

Interior Columbia Basin TRT: Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs

Interior Columbia Basin Technical Recovery Team

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This document summarizes the current draft of ICTRT viability criteria for application to Interior Columbia Basin salmonid ESUs. We incorporate and update information provided in the two previous summaries posted at the ICTRT website (http://www.nwfsc.noaa.gov/trt/trt_columbia.htm). In addition, this document includes descriptions of our proposed approaches for 1) integrating across spatial structure and diversity criteria and 2) integrating the abundance/productivity and spatial structure/diversity risk assessments to arrive at a composite viability rating for a population. Specific viability curves are provided for application to specific stream type chinook and steelhead ESUs. This draft also includes updates to the descriptions of several of the spatial structure diversity criteria and modifications to the intrinsic potential analyses (i.e., expanded use of a valley width metric and incorporation of an erodibility/soil type metric for relatively low gradient reaches).

Attachment A: Abundance/Productivity Viability Curves for Interior Columbia ESUs

Attachment B: Population Size Categories based on Historical Intrinsic Potential Analyses

Attachment C: General Approach: Defining Major Spawning Areas within Populations

Attachment D: Habitat Diversity Summary

Attachment E: Population/Major Population Grouping Summaries (by ESU)

Background

One of the main tasks assigned to NOAA Fisheries Technical Recovery Teams (TRTs) is the establishment of biologically based viability criteria for application to Evolutionarily Significant Units (ESUs) of salmon and steelhead listed under the Endangered Species Act. The Northwest Fisheries Science Center developed a NOAA Technical Memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000) to provide general guidance for setting viability objectives at the ESU and component population levels. The viability guidelines provided in McElhany et al. (2000) are organized around four major considerations: abundance, productivity, spatial structure and diversity. ESU level viability criteria consider the appropriate distribution and characteristics of component populations in order to maintain the ESU in the face of longer-term ecological and evolutionary processes.

The Interior Columbia Basin Technical Recovery Team (ICTRT) has developed a draft set of specific viability criteria and guidelines for Interior Columbia Basin listed ESUs. The ESU and population viability criteria described below were based on guidelines in McElhany et al. (2000), the results of previous applications (i.e., Puget Sound and Lower Columbia/Willamette TRTs and the upper Columbia QAR effort), and a review of specific information available relative to listed Interior Columbia ESU populations.

General – Hierarchical Levels for Estimating ESU Viability

Salmonid population structure is hierarchical, from species to sub-population, reflecting varying degrees of exchange of individuals. Two levels in this hierarchy have been formally defined for recovery planning efforts. First, an ESU is defined by two criteria: 1) it must be substantially reproductively isolated from other nonspecific units, and 2) it must represent an important component of the evolutionary legacy of the species (Waples 1991). Because ESUs are the units listed under the Endangered Species Act (as Distinct Population Segments), biological viability criteria at the ESU-level contribute to broad-sense recovery goals. The second level that has been formally defined is population (McElhany et al. 2000). A population is a group of individuals that are demographically independent from other such groups over an 100-year time period. Differences among ESUs within a species are considered to be greater than the differences among the populations within ESUs due to the greater reproductive isolation that exists among ESUs than among populations within an ESU.

The ICTRT has described an additional level in the hierarchy intermediate to the population and ESU levels. “Major population groupings” (MPGs) are groups of populations that share similarities within the ESU. They are defined on the basis of genetic, geographic (hydrographic), and habitat considerations (McClure et al. 2003). These major population groupings are analogous to “strata” as defined by the Lower Columbia-Upper Willamette TRT and “geographic regions” described by the Puget

Sound TRT. The ICTRT has developed or adapted draft viability guidelines for each of these three levels.

Historically, ESUs typically contained multiple populations connected by some small degree of genetic exchange. Populations identified by the ICTRT range widely in tributary drainage area. Examples of populations occupying smaller drainages include Asotin Creek and Sulphur Creek (Snake River Steelhead and Spring/summer Chinook ESUs); Rock Creek and Fifteen Mile Creek (Middle Columbia ESU) and the Entiat River (Upper Columbia Steelhead and Spring Chinook ESUs). Populations using relatively large, complex tributaries include Upper John Day steelhead, Wenatchee and Methow River steelhead and spring chinook; and Lemhi River steelhead and spring/summer chinook. This natural variation in size and complexity suggests that even historically, populations likely varied in their relative robustness, or resilience to perturbations. Because of this variation, the TRT did not adopt a “one-size-fits-all” approach to population-level criteria. Considerations for relative population size and complexity characteristics are reflected in the population and Major Population Grouping viability criteria developed by the ICTRT.

Population Level Viability Criteria

The ICTRT has developed a set of criteria for use in assessing viability at the individual population level. We have grouped specific population level criteria into two basic subsets; measures addressing abundance and productivity considerations and a set reflecting spatial structure/diversity elements. In addition, we have developed a framework for compiling an aggregate risk score for a population based on the results of applying the individual criteria. We describe the individual criteria and the integration framework in the following sections. ESU level viability criteria developed by the ICTRT are designed to work from the individual risk ratings for component populations.

Abundance and Productivity

Ultimately, population abundance and productivity drive extinction risk. A population at low abundance is more prone to extinction due to demographic or environmental stochasticity. A population without the ability to replace itself (i.e. with low productivity) will deterministically go extinct, even if current abundance levels are relatively high.

The VSP guidelines for abundance recommend that a viable population should be large enough to: have a high probability of surviving environmental variation observed in the past and expected in the future; be resilient to environmental and anthropogenic disturbances; maintain genetic diversity; and support/provide ecosystem functions (McElhany et al. 2000). Viable populations should demonstrate sufficient productivity to support a net replacement rate of 1:1 or higher at abundance levels established as long-

term targets. Productivity rates at relatively low numbers of spawners should, on the average, be sufficiently greater than 1.0 to allow the population to rapidly return to abundance target levels.

ICTRT Abundance & Productivity Objective:

Abundance should be high enough that 1) in combination with intrinsic productivity, declines to critically low levels would be unlikely assuming recent historical patterns of environmental variability; 2) compensatory processes provide resilience to the effects of short term perturbations; and 3) subpopulation structure is maintained (e.g., multiple spawning tributaries, spawning patches, life history patterns).

The ICTRT has adopted the Viability Curve concept (e.g., LCWTRT, 2003) as a framework for defining population specific abundance and productivity criteria. A viability curve describes those combinations of abundance and productivity that yield a particular risk threshold. The two parameters are linked relative to extinction risks associated with short-term environmental variability. Relatively large populations are more resilient in the face of year to year variability in overall survival rates than smaller populations. Populations with relatively high intrinsic productivity – the expected ratio of spawners to their parent spawners *at low levels of abundance*– are also more robust at a given level of abundance relative to populations with lower intrinsic productivity. Combinations of abundance and productivity falling above the curve would result in lower extinction risk, whereas points below the curve represent higher risk

Combinations of abundance and productivity along the curve provide equal extinction risk. Multi-year trends in abundance-productivity could be evaluated against the curve defining the “viable” state to assess population status. In general terms, high abundance combined with moderate productivity could provide the same extinction risk as that of a lower abundance but higher productivity. While the level of acceptable risk is a policy decision, the ICTRT is currently defining risk associated with a 5% probability of extinction in a 100-year period, consistent with VSP guidelines and the conservation literature (McElhany et al. 2000). Under historical conditions, most populations within the region would have been rated as very low risk relative to the 5% viability curve. At the population level, recovery strategies should be targeted to achieving combinations of abundance and productivity above the 5% viability curve threshold.

The ICTRT has focused on developing ESU specific viability curves based on direct measures of abundance and productivity. It is possible to express the productivity term in a viability curve in terms of stock-recruitment functions, e.g., Beverton-Holt or Ricker curves. In most cases, data used to evaluate current status will be based on a relatively limited number of years. Uncertainty levels and bias in parameter estimates can be very large. Status assessments that use fitted stock recruit curve parameters as an index of current productivity should directly incorporate considerations for sampling induced errors and bias in their assessments.

Adjustments for Population Size

Populations of listed Chinook salmon and steelhead within the Interior Columbia River vary considerably in terms of the total area available to support spawning and rearing. The ICTRT developed a method for adapting viability curves to reflect estimates of the historical amount of potentially accessible spawning and rearing habitat available to a specific population. A more detailed description of the approach is provided in Attachment B.

In summary, a measure of spawning/rearing area used to index the population spawning/rearing areas is generated using a simple model of historical intrinsic potential. That model is driven by estimates of stream width, gradient, and valley width derived from a GIS-based analysis of the tributary habitat associated with each population. Each accessible 200-m reach within the tributary habitat associated with a specific population is assigned an intrinsic productivity rating based on the particular combination of physical habitat parameters listed above. Four categories were used: high, moderate, low, and not rated or zero potential. For application to yearling type chinook, sufficient information was available to add a negligible category. A weighted estimate of the total amount of rated habitat historically available to each population was constructed by summing the habitat by rating category, multiplying each sum by a relative weighting factor (1 = high, .5 = moderate, and .25 = low), and totaling the weighted sums. For this calculation, reaches rated as negligible were assigned a relative weight of 0.

Table 1. Minimum abundance thresholds by species and historical population size (spawning area) for Interior Columbia Basin stream type chinook and steelhead population (Table 3). Median weighted area and corresponding spawners per km (calculated as ratio with corresponding threshold) provided for populations in each size category (see attachment B).

Population Size Category	Stream Type Chinook (Upper Columbia Spr, Snake Spr/Sum ESUs)			Steelhead (Upper Columbia, Middle Columbia & Snake River ESUs)		
	Threshold	Median Weighted Area (m X 10,000)	Spawners per KM (weighted)	Threshold	Median Weighted Area (m X 10,000)	Spawners per KM (weighted)
<i>Basic</i>	500	20	25.0	500	63	4.9
<i>Intermediate</i>	750	42	18.0	1,000	302	3.3
<i>Large</i>	1,000	77	13.0	1,500	627	2.4

Because populations with fewer than 500 individuals are at higher risk for inbreeding depression and a variety of other genetic concerns (McClure et al. 2003 discusses this topic further), the ICTRT does not consider any population with fewer than 500 individuals to be viable, regardless of its intrinsic productivity. Therefore, viability curves for populations in the Basic size category are truncated at a minimum spawning level of 500. Incrementally higher spawning abundance thresholds were established for the remaining three population size categories (Table 1). Increased thresholds for larger populations promote achieving the full range of abundance objectives including utilization of multiple spawning areas, avoiding problems associated with low population densities (e.g., Allee effects) and maintaining populations at levels where compensatory processes are functional. We set thresholds for the two larger size categories (Large and Very Large) so that the expected average abundance at threshold levels was the equivalent to ½ of the density associated with achieving 500 spawners for populations similar in size. Threshold levels for application to populations in the intermediate group were set so as to achieve median spawner densities at approximately half the range between the median population size for Basic and Large population groups.

We have used two methods to characterize the relative within population complexity of tributary spawning habitats – assigning each population to one of four general structural categories (Table 2), and estimating the number of relatively large, contiguous production areas within each population (Attachment C). Major spawning aggregations (MSAs) were defined as a system of one or more branches that contain sufficient habitat to support 500 spawners. For spring/summer chinook, this value was 100,000m², and for steelhead it equaled 250,000m². We generated aggregation values by using hydrology tools within the GIS. We defined contiguous production areas capable of supporting between 50 and 500 spawners as minor spawning areas (mSAs).

Table 2 . Population spatial complexity designations.

Category	Description
A.	Linear structure, with no more than 2 branches in one major spawning area. Typically small (basic) drainages.
B.	Dendritic tributary structure including 2 or more major spawning areas. Typically intermediate or large drainages.
C.	Trellis-structured drainage including mainstem spawning and multiple branches.
D.	Populations with one or more major spawning areas with well-separated minor spawning areas downstream.

Each population was assigned to a size category based on the total amount of weighted spawning habitat and given a complexity rating based on the estimated relative distribution of historical spawning habitat (Table 3a-e).

Table 3.a: Intrinsic size and complexity ratings for **extant Snake River Spring Chinook ESU** populations organized by Major Population Groupings. Complexity categories: A Simple linear; B=Dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	#MSAs/ (#mSAs)
<i>Lower Snake</i>	Tucannon R	Intermediate	D	2 (0)
	Asotin R.	Basic	A	1 (0)
<i>Grande Ronde/Imnaha R</i>	Lostine/Wallowa R.	Large	B	3 (2)
	Upper Grande Ronde R.	Large	B	4 (1)
	Catherine Creek	Large	B	3 (2)
	Imnaha R. Mainstem	Intermediate	A	1 (1)
	Minam R.	Intermediate	A	1 (0)
	Wenaha R.	Intermediate	A	1 (0)
	Big Sheep Cr. Lookingglass Cr.	Basic Basic	A A	0 (1) 0 (1)
<i>South Fork Salmon</i>	South Fk Mainstem	Large	C	2 (2)
	Secesh R.	Intermediate	A	1 (1)
	East Fk/Johnson Cr.	Intermediate	B	1 (0)
	Little Salmon R.	Intermediate	D	- (3)
<i>Middle Fork Salmon</i>	Big Creek	Large	B	3 (0)
	Bear Valley	Intermediate	C	3 (0)
	Upper Mainstem MF	Intermediate	C	1 (2)
	Chamberlain Cr.	Intermediate	D	1 (3)
	Camas Creek	Basic	B	1 (1)
	Loon Creek	Basic	C	1 (0)
	Marsh Creek	Basic	C	1 (0)
	Lower Mainstem MF Sulphur Creek	Basic Basic	A A	- (1) 1 (0)
<i>Upper Salmon</i>	Lemhi	Very Large	B	3 (2)
	Lower Mainstem	Large	C	2 (1)
	Pahsimeroi	Large	B	1 (0)
	Upper Salmon East Fk	Intermediate	C	1 (0)
	Upper Salmon Mainstem	Intermediate	C	3 (0)
	<i>Panther Cr (ext)</i>	Intermediate		1 (1)
	Valley Cr.	Basic	A	1 (0)
	Yankee Fork	Basic	C	1 (0)
	North Fork Salmon R.	Basic	D	1 (0)

Table 3.b: Intrinsic size and complexity ratings for historical **Snake River Steelhead ESU** populations organized by Major Population Groupings. Complexity categories: A = Simple linear; B=Dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries. * = Number of MSAs would be reduced if 22 deg. C applied.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	#MSAs/ (#mSAs)
<i>Lower Snake</i>	Tucannon R	Intermediate	A	2 (8)
	Asotin R.	Intermediate	D	4* (10)
<i>Grande Ronde</i>	Upper Grand Ronde R.	Large	B	9 (8)
	Wallowa River	Intermediate	B	6 (1)
	Lower Grande Ronde R.	Intermediate	B	4 (11)
	Joseph Creek	Intermediate	B	2 (0)
<i>Imnaha R.</i>	Imnaha River	Intermediate	B	4 (0)
<i>Clearwater R.</i>	Lower Mainstem	Large	B	5 (14)
	Selway River	Large	B	9 (8)
	Lochsa River	Large	B	7 (6)
	South Fork	Intermediate	B	4 (4)
	Lolo Creek	Basic	C	1 (0)
	<i>North Fork (blocked)</i>	Very Large		
<i>Salmon River</i>	Lemhi	Intermediate	B	5 (4)
	Upper Salmon East Fk	Intermediate	B	3 (5)
	Upper Salmon Mainstem	Intermediate	B	5 (2)
	Upper Middle Fork	Intermediate	B	7 (2)
	Lower Middle Fork	Intermediate	B	6 (6)
	Chamberlain Cr.	Intermediate	D	3 (9)
	Pahsimeroi River	Intermediate	C	3 (4)
	Panther Cr	Intermediate	D	4 (1)
	Little Salmon River	Intermediate	D	5* (8)
	South Fork	Intermediate	B	3 (2)
	Secesh R.	Basic	C	2 (0)
	North Fork	Basic	D	1 (3)
<i>Hells Canyon Tributaries</i>	Wild Horse/Powder R.	Note: Core spawning areas for this population are blocked to anadromous migration.		

Table 3.c: Intrinsic size and complexity ratings for historical populations within the **MIDCOLUMBIA RIVER STEELHEAD ESU**. Organized by Major Population Groupings. Complexity categories: A = Simple linear; B=Dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries. * = Number of MSAs would be reduced if 22 deg. C applied.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	# MSAs (# Msas)
<i>Eastern Cascades</i>	Deschutes (westside)	Large	B	8 (11)
	Deschutes (eastside)	Large	B	6* (4)
	Klickitat River	Large	B	8 (9)
	Fifteen Mile Creek	Intermediate	C	3 (5)
	Rock Creek	Basic	A	1 (0)
	White Salmon (sthd ext)	Intermediate	A?	
<i>Yakima River</i>	Upper Yakima River	Very Large	B	10 (11)
	Naches River	Large	B	7 (2)
	Toppenish River	Intermediate	B	2 (1)
	Satus Creek	Intermediate	B	3 (0)
<i>John Day River</i>	John Day Lower Mainstem	Very Large	B	14* (20)
	John Day North Fork	Intermediate	B	10(5)
	John Day Upper Mainstem	Intermediate	B	3 (4)
	John Day Middle Fork	Intermediate	B	4(2)
	John Day South Fork	Basic	B	3 (7)
<i>Umatilla/Walla Walla</i>	Umatilla River	Very Large	B	9*(11)
	Walla-Walla Mainstem	Intermediate	B	5*(6)
	Touchet River	Intermediate	A	3* (3)
	Willow Cr. (sthd ext)			

Table 3.d: Intrinsic size and complexity ratings for historical populations within the **UPPER COLUMBIA RIVER SPRING CHINOOK ESU**. Organized by Major Population Groupings. Complexity categories: A = Simple linear; B=Dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	# MSAs (# Msas)
<i>Eastern Cascades</i>	Wenatchee	Very Large	B	5 (4)
	Methow	Very Large	B	4 (1)
	Entiat	Basic	A	1
	Okanogan River (ext)			1 (3)

Table 3.e: Intrinsic size and complexity ratings for historical populations within the **UPPER COLUMBIA RIVER STEELHEAD ESU**. Organized by Major Population Groupings. Complexity categories: A = Simple linear; B=Dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	# MSAs (# Msas)
<i>Eastern Cascades</i>	Wenatchee River	Large	B	6* (11)
	Methow River	Large	B	4 (9)
	Okanogan River	Intermediate	B	10* (9)
	Entiat River	Basic*	A	3* (2)

The ICTRT has developed a set of generalized Viability Curves using variance estimates derived from return per spawner data sets (expressed in terms of spawner to spawner ratios) for each ESU (Table 3). Viability curves were generated for use with two alternative productivity metrics: Return/Spawner and Annual population growth rate (λ). An example of an ESU viability curve set in graph format (Snake River Spring Chinook) is provided in Figure 1. Graphic representations for all of the Interior Basin stream type chinook and steelhead ESUs are included in Attachment A.

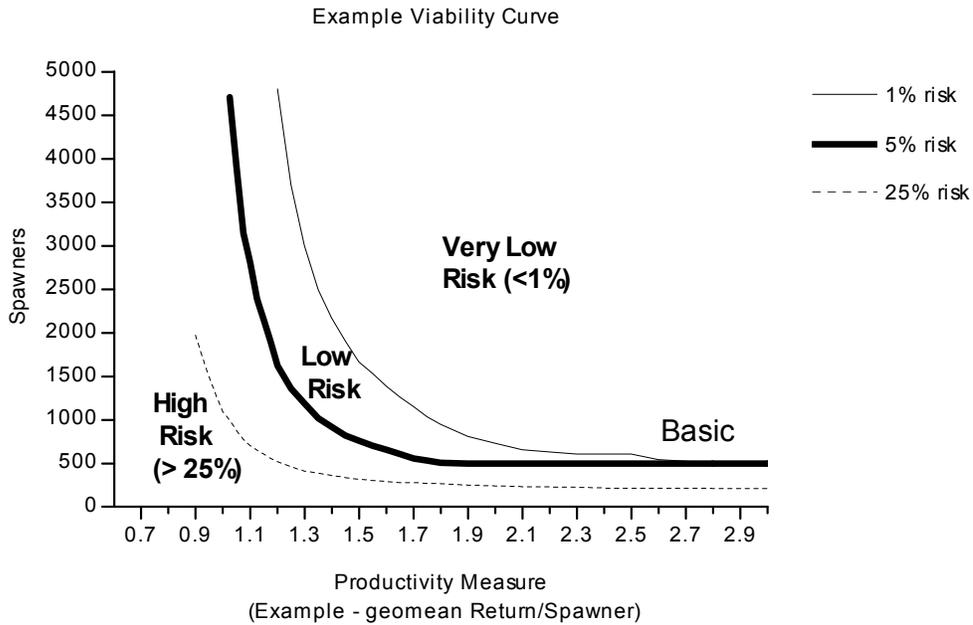
Viability Curves for Interior Basin ESU Populations

We have generated viability curves for application to populations in each of the yearling chinook and steelhead ESUs in the Interior Columbia basin (Table 3). The viability curves are defined using a specific risk metric, no more than a 5% probability of decreasing to below 50 spawners per year for a generation (typically 4 to 5 years) in a 100-year period. The example curves are based on average estimates of population variability for the major groupings and/or ESUs. A relatively high level of correlation between successive years in data series was noted and included in the modeling.

The ICTRT is also investigating the use of metrics at other life stages, including juvenile productivity. Adding specific measures that reflect survival from spawning to outmigrating smolt and from outmigrant to adult return would address a major confounding factor, high year-to-year variability in marine survival rates. Incorporating smolt production measures would also aid in evaluating tributary habitat effects.

Figure 1: Example of Viability Curves incorporating population size category threshold abundance levels. **Snake River Spring-Summer Chinook ESU**

(a) Viability curve for application to populations in BASIC - small size category. Includes minimum average spawner threshold at 500.



(b) Viability Curve including minimum population threshold of 1,000 spawners for use with Large size populations.

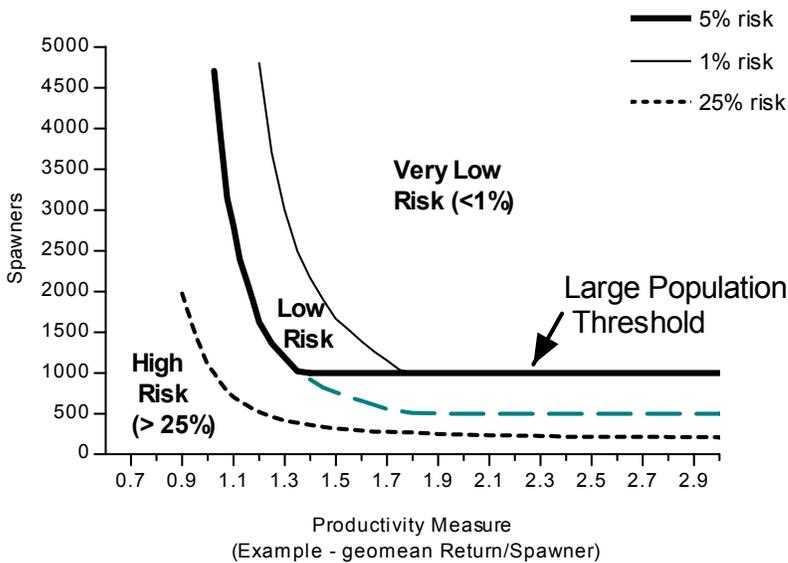


Table 4a. SNAKE RIVER SPRING/SUMMER CHINOOK. Population Viability curves in tabular format (return per spawner and population growth rate versions). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Generated using Hockey-Stick recruitment function and average variance (0.95), autocorrelation (0.44) and age structure (.57 age 4/.43 age 5) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (.13) for ESU populations.

Snake River Spr/Sum Chinook Growth Rate (S/S)	Spawner to Spawner Measure				Population Growth Rate (Lambda) Measure				
	Minimum Abundance by Population Size Categories				Population Growth Rate	Minimum Abundance by Population Size Categories			
	Basic	Intermediate	Large	Very large		Basic	Intermediate	Large	Very large
1	7829	7829	7829	7829	1.02	26973	26973	26973	26973
1.05	5096	5096	5096	5096	1.04	8640	8640	8640	8640
1.075	4315	4315	4315	4315	1.06	4295	4295	4295	4295
1.1	3925	3925	3925	3925	1.078	2000	2000	2000	2000
1.13	3144	3144	3144	3144	1.08	1952	1952	1952	2000
1.15	2518	2518	2518	2518	1.1	1390	1390	1390	2000
1.175	2200	2200	2200	2200	1.11	1000	1000	1000	2000
1.2	2000	2000	2000	2000	1.12	877	877	1000	2000
1.25	1581	1581	1581	2000	1.14	633	750	1000	2000
1.3	1350	1350	1350	2000	1.16	560	750	1000	2000
1.35	1152	1152	1152	2000	1.17	500	750	1000	2000
1.4	1035	1035	1035	2000	1.18	500	750	1000	2000
1.45	957	957	1000	2000	1.2	500	750	1000	2000
1.5	858	858	1000	2000	1.22	500	750	1000	2000
1.55	785	785	1000	2000	1.24	500	750	1000	2000
1.6	722	750	1000	2000	1.26	500	750	1000	2000
1.65	650	750	1000	2000	1.28	500	750	1000	2000
1.7	605	750	1000	2000	1.3	500	750	1000	2000
1.8	527	750	1000	2000					
1.9	500	750	1000	2000					

Table 4b. UPPER COLUMBIA RIVER SPRING CHINOOK. Population Viability curves in tabular format (return per spawner and population growth rate versions). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Generated using Hockey-Stick recruitment function and average variance (0.53), autocorrelation (0.68) and age structure (.60 age 4/.40 age 5) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (.13) for ESU populations.

Upper Columbia Spring Chinook	Spawner to Spawner Measure				Population Growth Rate (Lambda) Measure				
	Minimum Abundance by Population Size Categories				Population Growth Rate	Minimum Abundance by Population Size Categories			
	<i>Basic</i>	<i>Intermediate</i>	<i>Large</i>	<i>Very large</i>		<i>Basic</i>	<i>Intermediate</i>	<i>Large</i>	<i>Very large</i>
1.4	6264	6264	6264	6264	1.02	47967	47967	47967	47967
1.45	5000	5000	5000	5000	1.04	15377	15377	15377	15377
1.5	4023	4023	4023	4023	1.06	6590	6590	6590	6590
1.55	3350	3350	3350	3350	1.08	3953	3953	3953	3953
1.6	2850	2850	2850	2850	1.1	2267	2267	2267	2267
1.65	2467	2467	2467	2467	1.104	2000	2000	2000	2000
1.7	2163	2163	2163	2163	1.12	1392	1392	1392	2000
1.75	1905	1905	1905	2000	1.14	1048	1048	1048	2000
1.8	1690	1690	1690	2000	1.145	1000	1000	1000	2000
1.9	1410	1410	1410	2000	1.16	829	829	1000	2000
2	1208	1208	1208	2000	1.18	580	750	1000	2000
2.1	1025	1025	1025	2000	1.2	511	750	1000	2000
2.2	916	916	1000	2000	1.21	500	750	1000	2000
2.3	839	839	1000	2000	1.22	500	750	1000	2000
2.4	785	785	1000	2000	1.24	500	750	1000	2000
2.5	735	750	1000	2000	1.26	500	750	1000	2000
2.6	693	750	1000	2000	1.28	500	750	1000	2000
2.8	618	750	1000	2000	1.3	500	750	1000	2000
3	556	750	1000	2000					
3.2	517	750	1000	2000					
3.4	500	750	1000	2000					

Table 4c. UPPER COLUMBIA RIVER STEELHEAD. Population Viability curves in tabular format (return per spawner and population growth rate versions). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Generated using Hockey-Stick recruitment function and average variance (0.27), autocorrelation (0.64) and age structure (.36 age 3/.46 age 4/.16 age 5/.1 age 6) for Interior Basin steelhead population trend data sets. Population growth rate based estimates generated using average running sums based variance (.16) for ESU populations

Upper Columbia Steelhead	Spawner to Spawner Measure				Population Growth Rate (Lambda) Measure					
	Growth Rate (S/S)	Minimum Abundance by Population Size Categories				Population Growth Rate	Minimum Abundance by Population Size Categories			
		<i>Basic</i>	<i>Intermediate</i>	<i>Large</i>	<i>Very large</i>		<i>Basic</i>	<i>Intermediate</i>	<i>Large</i>	<i>Very large</i>
1.05	12515	12515	12515	12515	1.04	22293	22293	22293	22293	
1.075	9391	9391	9391	9391	1.06	8634	8634	8634	8634	
1.1	6268	6268	6268	6268	1.08	4460	4460	4460	4460	
1.125	5487	5487	5487	5487	1.1	2702	2702	2702	2702	
1.13	4706	4706	4706	4706	1.116	2000	2000	2000	2250	
1.15	3766	3766	3766	3766	1.12	1860	1860	1860	2250	
1.175	3142	3142	3142	3142	1.14	1128	1128	1500	2250	
1.2	2500	2500	2500	2500	1.15	1000	1000	1500	2250	
1.25	1893	1893	1893	2250	1.16	908	1000	1500	2250	
1.3	1425	1425	1500	2250	1.18	630	1000	1500	2250	
1.35	1183	1183	1500	2250	1.2	578	1000	1500	2250	
1.4	950	1000	1500	2250	1.21	500	1000	1500	2250	
1.45	761	1000	1500	2250	1.22	500	1000	1500	2250	
1.5	644	1000	1500	2250	1.24	500	1000	1500	2250	
1.55	580	1000	1500	2250	1.26	500	1000	1500	2250	
1.6	530	1000	1500	2250	1.28	500	1000	1500	2250	
1.65	500	1000	1500	2250	1.3	500	1000	1500	2250	

Table 4d. SNAKE RIVER STEELHEAD. Population Viability curves in tabular format (return per spawner and population growth rate versions).). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Spawner/Spawner estimates generated using Hockey-Stick recruitment function and average variance (0.35), autocorrelation (0.54) and age structure (.03 age 3/.61 age 4/.35 age 5/.02 age 6) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (.19) for ESU populations.

Snake River Steelhead	Spawner to Spawner Measure Minimum Abundance by Population Size Categories				growth rate	Population Growth Rate (Lambda) Measure Minimum Abundance by Population Size Categories			
	Basic	Intermediate	Large	Very large		Basic	Intermediate	Large	Very large
growth rate									
1	5487	5487	5487	5487	1.04	35732	35732	35732	35732
1.025	3925	3925	3925	3925	1.06	15592	15592	15592	15592
1.05	3144	3144	3144	3144	1.08	9404	9404	9404	9404
1.075	2363	2363	2363	2363	1.1	5009	5009	5009	5009
1.1	1900	1900	1900	2250	1.12	2849	2849	2849	2849
1.125	1582	1582	1582	2250	1.138	2000	2000	2000	2250
1.13	1500	1500	1500	2250	1.14	1750	1750	1750	2250
1.15	1290	1290	1500	2250	1.16	1494	1494	1500	2250
1.175	1094	1094	1500	2250	1.18	1091	1091	1500	2250
1.2	946	1000	1500	2250	1.19	1000	1000	1500	2250
1.25	742	1000	1500	2250	1.2	798	1000	1500	2250
1.3	615	1000	1500	2250	1.22	715	1000	1500	2250
1.35	508	1000	1500	2250	1.24	578	1000	1500	2250
1.4	500	1000	1500	2250	1.26	505	1000	1500	2250
1.45	500	1000	1500	2250	1.28	500	1000	1500	2250
1.5	500	1000	1500	2250	1.3	500	1000	1500	2250

Table 4e. MID-COLUMBIA RIVER STEELHEAD. Population Viability curves in tabular format (return per spawner and population growth rate versions).). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Spawner to spawner based estimates generated using Hockey-Stick recruitment function and average variance (0.23), autocorrelation (0.69) and age structure (0.22 age 3/.46 age 4/.28 age 5/0.04age 6) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (0.17) for ESU populations.

Mid-Columbia Steelhead	Spawner to Spawner Measure				Population Growth Rate (Lambda) Measure				
	Minimum Abundance by Population Size Categories				Minimum Abundance by Population Size Categories				
<i>Growth Rate</i>	<i>Basic</i>	<i>Intermediate</i>	<i>Large</i>	<i>Very large</i>	<i>Growth Rate</i>	<i>Basic</i>	<i>Intermediate</i>	<i>Large</i>	<i>Very large</i>
1.05	12515	12515	12515	12515	1.02	76,528	76,528	76,528	76,528
1.075	9391	9391	9391	9391	1.04	25,094	25,094	25,094	25,094
1.1	6268	6268	6268	6268	1.06	10,764	10,764	10,764	10,764
1.125	5000	5000	5000	5000	1.08	4,686	4,686	4,686	4,686
1.13	4600	4600	4600	4600	1.1	3,026	3,026	3,026	3,026
1.15	4203	4203	4203	4203	1.115	2,000	2,000	2,000	2,250
1.175	3565	3565	3565	3565	1.12	1,829	1,829	1,829	2,250
1.2	2818	2818	2818	2818	1.14	1,341	1,341	1,500	2,250
1.25	2041	2041	2041	2250	1.15	1,000	1,000	1,500	2,250
1.3	1581	1581	1581	2250	1.16	975	975	1,500	2,250
1.35	1269	1269	1500	2250	1.18	829	829	1,500	2,250
1.4	957	1000	1500	2250	1.2	682	750	1,500	2,250
1.45	800	1000	1500	2250	1.22	560	750	1,500	2,250
1.5	682	1000	1500	2250	1.23	500	750	1,500	2,250
1.55	605	1000	1500	2250	1.24	500	750	1,500	2,250
1.6	540	1000	1500	2250	1.26	500	750	1,500	2,250
1.65	500	1000	1500	2250	1.28	500	750	1,500	2,250
1.7	500	1000	1500	2250	1.3	500	750	1,500	2,250

Evaluating Population Status vs Viability Curves

Evaluating a population against the Viability Curve requires measures of recent abundance and intrinsic productivity (the maximum productivity that a population can maintain). Populations would be rated at low extinction risk (high potential viability) if acceptable measures of recent abundance and productivity at low abundance fall above the corresponding viability curve. We provide two variations of viability curves for each Interior Columbia Basin stream type type chinook or steelhead ESU. Viability objectives for a particular population can be expressed a number of ways relative to the appropriate curve. If sufficient information is available to directly evaluate abundance and productivity, viability targets can be expressed as a particular combination of abundance and intrinsic productivity that exceeds the appropriate viability curve. The Willamette-Lower Columbia TRT has developed an alternative viability curved based method, the Population Change Criteria (PCC) approach (WL-LC TRT, 2003). This approach can be adapted to Interior Basin ESU viability curves for application to populations with relatively poor trend data sets.

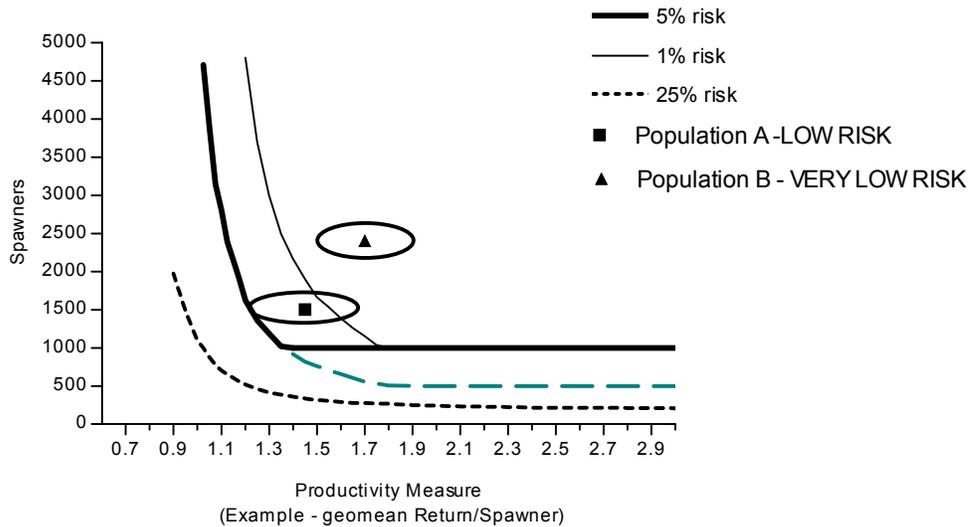
The underlying objective of the comparison of current status against a viability curve is to evaluate the relative likelihood the population of interest is capable of being self-sustaining. Comparing current status against the appropriate viability curve requires a measure of recent abundance and a measure of recent average intrinsic productivity. The recent abundance metric should be measured in terms of spawners of natural origin. The measure of recent average productivity should reflect natural origin returns relative to total spawners in the parent generation. In some cases an estimate of the relative productivity of hatchery origin spawners may be available for the population of interest. In those instances, the estimate of intrinsic productivity should be adjusted to reflect the rate associated with natural origin spawners.

Simple measures of current intrinsic productivity (both return/spawner and population growth rate metrics) can be influenced by the relative density of parent spawners. Most populations of listed Interior Columbia Basin stream type chinook and steelhead are currently at relatively low levels of abundance. As a result, adjustments to separate out the effects of carrying capacity are not necessary. However, as stock approach rebuilding target levels, direct estimates of intrinsic productivity can be affected by carrying capacity. There are options for addressing carrying capacity effects. Population growth rate approaches could employ threshold average spawning levels – if recent average total escapements exceed levels associated with carrying capacity effects, the expected population growth rate targets could be referenced to population maintenance (e.g., low likelihood average population growth rate is less than 1.0). Return per spawner series can be filtered, return per spawner pairs in which the parent escapements exceed a threshold associated with carrying capacity can be left out of the calculation of a recent average productivity. The ICTRT is continuing to develop specific guidance for addressing carrying capacity in estimating current status.

The number of years included in the measures of recent abundance and productivity will be a function of the specific methods used in generating measurements, the form of the

criteria and the variance in annual return rates. Previous attempts to set recovery objectives (e.g., Bevan et al., 1995; Ford et al. 2001, McElhany et al., 2003) recommended minimum time series ranging in length from 8 to 20 years. Preliminary sensitivity analyses indicate that directly incorporating a measure of the relative uncertainty in estimates of current productivity and abundance can reduce the potential for Type II error, e.g. concluding that a population is at low risk when the ‘true’ risk level is actually high. Therefore, we recommend that current status estimates for comparison against the appropriate viability curve should include an adjustment based on the standard errors associated with point estimates of productivity and abundance. Preliminary evaluations indicate that the results are particularly sensitive to the estimate of intrinsic productivity. Adjusting the point estimate of intrinsic productivity downward by subtracting one standard error can substantially improve the ability of the analysis to discriminate relative risk levels.

Figure 2: Evaluating the abundance and productivity of a population relative to the Viability Curve. Individual symbols depict the geomeans, ovals illustrate uncertainty (joint probability intervals) associated with each estimate. Population A would be rated at Low Risk with respect to abundance/productivity, Population B at Very Low Risk.



The ICTRT is continuing to explore the potential for directly incorporating an index of juvenile productivity into viability assessments Interior basin chinook or steelhead populations. Adding specific measures reflecting survival from spawning to outmigrating smolt and from outmigrant to adult return would help deal with a major confounding factor, high year-to-year variability in marine survival rates. Incorporating smolt production measures would also aid in evaluating tributary habitat effects.

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Spatial Structure and Diversity

The viability of a population is affected by its spatial structure and diversity as well as by its abundance and productivity.

Spatial structure concerns a population's geographic distribution and the processes that affect the distribution (McElhany et al. 2000). This distribution can affect population viability in several ways. For example, populations with a restricted distribution are more subject to loss due to a fine-scale environmental event (such as a single landslide) than populations with a more widespread or complex spatial structure. In addition, spatial structure can influence patterns of gene flow both within the population and between populations. It can thus affect a population's adaptation to local environmental conditions. Spatial structure's impact on extinction risk therefore spans both population dynamics and evolutionary processes.

Population-level diversity is similarly important for long-term persistence. Environments continually change due to natural process and anthropogenic influences. Populations exhibiting greater diversity are generally more resilient to these environmental changes in the short and long term. Phenotypic diversity, which includes variation in morphology and life history traits, allows more diverse populations to use a wider array of environments and protects populations against short-term temporal and spatial environment changes. Underlying genetic diversity provides the ability to survive long-term changes in the environment.

McElhany et al (2000) provide a number of guidelines for the spatial structure and diversity of viable salmonid populations that consider these principles (Box 1.)

Box 1. Viable Salmonid Population Spatial Structure and Diversity Guidelines (McElhany et al. 2000)

Spatial Structure

1. Habitat patches should not be destroyed faster than they are naturally created.
2. Natural rates of straying among subpopulations should not be substantially increased or decreased by human actions.
3. Some habitat patches should be maintained that appear to be suitable or marginally suitable, but currently contain no fish.
4. Source subpopulations should be maintained.
5. Analyses of population spatial processes should take uncertainty into account.

Diversity

1. Human-caused factors such as habitat changes, harvest pressures, artificial propagation, and exotic species introduction should not substantially alter variation in traits such as run timing, age structure, size, fecundity, morphology, behavior, and molecular genetic characteristics.
2. Natural processes of dispersal should be maintained. Human-caused factors should not substantially alter the rate of gene flow among populations.
3. Natural processes that cause ecological variation should be maintained.
4. Population status evaluations should take uncertainty about requisite levels of diversity into account.

Interior Columbia Spatial Structure and Diversity Applications:

Goals, Mechanisms, Factors and Metrics

The ICTRT has used the general guidelines presented by McElhany et al. (2000) to develop criteria with which to assess the robustness of a population. Because the spatial structure and diversity guidelines outlined are broadly overlapping (see Box 1.), we combined these considerations into a single metric. We do follow the suggestion of McElhany et al. (2000) to use historical spatial structure and diversity as a default benchmark, since neither the precise role that diversity plays in salmonid population viability nor the relationship of spatial processes to viability is well-understood. Finally, we consider all these guidelines to be based on the conditions expressed by natural-origin fish.

In our previous documents, we combined all the spatial structure and diversity viable salmonid population (VSP) guidelines into a hierarchical format that outlines the goals, mechanisms to achieve those goals, and examples of factors to be considered in assessing a population's risk level. We then provided some examples of scenarios leading to various levels of risk. In this document, we use the same structure (slightly modified from earlier versions to simplify the presentation), but present metrics appropriate for assessing population status with respect to each mechanism, and ultimately with respect to our biological goals. For clarification, we present the following definitions:

A *goal* is the biological or ecological objective that spatial structure and diversity criteria are intended to achieve. We have identified two primary goals:

1. Maintaining natural rates and levels of spatially-mediated processes. This goal serves to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial arrangement of the population.
2. Maintaining natural patterns of variation. This goal serves to ensure that populations can withstand environmental variation in the short and long terms.

Mechanisms are biological or ecological processes that contribute to achieving those goals (e.g., gene flow patterns affect the distribution of genotypic and phenotypic variation in a population).

Factors are characteristics of a population or its environment that influence mechanisms (e.g., gaps in spawning distribution affect patterns of gene flow, which then affect patterns of genotypic and phenotypic variation). In some cases the same factor can affect more than one mechanism or goal. The distribution of spawning areas in a branched vs. a linear system, for example, can affect both patterns of gene flow *and* the patterns of spatially mediated processes, such as catastrophes.

Metrics are measured and assessed at regular intervals to determine whether a population has achieved goals, or to evaluate its current risk level. Each factor has one or more metrics associated with it.

Criteria are specific values of metrics that indicate different risk levels.

We summarize the association between our defined goals, mechanisms, factors and metrics in Table 5. When a factor affects more than one mechanism or goal, we listed it under the mechanism for which it is most directly relevant.

Table 5. Organization of goals, mechanisms, factors and metrics for spatial structure and diversity risk ratings.

Goal	Mechanism	Factor	Metrics
A. Allowing natural rates and levels of spatially-mediated processes.	1. Maintain natural distribution of spawning aggregates.	a. number and spatial arrangement of spawning areas.	Number of MSAs, distribution of MSAs, and quantity of habitat outside MSAs.
		b. Spatial extent or range of population	Proportion of historical range occupied and presence/absence of spawners in MSAs
		c. Increase or decrease gaps or continuities between spawning aggregates.	Change in occupancy of MSAs that affects connectivity within the population.
B. Maintaining natural levels of variation.	1. Maintain natural patterns of phenotypic and genotypic expression.	a. Major life history strategies.	Distribution of major life history expression within a population
		b. Phenotypic variation.	Reduction in variability of traits, shift in mean value of trait, loss of traits.
		c. Genetic variation.	Analysis addressing within and between population genetic variation.
	2. Maintain natural patterns of gene flow.	a. Spawner composition.	(1) Proportion of hatchery origin natural spawners derived from a local (within population) brood stock program using best practices.
			(2) Proportion of hatchery origin natural spawners derived from a within MPG brood stock program, or within population (not best practices) program.
			(3) Proportion of natural spawners that are unnatural out-of MPG strays.
			(4) Proportion of natural spawners that are unnatural out-of ESU strays.
	3. Maintain occupancy in a natural variety of available habitat types.	a. Distribution of population across habitat types.	Change in occupancy across ecoregion types
	4. Maintain integrity of natural systems.	a. Selective change in natural processes or impacts.	Ongoing anthropogenic activities inducing selective mortality or habitat change within or out of population boundary

Distribution and Occupancy

Several of our indices relevant for spatial structure and diversity are dependent upon a comparison between historical conditions or distribution and current distribution.

- *Historical or potential distribution.* We use our analysis of intrinsic potential (Appendix B) as our hypothesis of potential or historically-occupied areas. Specifically, we assume that areas rated “high” or “moderate” in that analysis were occupied, for purposes of our spatial structure and diversity assessments.
- *Current distribution.* Occupied areas are those in which two or more redds have been observed in all years of the most recent brood cycle (i.e. the most recent generation) and have been observed for at least half of the most recent three brood cycles (approximately 15 years for steelhead and chinook). An MSA is regarded as occupied when occupied areas occur within BOTH the upper and lower half of the weighted spawning area within that MSA; an mSA is regarded as occupied when it has met the basic requirements of occupancy.

We recognize that currently data may not be available at the appropriate scale to thoroughly evaluate populations against the range of criteria described below. For immediate needs, we assess current occupancy using agency-defined occupied areas. Future monitoring should be structured to assess occupancy more rigorously.

We do not consider the areas that are currently accessible but are not occupied, in any of our spatial structure and diversity metrics. We regard the current vs. historical distribution comparison to be critical for assessing population status, in which we determine which aspects of the population’s demographic and population-level characteristics put it at risk. However, we recognize that a comparison of areas that could be occupied to historical and current distribution is an important component of a limiting factors analysis, in which the aim is to determine “what needs to be altered in the population’s environment to improve its status.”

Addressing Uncertainty in Spatial Structure and Diversity Assessments

An assessment of spatial structure and diversity at the population level requires consideration of a range of factors and the certainty of the information used to assess risk. The INTRT has identified a set of ten metrics (Integration Table) for use in assessing population level risks relative to spatial structure and diversity. For a given population, assessments against each of the specific metric criteria are integrated into a single population level Spatial Structure and Diversity (SSD) risk rating using a simple weighting framework described below.

Information certainty needs to be considered in the risk assignment for SSD criteria. The confidence in the assigned risk level is directly related to the certainty in the data and information used to assess risk. Taking a conservative approach, risk assignments based on data and information that have low certainty need to be raised to higher risk ratings.

For many of the metrics (associated with spatial structure and diversity), there are varying levels of certainty related to data quality, surrogate information, and in some cases no data at all. These types of certainty differ across ESUs and for populations within ESUs.

In general for an individual population and each of the SSD criteria, uncertainties fall in three major categories, with each of the categories containing subcategories:

- A. Data quality for a particular metric for the population of interest
 - a. Completeness of spatial and temporal coverage within a year
 - b. Length of the time series of the metric
 - c. Consideration of precision and accuracy for the metric
- B. Surrogate information for a metric
 - a. Information for a specific metric from a population deemed to have similar characteristics
 - b. Using other information from surrogate metrics
- C. No data or information available for a metric

High level of certainty, for a specific metric, can be achieved when there is specific information for the population of interest and the data is spatially and temporally complete for each year in the time series. In addition, the time series must be of adequate length (see criteria and occupancy descriptions) and the data must have high level of precision and accuracy as it relates to the metric of interest.

Moderate level of certainty, for a specific metric, is assigned when there is at least surrogate information from a population deemed to have similar characteristics or surrogate metric information. The surrogate information should be spatially and temporally complete for each year in the time series, the time series must be of adequate length, and the data must have high level of precision and accuracy as it relates to the metric of interest.

An additional way of assigning a moderate level of certainty, for a specific metric, is when information for the population of interest does not meet the conditions described for the high level of certainty for one of the following characteristics: spatial and temporal completeness; time series length; or precision and accuracy.

Low level of certainty, for a specific metric, is assigned when surrogate information does not meet the conditions described for the high level of certainty for one of the following characteristics: spatial and temporal completeness; time series length; or precision and accuracy.

An additional way of assigning a low level of certainty, for a specific metric, is when information for the population of interest does not meet the conditions described for the high level of certainty for two or more of the following characteristics: spatial and temporal completeness; time series length; or precision and accuracy.

Metrics for which there are no data(lowest level of certainty) are presently assigned a moderate level of risk. Risk levels for metrics for which the data are assigned high or moderate certainty should not be adjusted. When the certainty is low the risk rating should be increased by one level.

Criteria

Goal A: Allowing natural rates and levels of spatially-mediated processes

Mechanism A.1. Maintain natural distribution of spawning aggregates

We identified three factors that we consider under this mechanism:

- Number and spatial arrangement of spawning areas
- Current spatial range compared to historical spatial range
- Change in gaps or continuities between spawning aggregates

Each of these factors addresses a different aspect of population distribution. The first addresses the inherent risk associated with different population configurations (e.g. linear vs. branched). The second considers shrinkage or contraction of the distribution at its edges or extremes. The third factor considers changes of distribution within the population.

Factor A.1.a. Number and spatial arrangement of spawning areas.

We have defined major spawning areas (MSAs) as contiguous areas of habitat of sufficient quality and quantity to support a minimum number of spawners (see Attachment C) separated from other such areas. Our criteria depend on the current number and arrangement of occupied MSAs and other spawning habitat (Table 6).

Table 6. Factor A.1a: Preliminary criteria describing risk levels associated with the number and spatial arrangement of occupied spawning areas.

Factor/metric	Pop. Group	Risk level			
		Very Low	Low	Moderate	High
Factor: Number and distribution of spawning areas	A B C D	4 or more MSAs in a non-linear configuration; or	2-3 MSAs in a non-linear configuration separated by 1 or more confluences	2 or more MSAs in linear configuration; or	<= 1 MSA
Metric: Number of MSAs, distribution of MSAs, and quantity of habitat outside MSAs		3 MSAs plus the sum of the other areas outside of MSAs with 75% capacity of an MSA		1 MSA plus one or more branches (outside of MSA) that sum to greater than 75% of capacity of an MSA	

Factor A.1.b. Spatial extent or range of population.

Reductions in the range of habitat used by a particular population can affect its vulnerability to local catastrophes. In addition, changes across significant habitat conditions (such as elevation) can affect life history or morphological diversity within a population. Finally, any change in range that increases or decreases the distance among populations may alter exchange of individuals between populations, hampering the exchange of genetic materials within an MPG and/or an ESU, and altering the likelihood of recolonization of extirpated areas. We use occupancy of MSAs across habitat conditions as our metric. (Table 7).

Table 7. Factor A.1.b. Preliminary criteria describing risk levels associated with spatial extent or range of population.

Factor/ Metrics	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Spatial extent or range of population	A	Not attainable	All historical MSAs occupied	Up to 50% of historical MSAs unoccupied.	Less than 50% of historical MSAs occupied.
Metrics: Occupancy of MSAs across likely historical habitat conditions	B	Current spawning	Historical range	50-75% of historical MSAs occupied	Less than 50% of historical MSAs occupied
	C	distribution mirrors	reduced: 75% of more of historical MSAs occupied		
	D	historical			

Factor A.1.c. Increase or decrease in gaps or continuities between spawning aggregates.

Given the strong homing instincts of anadromous salmonids, significant changes in the distance between spawning areas may have impacts on gene flow within and among populations. The size of gaps between spawning areas may also affect the ability of a population to recolonize extirpated areas. A general dispersal distance relationship was used as one factor in defining distinct historical populations within Interior Basin ESUs. Based on that curve, dispersal or straying rates between spawning areas less than 10 km apart were relatively high. We suggest a simple index based on discontinuities between MSAs (Table 8). The gaps criteria also incorporate consideration for the loss of spawning areas (MSAs or mSAs) at the lower end of populations. Such losses can substantially increase the distance from adjacent populations.

Table 8. Factor A.1.c. Preliminary criteria describing risk levels associated with a change in gaps or continuities between spawning aggregates.

Factor/ Metrics	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Gaps between MSAs	A	Population included 75% of more of	Currently occupied	Occupied MSAs	
	B	3 or more historical historical MSAs	MSAs separated by	separated by 15 km	
	C	MSAs AND All occupied, gaps	10 km or more AND	or more AND	
	D	historical MSAs and between MSAs	intervening	intervening	
		mSAs currently separated by 10 km historical spawning	historical spawning	historical spawning	
		occupied or less and one or e areas (MSA or	mSAs) not	areas (MSA or	
		more historical mSAs currently	occupied. OR	mSAs) not	
		occupied.		occupied	
			Loss of mSAs at		
			lower end of		
			population increase		
			sufficient to		
			increase distance		
			to adjacent		
			population by 25		
			km or more.		

Goal B: Maintaining natural levels of variation

We identified four mechanisms that support our goal of maintaining natural levels of variation. We arranged these in a hierarchy, from direct measures of phenotypic and genotypic variation to measures of environmental or other conditions that are likely to affect population-level diversity. We include both these indirect and direct measures for two reasons. First, in many cases, direct measures of diversity are not available. Second, even when available, detectable change in phenotypic or genotypic measures may lag behind the impact causing that change. Including indirect, causal mechanisms thus serves to identify situations that are likely to become detectably impaired.

Mechanism B.1: Maintain natural patterns of phenotypic and genotypic expression

This mechanism focuses directly on observed genotypic and phenotypic variation within populations and on changes in that variation. This is the variation that we seek to preserve in viable populations. Changes in these natural patterns are the strongest possible evidence that the population may be at risk with respect to diversity.

Factor B.1.a. Major life history strategies.

We consider a major life history strategy to include a suite of phenotypic characteristics that are relatively correlated (at least phenotypically). Summer run-timing in stream-type chinook salmon, for example, rises to the level of a major life history strategy, as it encompasses not only adult run-timing, but also spawn-timing, age structure, size and to some extent, habitat preferences. Although life history strategies are a subset of phenotypic expression, we did not include this factor within “phenotypic variation” because we felt that these suites of characters were particularly important for overall population viability.

We consider the following to be major life history strategies:

- Residence and anadromy

- Seasonal run-timing, including;

 - spring- and summer- run in the Snake River spring/summer chinook ESU,

 - winter and summer run steelhead,

 - A and B-run steelhead.

- Significant alternative juvenile migration patterns. These should include:

 - consideration of timing of ocean migration (e.g., subyearling vs yearling)

 - relative distribution for summer rearing (e.g., natal tributary vs downstream mainstem)

 - relative distribution for overwintering (e.g, natal tributary vs fall downstream emigration).

Our metrics for major life history patterns consider the presence and distribution of adult and juvenile life history strategies within a population (Table 9). In many cases,

historical pathways will need to be inferred from habitat assessments and information from representative systems or from model based projections (e.g., EDT). In those cases key assumptions should be clearly described and justified.

Table 9. Factor B.1.a. Preliminary criteria describing risk levels associated with major life history strategies.

Factor	Pop. Group	Risk Level				
		Very Low	Low	Moderate	High	
Factor: Major life history strategies	A	No evidence of loss in variability or change in relative distribution	All historical pathways present, but variability in one reduced or relative distributions shifted slightly	All historical pathways present, but significant reduction in variability or substantial change in relative distribution	Permanent loss of major pathway (e.g. anadromy for <i>O. mykiss</i> , or loss of a juvenile pathway)	
Metric: Distribution of major life history expression within a population	B		No evidence of loss in variability or change in relative distribution	All historical pathways present, but variability in one reduced or relative distributions shifted slightly	All historical pathways present, but significant reduction in variability or substantial change in relative distribution	Permanent loss of major pathway (e.g. anadromy for <i>O. mykiss</i> , or loss of a juvenile pathway)
	C					
	D					

Factor B.1.b. Phenotypic variation.

This factor includes morphological, life history, and behavioral traits. Loss or severe truncation of specific traits reduces the resilience of a population to environmental perturbations, both in the short term (annual fluctuations, multiyear cycles) and long term (shifts in climatic conditions, etc.). We assess change in phenotypic variation by examining the mean, variation, and presence/absence of each trait (Table 10). Specific information on traits may not be available for all populations. Initial status reviews may be able to incorporate inferences based on information from similar populations within the same MPG or ESU.

Table 10. Factor B.1.h. Preliminary criteria describing risk levels associated with change in phenotypic characteristics.

Factor/Metrics	Pop. Group	Risk Level				
		Very Low	Low	Moderate	High	
Factor: Phenotypic characteristics.	A	No evidence of loss, reduced variability, or change in any trait	Evidence of change in mean or variability in 1 trait (e.g., migration timing, age structure, size-at-age)	Loss of 1 trait or evidence of change in mean and variability of 2 or more traits	Loss of 1 or more traits and evidence of change in mean and variability of 2 or more traits (e.g., loss of a spawning peak and significant reduction in older age fish)	
Metric: Reduction in variability of traits, shift in mean value of trait, loss of traits.	B		No evidence of loss, reduced variability, or change in any trait	Evidence of change in mean or variability in 1 trait (e.g., migration timing, age structure, size-at-age)	Loss of 1 trait or evidence of change in mean and variability of 2 or more traits	Loss of 1 or more traits and evidence of change in mean and variability of 2 or more traits (e.g., loss of a spawning peak and significant reduction in older age fish)
	C					
	D					

Factor B.1.c. Genetic variation. This factor addresses observed changes in genetic variation, regardless of the cause of that change (e.g., whether the change is due to introgression from non-local hatchery spawners or from the adverse genetic consequences of small population size).

We recommend that current and past population-specific genetic data sets be evaluated for:

- The amount of genetic variation detected within the population or subpopulations;
- The level of differentiation between subcomponents of the population;
- The level of differentiation between the population and other populations (including hatchery stocks); and,
- Temporal change in levels of variation or differentiation within and between populations.

These characteristics may be expressed by such measures as statistically significant reductions in heterozygosity, number of alleles, changes in allele frequencies, presence of non-native alleles, or as among locus (gametic) or within locus (genotypic) disequilibria consistent with ongoing or recent admixture with non-native populations.

However, we did not include specific genetic metrics or cutoffs in our criteria for three reasons. Most importantly, the wide variety of circumstances in the interior Columbia Basin requires a case-by-case examination of genetic data. For instance, available baseline genetic information may not be a reasonable picture of natural levels of genetic variation due to bottlenecks the population has experienced, or to extreme introgression from hatchery fish. Therefore, in some cases, change from a baseline might reduce the apparent risk to a population, whereas in others, the same degree of change might constitute a significant increase in risk level. Second, the ever-changing nature of molecular genetic techniques and analyses suggests that new advances may provide additional or improved methods to measure genetic variation. Finally, degree or magnitude of differentiation that could be gauged to be “high” or “low” will vary between species and data type and quality.

We do suggest risk levels associated with degree of change from “actual or presumed historical conditions” for genetic characteristics (Table 11.) Requiring populations to show low levels of change from “actual or presumed historical conditions” is not meant to imply that the population must have the precise distribution of alleles that it had historically. Rather, we mean that the general pattern of differentiation exhibited within and between populations should be similar to that which existed historically (if a suitable baseline exists) or that which can be inferred as being likely from other similar populations. For example, Upper Columbia stream-type chinook were essentially homogenized during the 1930s and 1940s, during the construction of Grand Coulee Dam. If the populations in the Upper Columbia ESU show differentiation between subcomponents of the population and between populations that is of a similar magnitude to that within and between population variation in other, untrammled stream-type chinook populations, they could be judged to have little change from “presumed historical conditions.”

Table 11. Factor B.1.c. Preliminary criteria describing risk levels associated with change in patterns of genetic variation.

Factor	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Genetic variation Metric: Genetic analysis encompassing within and between population variation	A	No change from actual or presumed historical conditions	No change from actual or presumed historical conditions or evidence for a consistent trend towards historical conditions	Low level of change from actual or presumed historical conditions or evidence for a consistent trend towards historical conditions	Moderate or greater level of change from actual or presumed historical conditions
	B	No change from actual or presumed historical conditions	Low level of change from actual or presumed historical conditions or evidence for a consistent trend towards historical conditions	Moderate level of change from actual or presumed historical conditions or evidence for a trend towards historical conditions	Significant change from actual or presumed historical conditions
	C,D	No change from actual or presumed historical conditions	Criteria for A or B populations, dependent upon number of MSAs in population	Criteria for A or B populations, dependent upon number of MSAs in population	Criteria for A or B populations, dependent upon number of MSAs in population

Mechanism B.2: Maintain natural patterns of gene flow

Maintaining natural patterns of gene flow is an indirect means of maintaining natural patterns of variation. We included spawner composition as an important factor supporting this mechanism. However, gaps within the population, and restrictions of spatial range (Factors A.1.b and A.1.c.) can also affect within and between population gene flow.

Factor B.2.a. Spawner composition.

Natural breeding groups of Pacific salmon and trout (*Oncorhynchus* spp.) tend towards maintenance at natal localities because of strong homing capabilities coupled with localized adaptations (Hendry et al. 1998, 1999, NRC 1996, Reisenbichler et al. 2003). Stability of such aggregates over generations through centuries, and as fine as the local reach (Gharrett and Smoker 1993, Bentzen et al. 2001), is influenced by numbers of returning natal individuals (Waples 2004), ecological variability (Montgomery and Bolton 2003), and gene flow from exogenous fish (Utter 2001). This spatial and potentially adaptive level of variability within and between populations is recognized as important and necessary for viability of salmonid populations (McElhany et al. 2000).

The stability of salmonid population structure can be undermined by effective straying resulting from returning hatchery releases and natural-origin strays induced by anthropogenically-altered conditions. Such increases of gene flow above natural levels are counterproductive to recovery efforts within listed ESUs because of hatchery adaptations or domestication (Epifanio et al. 2003, Waples and Drake 2004), losses of

genetic variability through supportive breeding (Ryman and Laikre 1991, Wang and Ryman 2001), and erosions of natural population structure such as homogenization (Utter 2005). The ultimate impact of these increases in gene flow is dependent upon the duration of the increase, the proportion of spawners that are not part of the normal system, and the origin of those spawners.

We have developed a flow-chart approach to assigning risk associated with exogenous spawners in salmonid populations (Figure 3). For this metric, we consider exogenous spawners to be all fish of hatchery-origin AND all natural-origin fish that are present due to unnatural, anthropogenically-induced conditions, but would not normally be present within the population. Upriver steelhead straying into the Deschutes River as an apparent result of unnatural high temperatures in the John Day reservoir would be one candidate for this category.

Our approach is sequential. It considers the source of the exogenous spawners first, providing increasing tolerance for both proportion and duration of exogenous spawners the more closely related they are to the population of interest. For exogenous spawners derived from the local population, we then consider the type of hatchery program from which those spawners were derived, allowing greater input from hatcheries using “best management practices. We do not specify specific management practices, because current and ongoing research will increase our understanding of the impact of hatchery operations and techniques on fitness characteristics. Rather we suggest that hatchery programs that conform to the principles described in recent publications (e.g. (Flagg et al. 2004, Olson et al. 2004, Mobrand et al. 2005) could be considered to have “best management practices.” Main components of the program to be considered include broodstock selection, efforts to minimize within-population homogenization, actions to prevent domestication or other in-hatchery selection, breeding protocols and other efforts to minimize effects on population structure and fitness components. Future assessments should consider advancements and updates in hatchery science when determining which category a particular program should be ascribed to.

There are several more detailed considerations for applying our criteria. First, when assessing the current status of a population, conditions in the most recent three generations should be considered. Second, the proportion of spawners belonging to a category should be calculated using the total number of spawners in the denominator. Finally, if there are multiple sources of exogenous spawners within a single population, the highest risk level assigned to any of those sources should be used for this metric, unless there are two or more “moderate” rated sources, in which case a risk level of “high” should be used. Finally, we do not extend our criteria beyond 5 generations for any source of exogenous spawners, because there is considerable uncertainty about the long-term impacts of this unnatural gene flow. We anticipate that future research will allow these criteria to consider longer time periods more robustly.

These criteria are generally consistent with other efforts to quantify risk (e.g. (Mobrand et al. 2005). However, we do encourage case-by-case treatment of conditions that may affect the risk experienced by the population. For instance, if exogenous spawners are localized within a large, complex population, leaving the bulk of the population unaffected, a somewhat higher proportion and/or duration of those exogenous spawners

could be associated with a lower risk level. Similarly, in a very diverse MPG, the presence of exogenous spawners derived from a highly divergent population might merit higher risk levels than shown. While we offer this flexibility, such situations should be well-documented and justified.

Mechanism B.3: Maintain occupancy in a natural variety of available habitat types

Maintaining spawner occupancy in a natural variety of available habitat types is an indirect mechanism to maintain natural patterns of variation. Differing habitats allow or promote the expression of differing phenotypes (Hendry and Quinn 1997, Hendry et al. 1998, Waples et al. 2001). Conceptually, the greater the range of habitat types available, the greater the potential for a population to express phenotypic diversity.

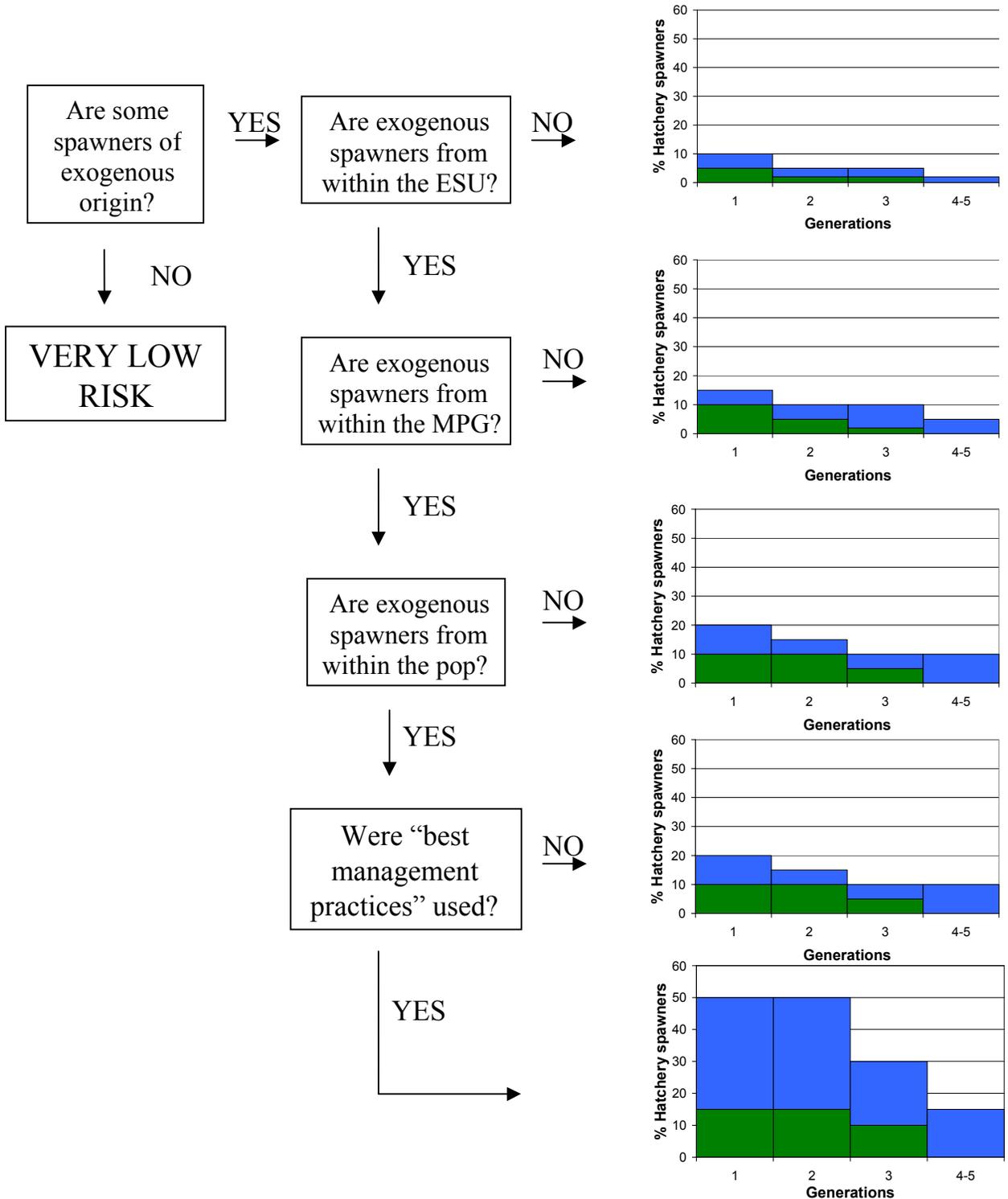


Figure 3. Graphical representation of risk criteria associated with spawner composition. Green areas indicate low risk combinations of duration and proportion of spawners, blue areas indicate moderate risk areas and red-stippled areas and areas outside the range graphed indicate high risk. Exogenous fish are considered to be all fish of hatchery origin, and non-normative strays of natural origin (see text).

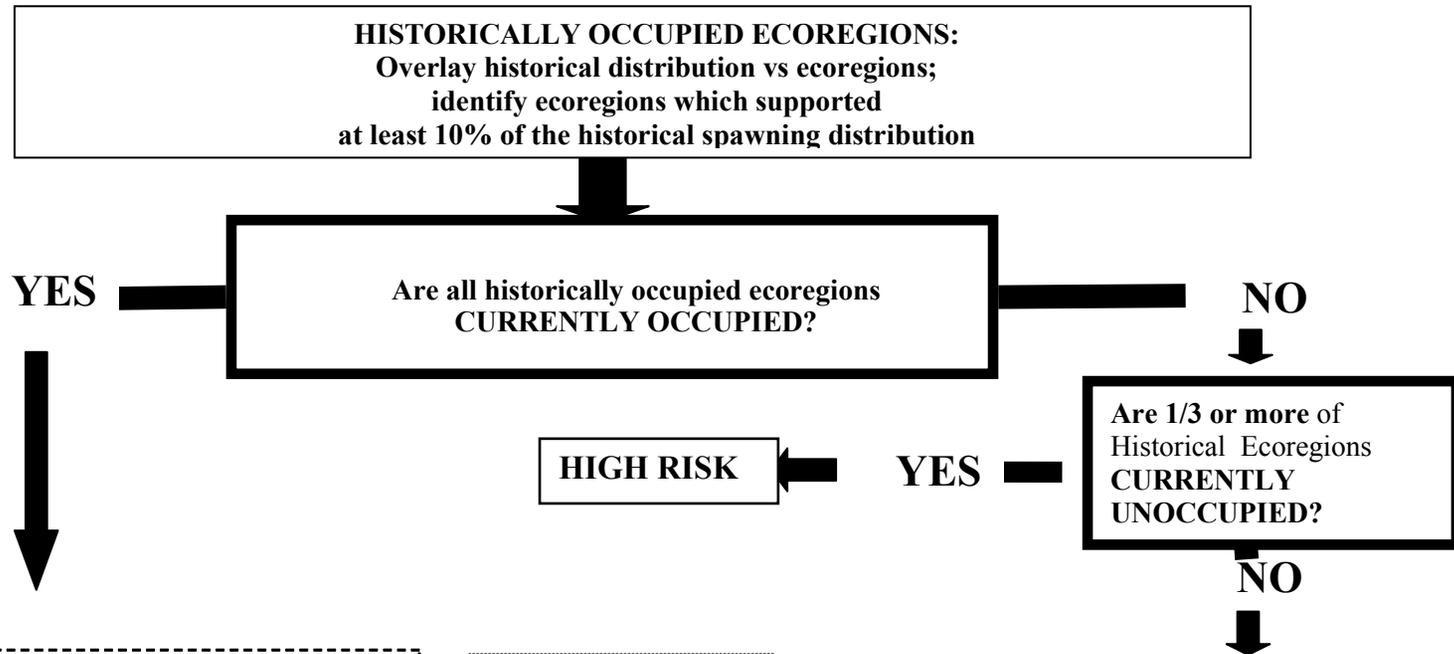
Factor B.3.a. Distribution of population across habitat types.

Salmonids regularly show local adaptations to habitat conditions they experience ((Crossin et al. 2004). We rely on evidence that unique aquatic habitat types are produced within the context of the terrestrial ecosystems that encompass or border stream segments (e.g. Frissell et al. 1986). This relationship between a terrestrial ecosystem and its incorporated aquatic system is apt to be strongest for small streams and rivers and to be weaker for large rivers. We consider the range of habitat types occupied by a population as part of our spatial structure/diversity scoring system. A habitat diversity metric is intended to identify situations where that range of occupied habitats has changed substantively from its historic condition.

We use EPA's ecoregion classification (Level IV) (Omernik 1987, Gallant et al. 1989, Omernik 1995) to assess the historic (intrinsic) and current range of habitat types occupied. This was done by determining the distribution of intrinsic spawning habitat for a target population among the terrestrial ecosystems described by Omernik (1995). EPA Level IV ecoregion classification has the advantage of being widely accessible, well-documented and providing continuous coverage throughout the Columbia basin. These ecoregions were not developed with a focus on aquatic habitat, and their development variably includes attributes such as precipitation, land form, geology, and vegetation that influence aquatic habitat diversity. However, they are strongly correlated with differences in elevation, precipitation, and temperature regimes (ICTRT, unpublished data). Thus, as a first approximation, we believe that they capture reasonably some of the relatively substantive differences in habitat and environmental conditions that we are seeking to identify. We do note, however, that future work aimed at characterizing habitat diversity associated with population-level phenotypic and genetic diversity would be extremely useful for refining this metric. Among the likely tools for classification of habitat characteristics of biological relevance, we note some useful hydrological analyses, such as those developed by (Orsborn 1990, Lipscomb 1998).

Our approach to defining the relative risk associated with major shifts in distribution of spawners relative to ecoregions is illustrated in Figure 4. We define substantial changes in occupancy relative to historical distributions based on our intrinsic potential assessment. Ecoregions that supported more than 10% of the historical spawning area within a population are considered in the analysis. We defined a substantial change in relative distribution as a reduction of 67 percentage points or more in the relative distribution of spawning within an ecoregions that historically contained more than 10% of the weighted spawning area for a population. For example, if ecoregions X contained 50% of the total historical spawning area for a population, and that ecoregion currently represents 15% of the spawning area, the relative distribution has shifted by $(50 - 15)/50$ or 70%. In this case the shift would be counted as a substantial change.

Figure 4: Evaluating changes in spawner distribution versus ecoregions.



	Number of HISTORICAL ECOREGIONS				RISK LEVEL				Number of HISTORICAL ECOREGIONS			Number of SUBSTANTIAL CHANGES in Ecoregion Occupancy
	1	2-3	4+		VERY LOW	LOW	MODERATE		HIGH	2-3	4-5	
Number of SUBSTANTIAL CHANGES in Ecoregion occupancy	NA	NA	0	→	←	NA	NA	NA	NA	NA	NA	
	0	0	1	→	←	NA	0	0	NA	0	0	
	NA	1	2	→	←	0	1	1	0	1	1	
	NA	2	3	→	←	1	2	3	1	2	3	

Mechanism B.4. Maintain integrity of natural systems

Maintaining the normative functioning of natural systems across the life cycle is an important component of maintaining natural patterns of diversity or variation. A variety of elements are encompassed under the aegis of “natural systems.” For example, landscape and habitat-forming processes contribute to the range of variation potentially expressed in the spawning and rearing life stages. Alterations to the hydrograph, for example, could substantially alter outmigration or spawn timing. Similarly, the effects of the biological community, such as predation, competition and nutrient availability have the potential to affect the range of diversity that is expressed within a population. Finally, changes to the system or environment across the salmonid life cycle that differentially affect subcomponents of the population can alter natural patterns of diversity. An obvious example of such a change is strong size-selective harvest; populations subject to such harvest have likely experienced a shift in phenotype. Importantly, in each of these situations it is not only that change has occurred, but also that the change is selective. In other words, that change causes a shift, truncation, or other alteration to the normal variation, and thus the fitness of the population, rather than merely a decrease in overall population survival or abundance. The focus of this mechanism is on activities that affect normal variation rather than change in that variation itself. The inclusion of this metric allows risks to diversity to be identified even in cases where phenotypic information is lacking.

Factor B.4.a.

Change in natural processes or impacts. Many factors may affect a specific subset of a population and result in intentional or unintentional selection on a population. While we consider all factors using the same decision process, it is useful conceptually to consider actions in two general categories. First, direct removal of individuals or *take* can be selective in nature. Several examples of selective take are well known in the fisheries literature with size-selective harvest perhaps being the best documented. Other examples include broodstock collection that preferentially removes one temporal component of a run and activities that preferentially remove a specific age class. Habitat modifications that cause selective mortality are the other category of activities to be considered. Examples of selective habitat changes include alterations to downstream or valley habitat that a specific subset of juveniles uses as rearing habitat. Similarly, alteration of the hydrograph that eliminates a specific window for juvenile outmigration would be selective in nature.

Assigning Risk Associated with Selective Activities

We use four questions and a decision tree to assign any given population to a risk category associated with selective activities (Figure 5). The first question determines if a selective activity is ongoing or has occurred in the recent past. Any take or habitat alteration that targets (either intentionally or unintentionally) a specific segment of a population should be considered selective. We do however exempt activities that cause

mortality to so few fish that the effect of that mortality is negligible. While we do not provide a specific numerical guideline to define “negligible” we would encourage a conservative approach and suggest classifying an activity non-negligible unless it is clearly of little consequence. The second question is intended to determine the intensity of selection with mortality of greater than 25% *of the individuals in the selected subset of the population* being a highly selective activity. Question three determines the duration of the selective activity and considers activities that continue beyond a single generation to be of increased risk. The ranking associated with both questions two and three are modified if the activity is no longer occurring (the fourth question).

Assigning Risk in Populations Affected by Multiple Selective Activities

Some populations may be affected by more than one selective activity. Two issues are important for assigning risk in these situations. The first is identifying what component of the population has been affected. In cases where more than one activity affects the same component of a population (e.g. two activities both affect early out-migrants), those two activities should be treated jointly when working through the decision process outlined in figure 5. The second issue is devising a cumulative score for the multiple activities (or joint activities). In these cases, once all activities have been considered, each activity (or joint activities affecting the same component of the population) should be assigned a risk level using Figure 5. The population risk level is set at the highest risk level for any single factor in most cases. The single exception to this approach is the case in which three or more factors are all rated as moderate. In this case, the cumulative effect of those activities is sufficient to merit a high risk rating for the population.

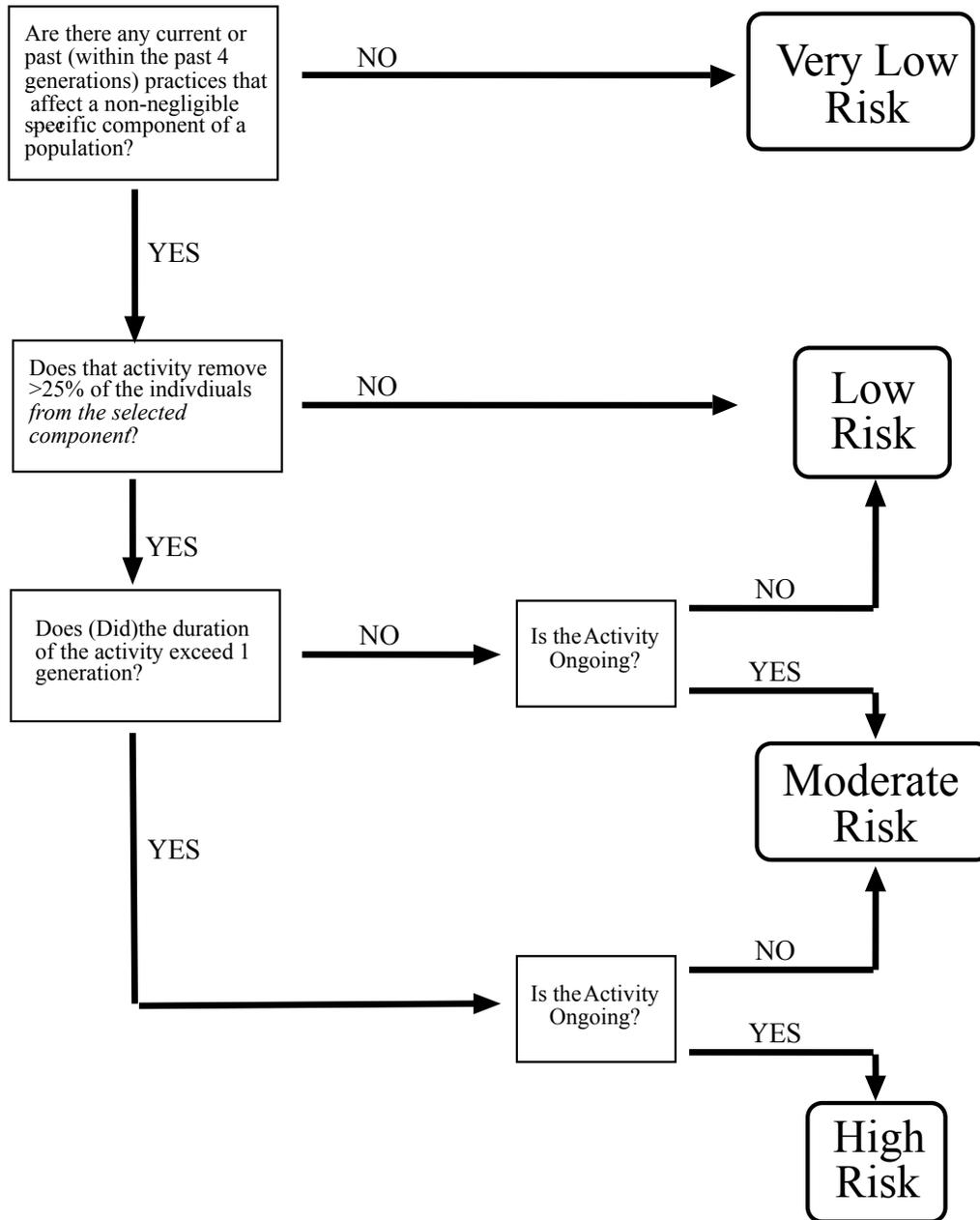


Figure 5. Decision process for assigning populations to a risk category associated with selective activities. Activities affecting the same component of the population should be considered simultaneously in this process. If multiple actions are selective in nature effect a single population that population will receive the highest risk category associated with a single action except in the case where 3 or more actions are associated with moderate risk in which case the population will be assigned to the high risk category for selective actions.

Generating a Final Spatial Structure and Diversity Rating

Table 12 provides the assessment tool to determine a population's risk level associated with spatial structure and diversity (SS/D). The table is organized hierarchically with the two primary goals of the SS/D criteria (McElhany et al. 2000) in the leftmost column. For each goal, one or more mechanism to achieve that goal is given in the next column. In general, these mechanisms describe the conditions associated with natural healthy populations. The third column lists the factors associated with each mechanism. Factors in this context are individual and population-level attributes that characterize each mechanism. The metrics outlined in the fourth column are the quantitative and qualitative measures used to assess a population's risk status relative to each metric. Metrics are designated as A type if they are direct measures of SS/D attributes. B type metrics are changes from natural conditions that are inferred to be a reflection of SS/D attributes but are themselves indirect measures of SS/D.

The next four columns are a mirror image of the first four and provide the rules under which each metric score is assimilated up the hierarchy of the risk table. Risks are entered at the metric level and then carried through to higher levels to the right. For example, at the Factor level, metric A.1.a is assigned the risk level it was given at the Metric level. For comparison, B.2.a metrics 1-3 are integrated at the factor level following the rule set provided in the table. Metric scores across the entire table are integrated in a similar manner until the final column is reached which provides the population-level risk associated with SS/D.

The rules governing the integration at each level are intended to reflect the effect each metric would have on SS/D. A-type factors are integrated by calculating the mean of the three metrics since these are direct measures of SS/D criteria. The lowest score (highest risk) from the three B1 metrics is carried through the table to the goal level. B1 metrics are measured deviations from natural patterns of phenotypic or genotypic expression. Thus, any measured deviation is likely to be an indicator of undetected changes and constitutes a substantial risk at the SS/D level. B2 metrics describe the influence that hatchery stocking may have on natural patterns of gene flow. In general, these metrics are integrated in the same manner as B1 metrics. However, the case in which two or more of the metrics are rated moderate provides two complementary lines of evidence that hatchery stocking is altering the natural conditions and the risk level is increased to high accordingly. Factors B3 and B4 have a single metric the score of which is carried to the mechanism level. At the goal level the mean of the A-type metrics is used for the same reasons described for the mechanism level. The B-type metrics are integrated either by taking the B1 score or by using the mean of all B-type scores, whichever is lower (higher risk). This approach recognizes that B1 mechanisms are direct measures of deviations from natural conditions and should be given increased attention over the remaining B metrics. The overall population risk level is determined by using either the A metric or B metric score, whichever is lower (highest risk).

Table 12. Scoring system for deriving a composite, population-level spatial structure and diversity risk rating. Metrics and descriptions in the “Assessed Risk” column indicate contribution of individual metrics to integrated population score (Scoring: Very Low = 2, Low =1, Moderate=0, High=-1)

Mechanism	Factor	Metrics	Assessed Risk			
			Factor	Mechanism	Goal	Population
1. Maintain natural distribution of spawning aggregates.	<i>a. number and spatial arrangement of spawning areas.</i>	Number of MSAs, distribution of MSAs, and quantity of habitat outside MSAs.	A.1.a	Mean of A.1.a., A.1.b, A.1.c.	Mean of A.1.a., A.1.b, A.1.c.	
	<i>b. Spatial extent or range of population</i>	Proportion of historical range occupied and presence/absence of spawners in MSAs	A.1.b			
	<i>c. Increase or decrease gaps or continuities between spawning aggregates.</i>	Change in occupancy of MSAs that affects connectivity within the population.	A.1.c			
1. Maintain natural patterns of phenotypic and genotypic expression.	<i>a. Major life history strategies.</i>	Distribution of major life history expression within a population	B.1.a	Lowest score (highest risk)		
	<i>b. Phenotypic variation.</i>	Reduction in variability of traits, shift in mean value of trait, loss of traits.	B.1.b			
	<i>c. Genetic variation.</i>	Analysis addressing within and between population genetic variation.	B.1.c			
2. Maintain natural patterns of gene flow.	<i>a. Spawner composition.</i>	Proportion of hatchery origin natural spawners derived from a local (within population) brood stock program using best practices.	If two metrics rated as moderate, then high risk; otherwise lowest score (highest risk)	If two metrics rated as moderate, then high risk; otherwise lowest score (highest risk)	B1 Mech. Score or Mean of B.1, B.2,B.3, and B.4, whichever is lower (higher risk)	Lowest score (highest risk)
		Proportion of hatchery origin natural spawners derived from a within MPG brood stock program, or within population (not best practices) program.				
		Proportion of natural spawners that are unnatural out-of MPG strays.				
		Proportion of natural spawners that are unnatural out-of ESU strays.				
3. Maintain occupancy in a natural variety of available habitat types.	<i>a. Distribution of population across habitat types.</i>	Change in occupancy across ecoregion types	B.3.a	B.3.a		
4. Maintain integrity of natural systems.	<i>a. Selective change in natural processes or impacts.</i>	Ongoing anthropogenic activities inducing selective mortality or habitat change within or out of population boundary	B.4.a	B.4.a		

Generating a Final Population-level Risk Rating

We integrate all four VSP parameters using a simple matrix approach (Table 13). We use two metrics to assess the status of each population. The first (A/P) combines the abundance and productivity VSP criteria (McElhany et al. 2001) using a viability curve. The second (SS/D) integrates across twelve measures of spatial structure and diversity. The risk category where any population is assigned is determined using two guiding principles. First, the VSP concept (McElhany et al. 2001) provides a 5% risk criterion to define viable populations. Therefore, any population scored moderate or high in abundance or productivity criteria can not meet viable standards. In addition, any population that is high risk in SS/D cannot be considered viable. Although SS/D status is more difficult to quantify, populations that do not meet these criteria are not consistent with long-term persistence and viability. Populations with a Very Low rating for A/P and at least a Low rating for SS/D are considered to be “Highly Viable.” Populations with a Low rating for A/P and a Moderate rating for Spatial Structure and Diversity are considered “Minimally Viable.”

Table 13. Matrix of possible Abundance/Productivity and Spatial structure/Diversity scores for application at the population level. Percentages for abundance and productivity (A/P) scores represent the probability of extinction in a 100-year time period. Cells that contain a “V” are considered viable combinations; “HV” indicates Highly Viable combinations and “MV” indicates Minimally Viable combinations. Cells that are gray are not viable.

		SS/D risk			
		Very Low (VL)	Low (L)	Moderate (M)	High (H)
A/P risk	Very Low (VL) <1%	HV	HV	V	
	Low (L) 1-5%	V	V	MV	
	Moderate (M) 6-25%				
	High (H) >25%				

MPG-level Viability Criteria

Our Major Population Group (MPG) risk criteria rely on the level of risk associated with its component populations. While individual populations meeting viability criteria are expected to have low risk of extinction, these additional, MPG-level criteria ensure robust functioning of the metapopulation and provide resilience to catastrophic loss of one or more populations. In developing these criteria, we assume that catastrophes do not increase dramatically in frequency, that populations are not lost permanently (due to catastrophe or anthropogenic impacts) and that permanent reductions in productivity, including long-term, gradual reductions in productivity do not occur.

Specifically, to be regarded as at low risk (viable), an MPG must meet the following six criteria:

1. One-half of the populations historically within the MPG (with a minimum of two populations) must meet at least minimum viability standards (Table 13).
2. At least one population must be categorized as being “Highly Viable (Table 13).
3. Viable populations within an MPG must include some populations classified (based on historical intrinsic potential) as “Very Large,” or “Large,” and “Intermediate” in the same proportion as were present within the MPG historically.
4. Populations not meeting viability standards should be maintained with sufficient productivity that the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks).
5. Where possible, given other MPG viability requirements, some populations meeting viability standards should be contiguous AND some populations meeting viability standards should be disjunct from each other.
6. All major life history strategies (e.g. spring and summer run-timing) that were present historically within the MPG must be represented in populations meeting at least the minimum viability requirements.

ESU-level Viability Criteria

Because Major Population Groups (MPGs) are geographically and genetically cohesive groups of populations, they are critical components of ESU-level spatial structure and diversity. Having all MPGs within an ESU at low risk provides the greatest probability of persistence of any ESU. Our ESU-level criteria are as follows:

1. All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU must be at low risk.
2. ESUs that contained only one MPG historically or that include only one MPG critical for proper function must meet the following criteria:
 - a. That single MPG must meet all the requirements to be at low risk (see above). In addition:
 - b. Two-thirds or more of the populations within the MPG historically must

- meet minimum viability standards; AND
- c. At least two populations must meet the criteria to be “Highly Viable.”

To determine whether extirpated MPGs are critical for proper functioning of the ESU, the Interior Columbia TRT will conduct an evaluation of these extirpated areas, considering the following:

- Likely demographic (abundance and productivity) contribution of the MPG and its component populations to the ESU.
- Spatial role of the MPG in the ESU (e.g. does the extirpated MPG create a gap in the distribution of the ESU?)
- Likely contribution to overall ESU diversity (e.g. does the extirpated MPG occupy habitats that are substantially different from other habitats currently occupied in the ESU?)

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