anadromous fish, although current distribution is more restricted. Due to the extremely low numbers of anadromous fish in this ESU, resident populations likely comprise a significant proportion of fish in the ESU. For some BRT members, the presence of resident fish the presence of relatively numerous resident fish reduces risks to ESU abundance, but provides an uncertain contribution to ESU productivity, spatial structure, and diversity. The strong majority opinion of the BRT was that the Southern California *O. mykiss* ESU is "in danger of extinction." The minority opinion was that the ESU is "likely to become endangered within the foreseeable future."

cc: Dick Neal, SWFSC
Peter Adams, SWFSC
John Stein, NWFSC