MEMORANDUM FOR: F/NWC – Usha Varanasi

FROM: F/NWC – Mary Ruckelshaus and the Puget Sound TRT

SUBJECT: TRT documents

Attached is the Puget Sound Technical Recovery Team (TRT) document describing planning ranges for population viability and initial guidelines for developing ESU recovery scenarios. This viability document builds on previous documents produced by the TRT that identified population structure—our document was publicly circulated as a draft a year ago.

As we previously agreed, this viability document is being provided to you at this time to help NMFS in its efforts through the Shared Strategy to provide timely guidance to stakeholders and regional planning groups regarding expectations for salmon recovery. This viability document is a draft, and numbers and technical recommendations in it are likely to change as a result of technical review by regional biologists as well as external peer reviewers. Nevertheless, we hope information contained in this document will help watershed groups and other salmon recovery planners begin to understand what magnitude of change in population parameters will be needed to achieve population and ESU viability in their regions.

These viability reports represent a major step in developing eventual delisting criteria at the ESU level, but the latter will require additional considerations that include both technical and policy aspects. We look forward to continuing to work with the Regional Office and the Shared Strategy in helping to guide the scientific aspects of recovery planning.

As you know, the Shared Strategy has been active in the Puget Sound area for over two years, and the TRT has worked closely with the Shared Strategy to develop a plan for the most effective transfer of technical information to regional recovery planners. In addition, the State and Tribal comanagers in Puget Sound have been involved in a parallel process to develop recovery goals for Puget Sound chinook salmon. The draft Puget Sound document includes input from the comanager analyses and is designed to meet the technical needs for Step 2 of the Shared Strategy (i.e., clear articulation of planning targets for population viability goals). The role of the TRT analyses at this stage in Puget Sound is to contribute to defining a range within which population viability parameters occur. Within this range, the Shared Strategy is presenting co-manager targets to motivate watershed planning (Step 3 of the Shared Strategy).

The Puget Sound document focuses on chinook salmon at this stage, following policy advice from NMFS' Northwest Regional Office. The TRT expects to identify populations of Hood Canal summer chum and Lake Ozette sockeye by early fall, 2002. Population and ESU viability criteria for those 2 ESUs will follow in 2003.

We would be happy to discuss this document with you further, and we look forward to moving on to our next tasks.

Planning Ranges and Preliminary Guidelines for the Delisting and Recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit

Puget Sound Technical Recovery Team
April 30, 2002

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1.0 Introduction

The Puget Sound Technical Recovery Team (TRT) (http://www.nwfsc.noaa.gov/cbd/trt/) is working with the Shared Salmon Strategy (http://www.sharedsalmonstrategy.org/) to develop a recovery plan for listed salmonids in Puget Sound. The members of the Shared Strategy have agreed to a process by which a recovery plan will be developed in 5 steps. Step 1—to develop an outline for the recovery plan that addresses the needs of the Endangered Species Act (ESA) and broader regional goals—is complete. The contents of this TRT document represent the technical underpinnings of Step 2—i.e., the information that follows articulates draft targets for recovery for populations of chinook salmon in Puget Sound. These fish-based targets—termed planning targets—are designed to be used in Step 3 of the Shared Strategy process. In Step 3, watershed groups around Puget Sound conduct necessary analyses to determine what magnitude of effort (in habitat actions) is needed to achieve their population-specific targets for recovery. Additional effects of hatchery and harvest management on achieving planning targets in watersheds must also be accounted for in Step 3. Steps 4 and 5 of the Shared Strategy process include agreeing on recovery actions across the Puget Sound region and documenting how they will be sufficient for ESA and broader recovery goals.

Also included in this Step 2 document are general guidelines for how to add up recovery efforts across individual populations within Puget Sound and determine whether they are sufficient for delisting and recovery of the listed Evolutionarily Significant Unit (ESU). It is important to note that the planning ranges contained in this document are related to, but are not the same as, population viability criteria that will be required for evaluating whether the ESU can be delisted. The TRT continues to conduct technical analyses that will be used to develop population viability criteria and for clearly articulating ESU delisting criteria. The TRT will coordinate communication of these additional technical results through the Shared Strategy.

2.0 Population-Specific Viability Criteria

2.1 Key Characteristics of Viable Populations

The TRT evaluates population viability using four key characteristics as described in the viable salmonid populations document (VSP) (McElhany et al. 2000): abundance, productivity/growth rate, spatial structure, and diversity. Population viability is defined based on a specified probability (e.g., 0.95) of persistence in 100 years. Abundance is the number of individuals in the population at a given life stage or time; productivity or growth rate is the actual or expected ratio of abundance in the next generation to current abundance; spatial structure refers to how the abundance at any life stage is distributed among available or potentially available habitats; and diversity is the variety of life histories, sizes, and other characteristics expressed by individuals within a population. The TRT is charged with developing criteria for each of these characteristics, which, considered together, will describe a viable population.

To date, the TRT has conducted quantitative analyses to estimate the abundance, growth rate, and productivity criteria for Puget Sound chinook salmon populations. Specification of these criteria at this stage is aimed at helping planners evaluate the magnitude of effort that will be needed from each population to achieve recovery. Quantitative viability criteria for spatial structure and diversity have not been thoroughly developed, but the TRT has developed a set of recommendations that describe criteria for each of these characteristics. The TRT is also developing ESU-wide recovery guidelines that will address the required status levels for all populations, considered together, necessary for ESU delisting. Initial guidelines for population spatial structure and diversity and ESU-wide recovery guidelines are presented here to help planners understand how these fit with the quantitative population-level abundance and productivity criteria.

Although the TRT is developing separate criteria for each of the four key characteristics, it is important to understand that they are closely interrelated. For example, opening up additional high quality habitat will benefit both abundance and spatial structure. It is also important to recognize, however, that addressing one key characteristic may negatively affect another one. For example, to meet spatial structure and diversity criteria, it may be necessary to provide opportunity for chinook salmon to occupy habitats where they are less productive than in the best habitats in the system. This may, in some cases, reduce the average productivity of the population.

2.2 Abundance and Productivity/Growth Rate Criteria

The TRT is using the results from six analyses to develop viability criteria for abundance and the productivity/growth rate of a population. The characteristics of all six are briefly summarized below, but two (VRAP and MEA) are under development and the results were not available for inclusion in this paper.

> The **Population Viability Analysis (PVA)** used by the TRT addresses the question "What is the equilibrium abundance associated with the observed variability in growth rates for Puget Sound chinook salmon that assures the population will persist for a prescribed period of years with a given level of probability?" The PVA predicts the equilibrium abundance level based solely on three fundamental demographic properties of a population (abundance, quasi-extinction threshold (QET), and variability in growth rate or σ^2) and two policy parameters (the probability and time period for persistence); that is, it predicts the abundance required for population persistence without consideration of ecological interactions, the spatial distribution of the population, or life history diversity. Because these factors are not considered, and a single estimate of the variability in growth rate is used for all populations, the predictions are not population specific.
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> The **Habitat Productivity Viability Analysis ($\mathbf{HPVA_{PFC}}$)** used by the TRT addresses the question "What is the equilibrium abundance associated with the habitat characteristics predicted to support a persistent population?" The $HPVA_{PFC}$ is an application of NMFS' concept of Properly Functioning Conditions (PFC), or the habitat conditions "essential to conservation of the species, whether important for spawning, breeding, rearing, feeding, migration, sheltering, or other functions"[1]. The $HPVA_{PFC}$ derives its prediction for equilibrium abundance by developing a set of explicit

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

relationships between habitat conditions and salmon survival, and applying the minimum thresholds for PFC for habitat throughout the watershed. By incorporating these minimum conditions for habitat throughout the watershed, the HPVA_{PFC} predictions for equilibrium abundance implicitly address several of the criteria for spatial structure and diversity developed by the TRT (see section 2.2 and 2.3).

The complementary characteristics of the HPVA_{PFC} and PVA models we have used are summarized below:

Characteristic	PVA	HPVA_{PFC}
Population Specific	No	Yes
Criteria Addressed		
Abundance	Yes	Yes
Productivity/Growth Rate	Yes	Yes
Diversity	No	Yes[2]
Spatial Structure	No	Yes[2]
Extinction Probabilities	Yes	No
Underlying Model	Demographically Driven	Habitat Driven

In order to be able to compare and combine results from the PVA and HPVA analyses in a simple way, the TRT is using a single reference point that is conceptually common to both analyses: the equilibrium spawner abundance. This equilibrium number of spawners represents the number of fish required for a viable population when one spawner produces only one spawner in the subsequent generation (i.e., the population is just replacing itself). Our technical results also can be used to express the number of spawners required for a viable population that has a level of productivity greater than 1:1.

HPVA also provides an estimate of the number of juvenile outmigrants to be expected under average freshwater PFC conditions and the number required to maintain population viability. When the HPVA and MEA analyses have been completed, the TRT will use estimates of juvenile outmigrant production from both HPVA and MEA (see below) to produce planning ranges for the juvenile outmigrants needed to maintain population viability.

Maximum Historical Habitat Capacity provides estimates of the maximum number of fish a watershed could support at a specific life stage. The estimates are based on historical reconstructions of the habitat characteristics of the watershed and biological parameters such as the average size of a redd. Historical habitat capacity has been estimated for spawners in eight populations.

Historical Abundance estimates are derived from historical fishery reports, newspaper articles, interviews, and other sources of historical information. Most quantitative

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[2] The extent to which diversity and spatial structure are addressed is constrained to average responses for steady state environmental conditions.

estimates are available only for the aggregate of Puget Sound chinook salmon populations, and therefore will probably be of more use in estimating ESU viability than individual population viability.

Viability Risk Assessment Procedure (VRAP) [results incomplete; not presented here] provides a risk assessment of the likelihood of population extinction, given various expectations of marine and freshwater survival into the future. A recruit to spawner relationship is estimated for a population based on 1) annual catch and escapement estimates, and 2) relationships to environmental covariates that may include a marine survival index, a freshwater survival indicator, and hatchery influence. The spawner/recruit algorithm also allows for density dependence at low and high densities to be included or not. As with the Dennis-Holmes Model above, results from this model depend on 1) the QET, or the number of spawners below which the population is assumed to be functionally extinct; 2) the time span over which extinction will be predicted; and 3) the allowable risk of extinction during that time span.

Migrant Equilibrium Analysis (MEA) [results incomplete; not presented here] provides an estimate of the number of juvenile migrants per spawner required to maintain population viability under adverse estuarine and marine conditions. This analysis is aimed at estimating the numbers of juvenile freshwater outmigrants per spawner needed to allow the population to persist under the lowest five-year period of estuarine and marine survival expected over a 100-year time span. The MEA and estimates of intrinsic productivity from the $HPVA_{PFC}$ analysis will be considered together in specifying the freshwater productivity required of viable populations.

The TRT has conducted a preliminary review of these analyses and has the following recommendations:

Recommendation 1. Population viability criteria should be presented in a form that reflects the level of scientific uncertainty in our predictions. Uncertainty in viability estimates stems from difficulties in estimating parameter values for any one model of environmental conditions and in alternative predictions of future environmental conditions (e.g., the frequency and amplitude of marine cycles, rate of change in habitat conditions that affect salmon growth.) Expression of uncertainty could include rounding, ranges, and confidence or prediction intervals.

Rationale. Significant scientific uncertainty exists in our ability to describe the characteristics of a viable chinook salmon population. This uncertainty results from: 1) our limited understanding of the interacting factors controlling population dynamics; 2) the quality and quantity of data available; and 3) our inability to predict the environmental conditions that will affect each population in the future. The following examples illustrate, but do not catalog, aspects of uncertainty in each analysis. The PVA model we used, for example, assumes that the environmental variability we observed in the past (over the relatively short time span of our data) will be the same as that we observe in the future (i.e., it assumes “stationarity” of environmental conditions). The effect of environmental variability on HPVA results is uncertain because there are no sensitivity analyses evaluating the relationships between habitat and population characteristics and the habitat conditions necessary to sustain a population. VRAP and MEA analyses attempt to address this problem by measuring risk under varying future environmental patterns. HPVA predictions of survival rates during the estuarine, nearshore, and early marine (up to age 2) life stages are likely to be confounded since the rates have rarely been estimated for each of these life stages individually. Historical abundance estimates provide a snapshot view of some period in the "historic past" and do not attempt to estimate variability in abundance or how that might be affected by variability in environmental characteristics.

Recommendation 2. Population persistence probabilities in the PVA model we are using should be set at 95% over 100 years, based on policy direction given to us from the NMFS' regional office. We need to continue to develop more detailed PVA models and collect the necessary information to calibrate them in order to improve our estimates. Recovery planning applications of the results from the PVA model should acknowledge the uncertainties in the accuracy and precision of the estimates.

Rationale. The structure and parameters included in the PVA model used by the TRT may result in under- or over- estimates of the abundance and productivity criteria. Qualitatively evaluating the net bias of the PVA is difficult due to the large number of confounding factors that must be considered. The lack of compensatory mortality (i.e., more fish are produced per spawner when the number of spawners declines) in the PVA model we used may result in an over-estimate of the abundance associated with population viability under some conditions. On the other hand, ecological interactions, the spatial distribution of the population, life history diversity, and variance of the estimate of the variability in the population growth rate were not incorporated into the analysis and are likely to result in under-estimates in the abundance criteria. Therefore, depending on the biological conditions in an individual population, the accuracy of the estimated probability of persistence for a population at a given level of abundance is uncertain.

Recommendation 3. Model assumptions and population characteristics should be carefully evaluated where inconsistencies exist in the results from $HPVA_{PFC}$ and PVA. For example, when the $HPVA_{PFC}$ predicts that a lower level of abundance will sustain the population, the prediction may depend on an assumption that the population has high productivity at low population size (i.e., high intrinsic productivity). Alternatively, it is possible that the predicted number of chinook ssalmon under HPVA is lower than that from PVA because we have incorrectly identified population boundaries. This could occur, for example, because fish in those watersheds were/are a subpopulation of a larger population. Recovery planning applications of the results from the HPVA model should acknowledge the uncertainties in the accuracy and precision of the estimates.

Rationale. When compared to PVA, HPVA will produce smaller (than PVA) viable population size estimates in small watersheds and larger (than PVA) viable population size estimates in large watersheds. This occurs for two reasons: PVA is a general method for assessing the effect of demographic stochasticity (variation) on extinction risk; it makes some assumptions about population growth rate, abundance levels that represent functional extinction (QET), and abundance that are applied to all populations in order to derive a viability estimate. All populations to which these general assumptions are applied will have the same viability estimate. Conversely, estimates from HPVA are population specific, increasing with the quantity of available habitat. At some level of habitat quantity, there will be sufficient habitat at PFC to support the viable population size as determined by PVA; as habitat quantity increases, HPVA estimates become larger than PVA estimates.

These characteristics of HPVA may result in under-estimates of the viability criteria for abundance in small watersheds because any reduction from the historical quality and quantity of habitat may result in productivity and abundance insufficient to sustain the population in the face of demographic and environmental variation. Over-estimates may occur in large watersheds because the viability criteria are addressed by maintaining PFC throughout the entire watershed. It is possible that some subset of the habitat could be degraded and the viability of the population maintained.

Recommendation 4. The Historical Spawner Capacity should be used only to constrain the range of predictions obtained from the PVA and HPVA. For populations with a predicted Historical Spawner Capacity that is less than the abundance predicted by the PVA, the TRT should re-evaluate the assumptions of the PVA, the Historical Spawner Capacity, and the criteria used to identify the population.

Rationale. Since the Historical Spawner Capacity analysis considers the number of spawners in isolation from other life stages, a limiting factor in any other life stage would reduce the abundance that could be achieved. Under those conditions, the historical spawner capacity estimate would be greater than the number of spawners actually returning to the stream. The assumption in this analysis is that historical (i.e., pre-European settlement) conditions supported salmon populations at or above minimum viable levels.

Recommendation 5. Given uncertainty in the analyses, a planning range should be established that brackets the values for population abundance, productivity, and growth rate that are likely to encompass viability. (See also Recommendation 1 in section 3.0 regarding ESU context for planning ranges and population viability.) A decision framework constructed from the conclusions discussed above can be used to identify the low and high values for the planning range.

Spawner Equilibrium Abundance

Low Value: minimum of the equilibrium abundance of spawners predicted from $\mathrm{HPVA}_{\mathrm{PFC}}$ and $\mathrm{PVA}_{.95,\,\sigma^2} = 0.07$.

High Value: maximum of the equilibrium abundance of spawners predicted from $\mathrm{HPVA}_{\mathrm{PFC}}$ and $\mathrm{PVA}_{.95,\,\sigma^2} = 0.30$; but cannot exceed the minimum of historic equilibrium abundance from $\mathrm{HPVA}_{\mathrm{H}}$ and Historic Spawner Capacity.

Population Growth Rate

Minimum Threshold: number of spawners (and number of recruits) stable (i.e., population growth rate; $\lambda = 1$)

Results for the populations for which PVA and HPVA analyses are complete are summarized in Table 1.

Rationale. The analyses we use to estimate population viability are complementary and assist the TRT in "triangulating" on viability criteria. Complementary aspects of the analyses include the life history stages assessed, the viability criteria addressed (abundance, productivity or growth rate, spatial distribution, and diversity), and the ecological factors considered. For example, predictions from PVA and HPVA can be evaluated relative to historical estimates derived from the Historical Spawner Capacity analyses.

The high and low values for the variability in the growth rate (σ^2) are derived from analyses of the time series of data for Puget Sound chinook salmon, with the effects of harvest and hatchery origin natural spawners removed from the analysis.

Recommendation 6. Population viability planning ranges should be presented in as straightforward and helpful a way as possible to watershed planners and others engaged in salmon recovery planning efforts. Illustrating the trade-offs between spawner abundance and intrinsic productivity will be important at some stage in the process of communicating population goals so that the biological behavior of a population and feedbacks between current and future spawners can be better understood.

Rationale. The relationship between abundance and productivity for a particular population in a particular environment can be represented as a curve along which productivity decreases as abundance increases. The results for abundance that we present are in terms of equilibrium spawners, or the point in the relationship where productivity has declined to a level where one spawner produces only one adult fish in the subsequent generation (i.e., the population is just replacing itself). If the population intrinsic productivity is greater than replacement, the resilience of the population to environmental changes is increased, and fewer spawners than the equilibrium level may be required to assure the viability of the population.

Table 1. Current escapement abundances and planning ranges for natural origin Puget Sound chinook salmon populations. Escapement abundances are given for both natural spawners and the natural origin (NOR) component only. The planning range is based on combined PVA and HPVA results using the equilibrium spawner metric from the two analyses. Additional results from HPVA, PVA, and historical estimates of spawner capacity are presented in Appendix Table A. Alternative combinations of spawner abundance and productivity associated with the same viability level from the PVA and HPVA analyses are available, but are not presented here.

Population	**Spawner abundance 1987-present**[1]	**NOR spawners 1987- present**[2]	**Planning Range for Equilibrium Spawner Abundance**[3]	
			Low	**High**
NF Nooksack	319	116	16,000	26,000
SF Nooksack	226*	159*	9,100	13,000
Lower Skagit	1,511	1,499	16,000	22,000
Upper Skagit	6,419	6,075	17,000	35,000
Upper Cascade	216	216	1,200	1,700
Lower Sauk	490	490	5,600	7,800
Upper Sauk	395	395	3,000	4,200
Suiattle	491	491	600	800
NF Stillaguamish	805	553	18,000	24,000
SF Stillaguamish	261	NA	15,000	20,000
Skykomish	3,036	1,796	17,000	51,000
Snoqualmie	1,098	840	17,000	33,000
NL Washington	194*	NA	NA	NA
Cedar	398*	NA	NA	NA
Green	7,191	1,529	NA	NA
White	329*	NA	NA	NA
Puyallup	2,105*	NA	17,000	33,000
Nisqually	753*	NA	13,000	17,000
Skokomish	1,500*	NA	NA	NA
Dosewallips	26	NA	3,000	4,700
Dungeness	123*	NA	4,700	8,100
Elwha	1,319*	NA	NA	NA

1) Geometric mean of spawner escapements from 1987-2001 (unless indicated with *, which indicates that we have not received 2001 escapements yet. The Skykomish data begin in 1990). These estimates include all natural spawners (natural and hatchery origin).

2) Geometric mean of natural origin (NOR) spawners for those populations with hatchery contribution estimates. NA indicates either no information on the fraction of hatchery fish is available or that the information is not adequately documented.

3) Natural origin spawner equilibrium abundance as derived from decision rules. NA indicates HPVA analysis not yet completed.

2.3 Spatial Structure Criteria

The spatial structure of a population results from a complex interaction of the genetic and life history characteristics of a population, the geographic and temporal distribution and quality of habitat, and the disturbance regime for the habitat. Although our understanding of these interactions is limited, the ability of an individual to successfully colonize and move through habitat at each subsequent life stage is essential for population viability.

Spatial structure should be taken into account for at least three reasons:

1) the spatial and temporal distribution, quantity, and quality of habitat (landscape structure) dictates how effectively juvenile and adult salmon can bridge freshwater, estuarine, nearshore and marine habitat patches during their life cycle;
2) there is a time lag between changes in spatial structure and population dynamics, and extinction risk at the 100-year time scale may be affected in ways not readily apparent from short-term observations of abundance and productivity; and
3) population spatial structure affects evolutionary processes and may therefore alter a population's ability to respond to environmental change.

Our approach to spatial structure will build on the VSP paper by incorporating the concepts of landscape structure. The composition, distribution, and arrangement of landscape elements regulate ecological functions that affect, and are affected by, salmon at all life stages. These recommendations are intended to be applied in addition to those discussed for abundance, productivity/growth rate, and diversity.

Recommendation 1. The historical spatial structure and processes in freshwater, estuarine, and marine waters should be the reference template for a viable population. The degree to which the population spatial structure can deviate from the reference template and still be considered viable should depend on the specific biological characteristics of the salmon population and the amount, distribution and quality of habitat available to the population.

Rationale. In general, there is less information available on how spatial processes relate to the viability of chinook salmon populations than for other VSP parameters. Since our premise is that historical structures typically assured persistence of populations, the historical landscape will serve as our reference condition to gauge recovery actions until alternative viable spatial structures can be demonstrated for a particular population.

Salmonid habitat and patterns of occupancy by salmon are dynamic, with suitable habitat being naturally continually created and destroyed and dispersal behavior changing through natural processes. The degree to which the spatial distribution of chinook salmon or their habitat patches can deviate from the historical condition and still be considered to be viable is not clear, but it is possible that historical conditions are not necessary for viability. As a default, we recommend that human activities should not result in a population spatial structure that significantly deviates from the historical template, unless it can be shown that lower occupancy rates or fewer habitat patches are consistent with viability. Finally, in the dynamics of natural populations, there may be time lags between the appearance of empty but suitable habitat and the colonization of that habitat. If human activity is allowed to render habitat unsuitable when no fish are present, the population as a whole may not be sustainable over the long term.

Many habitats other than the delineated spawning areas for the 22 independent populations of chinook salmon support various life history stages and trajectories that contribute to the viability of individual populations and the ESU. In particular, these habitats include 1) freshwater spawning habitats in streams outside watersheds containing the 22 independent populations; 2) freshwater habitats that support juvenile rearing and migratory pathways of downstream and upstream migrants; and 3) estuarine and nearshore habitats that support rearing and migration of juveniles and returning adults. In short, these areas can contribute consistent or intermittent spawning, rearing and migratory habitats for chinook salmon. Therefore the condition of these habitats and the numbers of chinook salmon in them could affect the level of extinction risk for the independent populations.

Recommendation 2. Human actions should not substantially affect natural rates of straying or migration within populations relative to historical rates.

Rationale. This recommendation means that habitat patches should be close enough together to allow appropriate exchange of juvenile migrants or spawners and the expansion of the population into under-used patches during times when salmon are abundant (see Guideline 3, McElhany et al. 2000). Also, stray and migration rates should not be much greater than historical levels because increases in stray rates may negatively affect a population's viability if fish disperse into unsuitable habitat or interbreed with genetically unrelated fish.

2.4 Diversity Criteria

Diversity in chinook salmon populations can range in scale from differences within and among populations in genes to complex life-history traits. Salmon traits often exhibit considerable diversity in traits such as anadromy, morphology, run timing, juvenile behavior, and physiology. The expression of diversity is important to population viability, since more diverse populations are better buffered against changes in environmental conditions. The approach to diversity taken builds on the principles and concepts in the VSP document, and the recommendations are intended to be applied in addition to those discussed for abundance, productivity/growth rate, and spatial structure.

Recommendation 1. The historical diversity of a population should be considered the default template for assessing the genetic and phenotypic variation required to sustain a viable population.

Rationale. Our understanding of the role diversity plays in Pacific salmonid viability is limited. Historically, salmonid populations were generally self-sustaining, and the historical representation of phenotypic diversity serves as a useful "default" goal in maintaining viable populations, until alternative levels of diversity for viable populations can be shown.

Recommendation 2. Human-caused factors such as habitat changes, harvest, artificial propagation, and exotic species introduction should not substantially alter variation in diversity traits relative to their historical patterns of variation.

Rationale. Variation in traits such as run timing, age structure, size, fecundity, morphology, behavior, and genetic characteristics may be adaptations to local conditions, or they may help buffer against environmental variation. A mixture of genetic and environmental factors usually causes phenotypic diversity, and this diversity should be maintained even if it cannot be shown to have a genetic basis. Although the amount of diversity required for viability is difficult to estimate, the historical condition should provide the baseline until alternative levels of diversity for viable populations can be shown.

Recommendation 3. Natural processes of dispersal that occurred historically within and among populations should be restored or maintained.

Rationale. Human-caused factors (e.g., transplantation, physical changes to stream connections) should not substantially alter the rate of gene flow among populations. Human-caused inter-ESU stray rates that are expected to produce sustained gene flow rates greater than 1% (into a population) should be cause for concern. Human caused intra-ESU stray rates that are expected to produce substantial changes in patterns of gene flow should be avoided. The historical template for dispersal should provide a baseline against which to estimate risk of extinction until alternative levels of dispersal for viable populations can be shown.

Recommendation 4. Natural processes that cause ecological variation similar to the historical condition should be restored or maintained.

Rationale. Phenotypic diversity can be maintained by spatial and temporal variation in habitat characteristics. This recommendation involves maintaining or restoring processes that promote ecological diversity similar to historical patterns, including natural habitat disturbance regimes, succession, and factors that maintain habitat patches of sufficient quality for successful colonization.

3.0 ESU-Wide Delisting and Recovery Criteria

The ESU, not a population, is the listed entity under the Endangered Species Act. The TRT is charged with identifying the biological characteristics of a recovered ESU as part of developing delisting and recovery criteria. These biological characteristics are based on the collective viability of the individual populations, their characteristics, and their distributions throughout the ESU. Using these ESU-wide characteristics, the TRT will provide technical assistance as the Shared Strategy evaluates scenarios to meet the biological viability criteria, broader regional goals for recovery, and NMFS's mandates under the Endangered Species Act and Magnuson-Stevens Fishery Conservation and Management Act, and federal trust responsibilities to treaty Indian tribes.

A variety of recovery scenarios may lead to a recovered ESU. Different scenarios of ESU recovery may be based on choosing different degrees of acceptable risk of extinction for different combinations of populations across the ESU. These scenarios will be generated by policy and technical interactions in groups such as the Shared Strategy. The ESU-wide recommendations that follow describe the biological characteristics of a recovered ESU that can be used to create the scenarios.

Recommendation 1. An ESU-wide scenario with all populations at the lower end of the planning range for viability is unlikely to assure persistence and delisting of the ESU. The final ESU-wide scenario for delisting will likely include populations with a range of risk levels, but when considered in the aggregate, the risks must be sufficiently low to assure persistence of the ESU. Final determination of the viability of a proposed ESU scenario will require careful review of model assumptions predicting viability for individual populations, the characteristics of the watersheds and populations, and the net effect of proposed actions for achieving population viability.

Rationale. The lower end of the planning range is the minimum value obtained from PVA and $\mathrm{HPVA}_{\mathrm{PFC}}$. As discussed in section 2.2, considerations of spatial structure, life history diversity, and other factors external to our present assessment methods for abundance may result in under-estimates of the viable abundance criteria for some populations.

Recommendation 2. An ESU-wide recovery scenario should include at least 2-4 viable chinook salmon populations in each of 5 geographic regions within Puget Sound, depending on the historical biological characteristics and acceptable risk levels for populations within each region.

Rationale. The geographical distribution of viable populations across the Puget Sound chinook salmon ESU is important for the ESU's recovery. The TRT identified five geographic regions (Figure 1) in the Puget Sound based on similarities in hydrographic, biogeographic, and geologic characteristics of the Puget Sound basin and freshwater catchments, which also correspond to regions where groups of populations could be affected similarly by catastrophes (volcanic events, earthquakes, oil spills, etc.) and regions where groups of populations have evolved in common. We believe that chinook salmon occurred historically in all five regions and that this geographic configuration was viable. Some populations within the ESU have since gone extinct,

Figure 1. Geographic regions for evaluation of ESU-wide recovery scenarios.

and the current risks to chinook salmon in all regions are greater now than they were historically. An ESU with well-distributed viable populations will avoid the situation where populations succumb to the same catastrophic risk(s), will allow for a greater potential source of diverse populations for recovery in a variety of environments (i.e., greater options for recovery), and increases the likelihood of the ESU survival rapid environmental changes. Geographically diverse populations in different regions also distribute the ecological and ecosystem services provided by salmon across the ESU. An additional implication of this guideline is that viable populations should not be so far apart that re-colonization or rescue of an extirpated or severely declining population cannot occur. Having at least two viable populations within each of five geographic regions is likely to satisfy the need for nearby viable populations within a region to re-colonize or populations in severe decline.

Recommendation 3. An ESU-wide recovery scenario should include within each geographic region one or more viable populations from each major genetic and life history group historically present within that geographic region.

Rationale. This recommendation helps maintain the genetic and phenotypic diversity necessary for populations to respond to environmental changes and maintain ESU viability. For example, fishery biologists have often identified major life-history groups in Pacific salmon based on run timing, age distribution, and migration patterns. The TRT is analyzing these differences, data from other life-history traits, and habitat differences that may be correlated with life-history differences to identify major life-history groups. Existing genetic groups —or "Genetic Diversity Units" (GDUs)—have been described by WDFW. These groups reflect management practices over the last 100 years. The TRT is using these data and others to identify historical GDUs.

Recommendation 4. Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations should be functioning in a manner that is sufficient to support an ESU-wide recovery scenario.

Rationale. Tributaries to Puget Sound not identified as primary freshwater habitat (PSTRT 2001) for 1 of the 22 identified populations can be important for viability in three ways: 1) they can provide spawning and rearing habitats for chinook salmon use during periods of low habitat quality or reduced access to primary areas; 2) they can provide "bridging points" that affect the likelihood of dispersal and recolonization; and 3) they can affect the estuarine and nearshore habitat used by the independent populations of chinook salmon. In practice, the presence of chinook salmon, the quality of habitats used throughout the life cycle, and the potential of those habitats to support specific life history stages should be considered when evaluating actions needed in individual populations and in developing ESU-wide recovery scenarios. For example, when considering ESU-wide recovery scenarios, a scenario containing populations separated by the same distance of degraded habitat may have a smaller chance of persistence than a scenario containing populations separated by high quality habitat with chinook salmon.

Recommendation 5. Production of chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations should occur in a manner consistent with an ESU recovery scenario.

Rationale. Chinook salmon in Puget Sound streams that are not part of independent viable populations still provide important contributions to the health of freshwater, estuarine and marine ecosystems within the region. The presence of naturally and hatchery produced chinook salmon in streams can maintain ecological and ecosystem services that have been degraded following declines in anadromous fish populations.

Recommendation 5. Populations that do not meet the viability criteria for all VSP parameters (i.e., abundance, productivity, spatial structure and diversity) should be sustained to provide ecological services and preserve options for ESU recovery. Furthermore, the indirect effects of habitat, hatchery and harvest management actions targeted at non-viable populations should be evaluated in the ESU-wide recovery scenario.

Rationale. Options for recovery across the ESU are preserved if chinook salmon in non-viable populations are not allowed to go extinct. As long as the management of chinook salmon in non-viable populations does not pose unacceptable risks to viable populations (e.g., through straying of hatchery fish, incidental harvest of mixed-stock fisheries, degraded estuarine/nearshore habitats used by chinook salmon from several populations), they can provide useful ecological services and help fulfill other goals such as harvest.

4.0 Literature Cited

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National Marine Fisheries Service (NMFS). 1996. Making ESA determinations of effect for individual or grouped actions at the watershed scale. Environmental and Technical Services Division, Habitat Conservation Branch. Portland, Oregon.

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Appendix Table A. Estimates of the lower equilibrium spawner abundance values from PVA, assuming a population growth rate equal to 1; equilibrium spawner abundance values from HPVA under properly functioning habitat conditions (PFC); and estimates of historical spawner capacity (i.e., the potential spawning abundance each watershed could have supported historically) based on estimates of the amount of suitable spawning habitat and from HPVA_{H}. The spawner numbers presented in this table are those that were used in the decision rules we developed to produce planning ranges for viability that are depicted in Table 1.

Population	**PVA lower**[1]	**HPVA_{PFC}**	**Historical spawner capacity**[2]	**Historical spawner capacity**[3]
NF Nooksack	17,000	16,400	NA	26,000
SF Nooksack	17,000	9,100	NA	13,000
Lower Skagit	17,000	15,800	190,000	22,000
Upper Skagit	17,000	26,000	90,000	35,000
Upper Cascade	17,000	1,200	11,000	1,700
Lower Sauk	17,000	5,600	47,000	7,800
Upper Sauk	17,000	3,000	30,000	4,200
Suiattle	17,000	600	2,000	830
NF Stillaguamish	17,000	18,000	23,000	24,000
SF Stillaguamish	17,000	15,000	23,000	20,000
Skykomish	17,000	39,000	NA	51,000
Snoqualmie	17,000	25,000	NA	33,000
NL Washington	17,000	NA	NA	NA
Cedar	17,000	NA	NA	NA
Green	17,000	NA	NA	NA
White	17,000	NA	NA	NA
Puyallup	17,000	18,000	NA	33,000
Nisqually	17,000	13,000	NA	18,000
Skokomish	17,000	NA	NA	NA
Dosewallips	17,000	3,000	NA	4,700
Dungeness	17,000	4,700	NA	8,100
Elwha	17,000	NA	NA	NA

1) The number of spawners corresponding to a 0.95 population persistence in 100 years and a population growth rate equal to 1. The variance in population growth rate used in the lower-end simulations was $\sigma^2 = 0.07$. The variance in population growth rate used in the upper-end simulations was $\sigma^2 = 0.30$; the resulting numbers were greater than all estimates of historical spawner capacity.
2) Estimate of the potential spawning abundance each population could have supported under historical conditions, derived from estimates of the amount of suitable spawning habitat and spawner densities in different habitat types.
3) Estimate of the potential spawning abundance each population could have supported under historical conditions, derived from the HPVA model.