

**Information Structure of
Ecosystem Diagnosis and Treatment (EDT)
and Habitat Rating Rules for
Chinook Salmon, Coho Salmon, and Steelhead Trout**

by

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“...the challenge for stream ecologists, especially those who study fish, is to understand how these continuous, hierarchical and heterogeneous habitats are arrayed in space and time and are linked by fish movement to influence the persistence, abundance, and productivity of fish populations and communities along the riverscape.”

(Fausch and others 2002)

SECTION 1. INTRODUCTION

Knowledge of how the quality and quantity of different habitats affect the performance of salmonid populations is a basic need of natural resources managers. Concerns about salmonid species and stocks at risk have prompted wide consideration of how land use practices affect aquatic habitats. While broad patterns of land use and environmental condition can generally be correlated with population abundance (Pess and others 2002, Feist and others 2003), such knowledge is often inadequate for the needs of decision makers and watershed planners.

For those charged with managing watersheds and fish populations, the need is for far more specific information about how fish populations might respond to various types and combinations of actions that could be taken in a watershed. Managers must prioritize actions to improve fish population performance; this requires information on spatial and temporal variation in habitat quality and quantity within a target watershed. This information can be used to evaluate outcomes of different strategies and actions. Managers must weigh trade-offs between different scenarios involving future development and devise scientifically accountable and cost effective solutions to management of freshwater systems.

Ecosystem Diagnosis and Treatment (EDT) was developed to provide such information for decision makers. EDT provides a diagnosis of current environmental constraints in a system and allows managers to explore alternative habitat restoration strategies. The method uses species-specific rules that relate environmental conditions in freshwater to life stage survival responses of salmonid fishes. The rules are one part of the modeling procedure to characterize habitat conditions in a stream and to assess how anthropomorphic changes to the environment constrain species performance. The general process for application of the EDT to watershed planning is explained in Lichatowich and others (1995). EDT species-habitat rules have been developed for most anadromous species of *Oncorhynchus* as well as several non-anadromous salmonid species. Using these rules, EDT has been successfully applied to most streams in the Columbia River and Puget Sound basins.

This document will explain the rules and information structure for EDT with specific application to the rules for Chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*) and steelhead trout (*O. mykiss*). The document should be used in conjunction with the EDT Rules Viewer software that allows users to explore the effects of specific EDT rules using an EDT stream reach data set. This document will describe the structure of the rules and provide illustrations of the EDT rule concepts using these three species. Each of the habitat rules used in EDT for spring Chinook, fall Chinook, coho, summer steelhead and winter steelhead are illustrated in the EDT Rules Viewer.

The documentation of the EDT rules is intended to encourage a dialogue between EDT practitioners and scientists regarding species-habitat relationships for salmonid fishes. The rules in EDT are hypotheses based on the scientific literature and expert knowledge. Their utility to produce useful and accurate representations of salmonid habitat potential has been shown in numerous applications throughout the Pacific Northwest. However, continued dialogue, review and refinement of the rules and EDT structure are encouraged.

SECTION 2. ECOSYSTEM DIAGNOSIS AND TREATMENT THEORY AND INFORMATION STRUCTURE

A. Theory

EDT is a process to rate the quality and quantity of habitat in a stream for a particular species. To do this, EDT assumes that the biological capacity and productivity of a fish population are functions of the underlying environment and that conditions are reflected in the shape of the production function (Reisenbichler 1989). Specifically, we assume that habitat based estimates of capacity and productivity create a Beverton-Holt production function (Beverton and Holt 1957) that serves as an index of potential biological performance of the species in the modeled environment (Figure 1). Capacity defines the “size” of the environment with respect to a species while productivity is the survival rate without any density effects (density independent survival). Moussalli and Hilborn (1986) showed that a Beverton-Holt function for a population can be disaggregated into similar functions describing survival and capacity of the environment at different life stages. In EDT, capacity and productivity are calculated for each life stage at a stream reach scale and then integrated to estimate overall population capacity and productivity.

Productivity in EDT is equivalent to the concept of intrinsic productivity discussed in McElhany and others (2000) to describe viable salmonid populations with respect to the Endangered Species Act. It is survival without density dependence effects, i.e., the approximate rate that would occur when competition for resources is eliminated. As abundance increases, productivity is increasingly modified by density dependent factors of the environment to the point that the quantity of resources becomes limiting and abundance approaches the capacity. In Figure 1, productivity is the slope of the abundance curve at its origin. Productivity in EDT is a function of the quality of the environment.¹ The definition of productivity as applied here is consistent with its use by Hilborn and Walters (1992) in population dynamics modeling.

1 / Empirically measured productivity would also incorporate sex ratio, fecundity, and fitness.

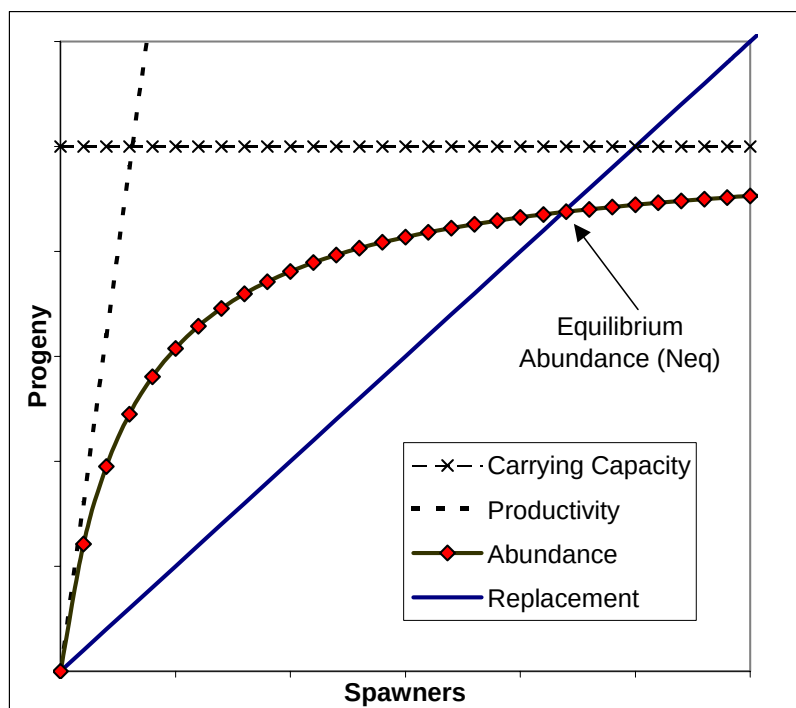


Figure 1. Features of a Beverton-Holt production function. Productivity is the density independent survival, which, along with density dependent factors of the environment, determines abundance limited by the total capacity of the environment. Replacement is the minimum number of spawners required to maintain a given abundance. Under steady-state environmental conditions, the population abundance equilibrates at Neq, the point where abundance crosses the replacement line.

Environmental capacity limits how large a population can grow given finite space and food resources, depicted by the asymptote in Figure 1. It controls the extent that density dependence is operative at different population (or density) levels. Capacity is a function of the quantity of key habitats and food resources available.² The term key habitat here refers to those habitat types that are the primary types utilized by the species in a life stage—they are the types that are preferred or required by the species in the life stage. Given steady-state condition, abundance will increase toward the capacity and will equilibrate at a point below capacity where the Progeny/Spawners is equal to 1.0 (Figure 1). This equilibrium abundance, or Neq, is a function of both capacity and productivity.

Using the recursive property of the Beverton-Holt function highlighted by Mousalli and Hilborn (1986), the population level production function is decomposed in EDT into similar functions for each life stage. Life stages for Chinook, coho and steelhead are provided in Appendix A. From the scientific literature we can describe optimal productivity (survival rate) and capacity (density) conditions under ideal conditions. We refer to these optimal survival and density values as reference benchmarks. Benchmarks provide us with a set of descriptions for performance under optimal conditions expressed as survival and maximum

² / Environmental carrying capacity illustrated in the stock-production relationship is actually a function of both quantity of resources (ones that are competed for) and environmental quality—easily seen in a disaggregated production function, see Moussalli and Hilborn (Moussalli and Hilborn 1986) and pages 284-285 in Hilborn and Walters (Hilborn and Walters 1992).

densities for each life stage. Benchmarks are the theoretical natural limits on survival and density for a species. These conditions constitute what can be thought of as “as good as it gets” for survival of the species in nature. Benchmarks survival for Chinook, coho and steelhead in EDT are provided in Appendix B.

The biological rules are used to adjust the optimal benchmark performance to account for habitat conditions in a specific stream. The EDT rules adjust the theoretical benchmarks downward to reflect local conditions because conditions in any stream are inherently constrained by local geology, climate and biology independent of anthropogenic constraints. As a result, fish performance is always less than the benchmark optimal levels. The EDT rules provide a systematic way of quantifying survival conditions for any reach by computing performance in the local environment relative to the benchmarks. This procedure ensures that productivity and capacity values computed for each life history segment are: a) bounded by the biological limits of the species, b) scaled consistently across time, space, and life stage, and c) scaled consistently with the benchmark values. While the rules are based on knowledge contained in the literature, they should be thought of as hypotheses about how survival is affected by environmental conditions.

It is important to distinguish the benchmarks from the historic or pristine conditions (often referred to as the Template or Reference condition in EDT). Maximum performance of fish in a particular stream is almost always less than the benchmarks because even pristine conditions are not “perfect.” The benchmark descriptions serve as a point of reference for both the present-day and historic conditions and for all watersheds.

B. EDT Information Structure

Information used to derive biological performance parameters in EDT is organized through the hierarchical EDT Information Structure. It structures information through three levels of organization. Together, these levels can be thought of as an information pyramid in which each level of information builds on information from the lower level (Figure 2). As we move up through the levels, we take an increasingly organism-centered view of the ecosystem.

Levels 1 and 2 together characterize the environment as it can be described by different types of data (Figure 2). This provides the characterization of the environment needed to analyze biological performance for a species. Level 1 and Level 2 information is not specific to a species but instead forms a species-independent description of the aquatic environment. The Level 3 category of information, on the other hand, is a characterization of that same environment from a different perspective: “through the eyes of the salmon”(Mobrand and others 1997). This category describes biological performance in relation to the state of the environment described by the Level 2 information.

The Information Structure begins with a wide range of environmental data (Level 1 input data) such as flow, sediment load, temperature, physical habitat, land use and ownership, elevation, slope, and so on. Included is information on the spatial and temporal structure of the data (Figure 3). These data exist in a variety of forms and pedigrees. Some watersheds are data rich, others might be comparatively data poor. Level 1 information includes empirical measurements as well as conclusions of expert observers. These data are the basis for the more refined description of the environment in Level 2.

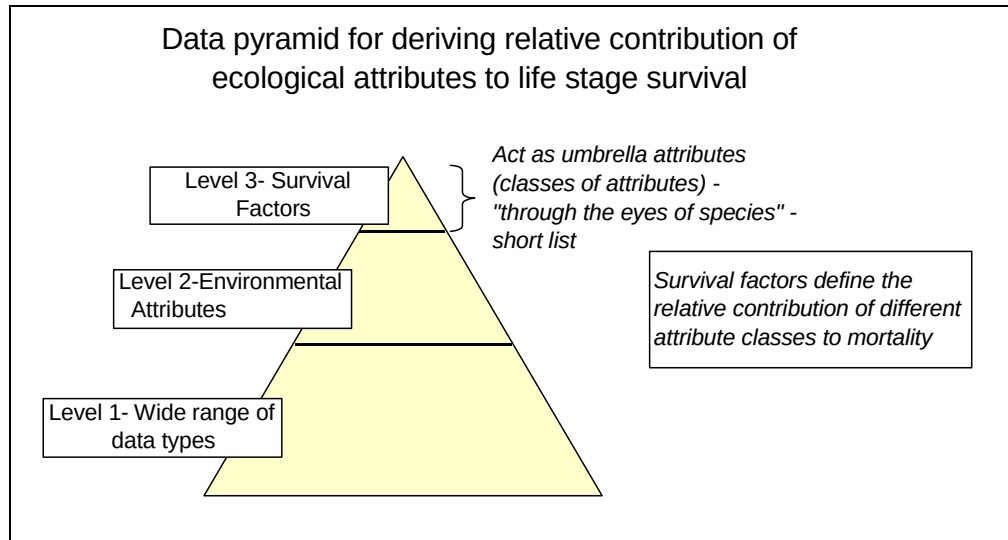


Figure 2. EDT Information Structure can be visualized as a “data pyramid.” Information begins as raw data and observations (Level 1), is organized into a species-neutral description of the environment (Level 2) and then characterized as performance of a particular species (Level 3).

Level 2 factors are referred to as Environmental Attributes. Level 2 information creates a generalized depiction of the aquatic environment, essentially as a set of conclusions derived from the Level 1 information (Figure 3). Level 2 Environmental Attributes are measurable characteristics of the environment that relate to salmonid performance. Level 2 Environmental Attributes are the main input to EDT and is organized in the Stream Reach Editor application. EDT Environmental Attributes are similar to the concept of Environmental Attributes used by (Morrison and others 1998) to describe species-habitat relationships for terrestrial environments. The Level 2 Environmental Attributes are measurable physical and biological characteristics about the environment relevant to a salmonid view of the stream. In concept though, a set of Level 2 Attributes can be described for analyzing the environment with respect to any species. The EDT Environmental Attributes (Level 2) are defined more fully in Appendix C.

The Level 2 characterization describes conditions in the watershed at specific locations (reaches along a stream), times of year (specific months), and by scenario (template, current³, or a future scenario). Thus values assigned for each Environmental Attribute represent conclusions about the stream by site, month, and scenario based on the Level 1 data and observations. These assumptions become operating hypotheses for these attributes under specific scenarios. Where Level 1 data are sufficient, Level 2 conclusions can be derived directly or through simple algorithms. However, where Level 1 data are incomplete, experts are needed to provide knowledge about geographic areas and attributes. Regardless of the types of information used to derive the Environmental Attribute ratings, the Level 2 Environmental Attributes are measurable characteristics of the environment that can be monitored and ground-truthed over time through an adaptive process.

³ The Current condition in EDT is often referred to as the Patient condition reflecting the terminology of Lichatowich and others (1995)

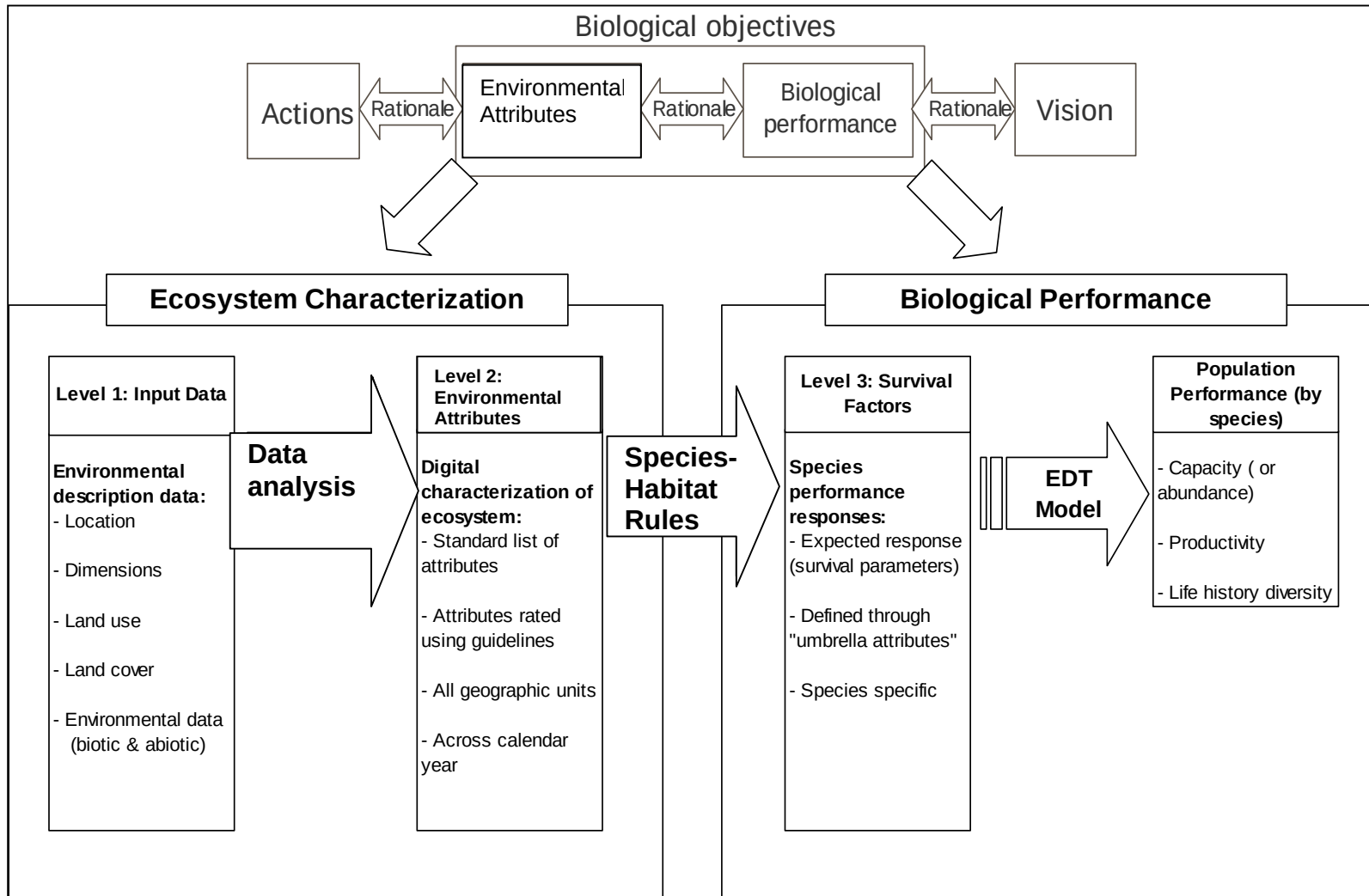


Figure 3. Ecological Information Structure. Species-Habitat rules relate characteristics of the environment to potential performance of the focal species.

Most Level 2 Attributes are characterized using ratings on a scale of 0 to 4, spanning a spectrum of conditions. Generally, there is a consistent direction to the attribute ratings, where 0 or low values will tend to correspond with pristine environmental conditions and higher values tend toward more degraded conditions. In these cases, a 0 corresponds to a condition of *no reduction of biological performance as a result of the attribute*, whereas a value of 4 is a *severe reduction in performance*. This pattern varies for several attributes, however. Table 1 gives examples of the index values for three Environmental Attributes, all addressing a different aspect of sediment load within the stream system. Integer values represent the midpoint of conditions for attributes when a range of conditions is associated with one value.⁴ The indexing system allows users to specify either continuous or integer values for the attributes, depending on the appropriate level of precision for particular stream reach given the available data. Conditions associated with index values for all Level 2 Environmental Attributes are described in Appendix D.

Table 1. Rating indexes used for three Level 2 Environmental Attributes that address different characteristics of sediment load in a stream system.

Embeddedness	
Rating	Rating definition
0	≤ 10% embedded
1	> 10% and ≤ 25% embedded
2	> 25% and ≤ 50% embedded
3	> 50% and ≤ 90% embedded
4	> 90% embedded
Fine sediment (intragravel)	
Rating	Rating definition
0	≤ 6% fines < 0.85 mm
1	> 6% and ≤ 11% fines < 0.85 mm
2	> 11% and ≤ 18% fines < 0.85 mm
3	> 18% and ≤ 30% fines < 0.85 mm
4	> 30% fines < 0.85 mm
Suspended sediment (from SEV index – after Newcombe and Jensen 1996)	
Rating	Rating definition
0	≤ 4.5 scale of severity (SEV)
1	> 4.5 and ≤ 7.5 scale of severity (SEV)
2	> 7.5 and ≤ 10.5 scale of severity (SEV)
3	> 10.5 and ≤ 12.5 scale of severity (SEV)
4	> 12.5 scale of severity (SEV)

Some Level 2 Attributes do not use the rating scale of 0-4. Instead they employ the appropriate metric for the attribute. These attributes are wetted channel width (maximum and minimum width in feet), channel length (miles), channel gradient (proportion) and percent of the wetted area of a reach represented by specific habitat types (e.g. pools, riffles and glides).

⁴ When generating Level 2 attribute values for the basin, integer values frequently mean that only a broad categorical conclusion can be reached about an environmental attribute, as reflected in the range of values shown for the sediment examples. In these cases, the rule would interpret an integer to represent the midpoint.

The species-habitat rules translate the species-neutral Level 2 characterization of the environment into a species-specific depiction of habitat in terms of 1) Level 3 Survival Factors by life stage, 2) and Level 3 Key Habitat. A third aspect of Level 3, Food, affects both Productivity and Capacity. The EDT model then integrates the Survival Factors (including the Productivity aspect of Food) across life stages to estimate population Productivity and uses Key Habitat and the Capacity aspect of Food to estimate population Capacity (Figure 3). The rules linking these three Level 3 factors and the Level 2 Environmental Attributes are quite different and will be discussed separately.

SECTION 3. RULES FOR ESTIMATING PRODUCTIVITY

Productivity in EDT is a measure of the quality of the environment with respect to the focal species. We calculate productivity in terms of the Level 3 Survival Factors. The Level 3 Factors are listed and defined in Appendix E. The Survival Factors act as "umbrella attributes", grouping the effects of Environmental Attributes into broader synthetic concepts of habitat conditions for the species (Figure 4). The purpose of grouping effects of classes of attributes in this manner is to allocate mortality by the types of factors that biologists typically refer to in environmental analysis (e.g., limiting factors analysis). Table 2 illustrates general relationships between Level 2 Environmental Attributes and Level 3 Survival Factors. Specific associations of Level 2 Attributes and Level 3 Factors for Chinook are found in Appendix F, for coho in Appendix G, and for steelhead in Appendix G.

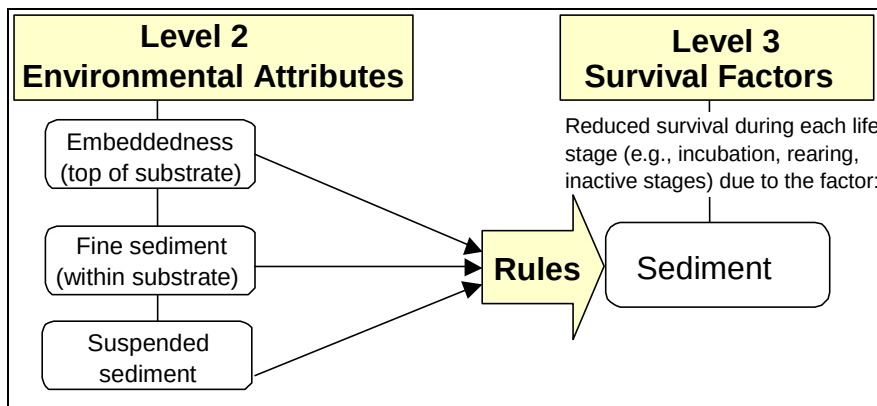


Figure 4. Concept of EDT rules relating Level 2 Environmental Attributes to Level 3 Survival Factors. Rules derive (as hypotheses) effects of Level 2 Attributes on species performance by life stage (example shows effects of sediment attributes on life stage productivity).

Table 2. Organization of Level 2 Environmental Attributes by categories of major stream corridor features. Salmonid Survival Factors (Level 3) are shown associated with groups of Level 2 attributes. Associations can differ by species and life stage. See Appendix F, G, and H for association matrices for Chinook, coho, and steelhead respectively.

Environmental Attributes (Level 2)		Related Survival Factors
1 Hydrologic Characteristics		
1.1 Flow variation	Flow - change in interannual variability in high flows	Flow Withdrawals (entrainment)
	Flow - changes in interannual variability in low flows	
	Flow - Intra daily (diel) variation	
	Flow - intra-annual flow pattern	
	Water withdrawals	
1.2 Hydrologic regime	Hydrologic regime - natural	
	Hydrologic regime - regulated	
2 Stream Corridor Structure		
2.1 Channel morphometry	Channel length	Channel length
	Channel width - month maximum width	Channel stability
	Channel width - month minimum width	Channel width
	Gradient	Habitat diversity
2.2 Confinement	Confinement - hydromodifications	Key habitat
	Confinement - natural	Obstructions
2.3 Habitat type	Habitat type - backwater pools	Sediment load
	Habitat type - beaver ponds	
	Habitat type - glides	
	Habitat type - large cobble/boulder riffles	
	Habitat type - off-channel habitat factor	
	Habitat type - pool tailouts	
	Habitat type - primary pools	
	Habitat type - small cobble/gravel riffles	
2.4 Obstruction	Obstructions to fish migration	
2.5 Riparian and channel integrity	Bed scour	
	Icing	
	Riparian function	
	Wood	
2.6 Sediment type	Embeddedness	
	Fine sediment (intragravel)	
	Turbidity (suspended sediment)	
3 Water Quality		
3.1 Chemistry	Alkalinity	Chemicals (toxic substances)
	Dissolved oxygen	Oxygen
	Metals - in water column	Temperature
	Metals/Pollutants - in sediments/soils	
	Miscellaneous toxic pollutants - water column	
	Nutrient enrichment	
3.2 Temperature variation	Temperature - daily maximum (by month)	
	Temperature - daily minimum (by month)	
	Temperature - spatial variation	
4 Biological Community		
4.1 Community effects	Fish community richness	Competition with hatchery fish
	Fish pathogens	Competition with other fish
	Fish species introductions	Food
	Harassment	Harassment
	Hatchery fish outplants	Pathogens
	Predation risk	Predation
	Salmonid carcasses	
4.2 Macroinvertebrates	Benthos diversity and production	

EDT rules are grouped into categories that describe the species-habitat relationships for different types of environments. Rule Categories relate to width of the stream and to the hydrologic regime (e.g. rainfed, glacial, spring-fed). The EDT Rules Viewer shows the appropriate Rule Category for each species-habitat rule based on the Level 2 input. In most cases, a single rule exists for one life stage-Level 3 Survival Factor combination. For example, the Level 3 Factor of Habitat Diversity is related to the Level 2 Attributes of Wood (large woody debris), Artificial Confinement and Gradient regardless of the size of the stream or the hydrologic regime. However, in some cases alternative forms of the rules exist for different Rules Categories to account for different biological responses to conditions in streams of different size (by channel width) and hydrologic regime (accounting for source of flow, e.g., groundwater vs. rain fed).

A. Structure of EDT Species-Habitat Rules for estimating productivity

The life stage productivity value associated with a specific stream reach is defined as the density independent survival rate expected if the entire life stage occurred under the conditions in that reach.⁵

The rules presented here assume that productivity, P , can be partitioned into a set of sixteen independent multiplicative survival factors F_i , i.e.

$$P = P_0 \cdot F_1 \cdot F_2 \cdot F_3 \cdots F_{16}$$

where $0 < F_i < 1$ are relative productivity values and P_0 is the benchmark survival (Appendix B and discussion above).. Each $F_i < 1$ acts to reduce P from the benchmark productivity due to habitat conditions that are less than optimal corresponding to that F_i in the given reach. When the reach has optimal conditions corresponding to all factors, i.e, $F_i = 1$ for all Level 3 factors, then $P = P_0$.

We then assume that each Level 3 Survival Factor F_i can be estimated as a function of the Level 2 Environmental Attributes for the reach. The EDT Rules Viewer calculates the individual F_i values based on a set of Level 2 inputs. These are seen in the right panel of the Viewer associated with each of the Level 3 Survival Factors. The functional form that we applied in formulating the present rule set assumes that a Level 3 Survival Factor will principally be driven by a single dominant, or primary, Level 2 Attribute, though other Level 2 Attributes can act to modify the overall effect. We refer to this rule structure as the **Synergistic Form**.

In this form for rule structure, we refer to the dominant Environmental Attributes as the **Primary Level 2** Attribute for that specific life stage-Level 3 factor. When the Primary Level 2 attribute (p) alone affects the Level 3 (i.e. there are no secondary Level 2 attributes in the rule) survival factor F_i , it is defined as:

⁵ / Differences in conditions between months are handled within EDT by modeling life history trajectories to capture how groups of fish experience changes in environmental conditions in space and time.

$$F_i = 1 - S_{P,i}$$

where $S_{P,i}$ is the sensitivity of survival of the species to the Primary Level 2 Attribute, here without other contributing Level 2 Attributes. The $S_{P,i}$ values for each rating (0 – 4) of the Primary Level 2 are estimated based on published studies, available data or where data is sparse, expert opinion. In the Rules Viewer, clicking first on a Level 3 Factor and then on a Level 2 Attribute will display a graph showing the shape of the relationship between an attribute rating (0-4) and $S_{P,i}$ value.

In most cases the sensitivity to the Primary Level 2 Attribute is affected by one or more **Modifying Level 2** Attributes. These attributes modify overall sensitivity associated with the Primary Level 2, either increasing it or, in some cases, decreasing it. The functional form used (unless otherwise specified) to capture this modifying effect is:

$$F_i = 1 - \left[\sum_j S_{j,i}^g \right]^{1/g}$$

where $S_{j,i}$'s are the sensitivities of all contributing Level 2 Attributes j (including the Primary) operating on factor i , and g is a "synergy parameter."

In all rules where this synergistic form is used the value of g is 0.4. This value of g derives from the way the 0 – 4 rating scale for Level 2 attributes was defined. The synergistic form shapes the overall combined effect of multiple Level 2 Attributes affecting a single Level 3 factor i consistent with the way in which ratings have been defined for Level 2 Attributes. In general, the rating system was devised so that values of 1 or 2 would have little effect on survival, whereas values between 3 and 4 tend to reflect severe conditions for survival. Use of $g = 0.37$ in the equation retains a minor effect on relative productivity when adding multiple Level 2 modifiers with low ratings, but rapidly increases sensitivity at higher values for modifying attributes. As more data and information become available this function should be tested against observations.

An alternative to the synergistic rule described above would be to assume that Level 2 Attributes operate independently of each other. The **Independent Form** of the rule would assume a simple multiplicative effect:

$$F_i = \prod_j (1 - S_{j,i})$$

None of the rules in the current EDT rule sets are structured using the Independent Form.⁶ It is important to recognize that sensitivities ascribed to Level 2 Attributes for each factor i in the existing rules database were formulated using the synergistic form—which means that sensitivities of those Environmental Attributes identified as being "modifiers" are likely set too low to be used without adjustment with the independent form. If a rule structure was to

⁶ / A special set of rules have been developed for use in large lakes that use the Independent Form of the rules. This document does not address those rules.

be modified to follow the Independent Form, then many of these sensitivities would need to be adjusted upwards.

B. Examples of EDT Species-Habitat Rules and their application

Three examples (Table 3) are presented below to show how rules were formulated and how they function within EDT. The logic, approach, and key studies applied are described. Each example looks at how Level 2 Environmental Attributes are used to derive relative productivity associated with the Level 3 Survival Factor "Sediment Load" illustrated in Figure 4. The examples show how these Level 2 Attributes are used to project a total effect on productivity associated with this survival factor. They also illustrate that different levels of confidence or "proof" can be given to the rules depending on how much is known from documented empirical relationships.

Table 3. List of examples to illustrate how rules were formulated and function. Each example projects total sensitivity (1- relative productivity) ascribed to the Level 3 survival factor "Sediment Load."

Type of example (shown to right)	Example 1	Example 2	Example 3
	<u>One Attribute affecting sensitivity</u> – based on empirical relationship	<u>Multiple Attributes affecting sensitivity</u> – based on empirically derived index with added inferences	<u>Multiple Attributes affecting sensitivity</u> – inferred from empirical observations and qualitative conclusions
Life stage	Incubation (to emergence)	Resident rearing	Inactive (overwintering)
Primary Attribute	Fine sediment (intragravel)	Suspended sediment	Embeddedness
Modifying sediment Attribute	none adding sensitivity	none adding sensitivity	Suspended sediment
Other modifying Attributes	none adding sensitivity	Temperature (max)	none adding sensitivity

Example 1: Incubation life stage – one Environmental Attributes based on an empirical relationship

This example illustrates the use of a documented relationship between fine sediment within the substrate of riffles and pool-tailouts and survival from egg deposition to fry emergence. Only one Level 2 Attribute is used in this rule. Evidence for the effect of intra-gravel fine sediment (e.g., particles < 1mm in size, most often expressed as <0.85 mm) is well documented (e.g. Chapman and McLeod 1987, Bjornn and Reiser 1991, Kondolf 2000). The many studies that have documented effects of sediment on egg-to-fry survival typically link reduced survival to this single aspect of sedimentation.

Kondolf (2000) outlines a procedure to consider two size classes of intragravel sediment in assessing effects on egg-to-fry survival, based on analyses by Tapel and Bjornn (1983) and Chapman and McLeod (1987). In areas where excessive fines < 1 mm are present, the major determinant of STE would be based on this size class. The effect in this case occurs due to restriction of oxygenated flow passing incubating eggs with loss of gravel permeability as percent fines increases. In areas where somewhat larger particle sizes are excessive (i.e., sand sized, 3-6 mm), such as in the Idaho Batholith, this size is believed to have the dominant effect. In this case, sand size particles can entomb pre-emergent fry. Definitions used to

describe the Level 2 Attribute for fine sediment provide an option for either using particle sizes <1 mm (as seen in Table 2) or particles between 3-6 mm in size (see Appendix D). Further discussion on how this Attribute is to be rated is provided in Lestelle (2004)

We employed the empirical relationship reported by Tagart (1984) for the effects of percent fine sediment (<0.85 mm) on survival to emergence for coho (Figure 5). We assumed the same relationship is applicable to chinook salmon and steelhead trout. Using a benchmark survival to emergence of 60% (assumed average survival under optimal conditions for chinook and coho), we can convert Tagart's survivals into sensitivity (as 1 minus survival divided by the benchmark) and plot the values against the appropriate Level 2 rating values on the x-axis (Figure 6). The resulting relationship forms the rule for sediment effects on the incubation life stage, except when the hydrologic regime is mainly characterized as groundwater fed.⁷ In that case, upwelling associated with groundwater sources appears to largely protect embryos from deleterious effects of high fines (Bjornn and Reiser 1991, Waters 1995). This explains why salmonids can have high rates of reproduction in some streams despite excessive deposits of fine sediment (e.g., chum and sockeye salmon are known to spawn heavily in groundwater fed streams, even in areas of excessive fines). We therefore created a Rule Category for this hydrologic regime that maintained high survivals even at high levels of fine sediment.

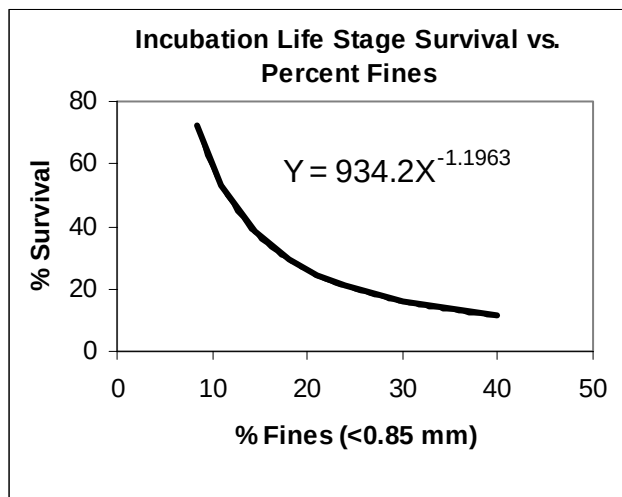


Figure 5. Relationship between percent fines and survival from egg deposition to emergence for coho salmon. Adapted from Tagart (1984)

It bears noting that there is some evidence suggesting that steelhead trout are more sensitive to sediment effects during egg incubation, particularly if the sediment particles are sand sized. Data collected by Irving and Bjornn (1984); also seen in (Bjornn and Reiser 1991)) suggest that steelhead are more sensitive, apparently due to a greater susceptibility to entombment

⁷ Hydrologic regime is a Level 2 Attribute. Five regimes are described through the ratings, of which one is predominately groundwater fed (see Appendix D).

associated with sand particles. The rules do not currently incorporate this difference; an update to the rules is expected sometime in the future.⁸

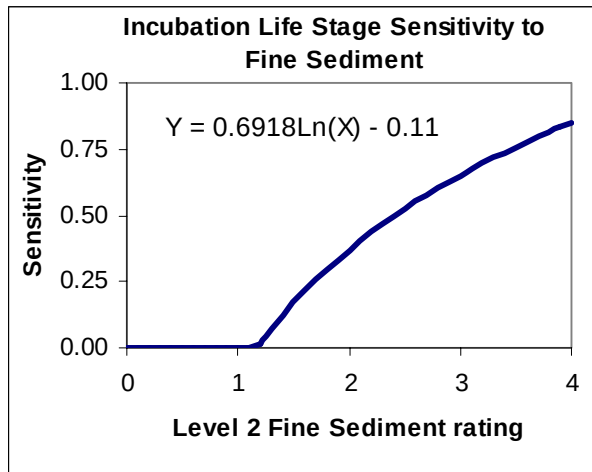


Figure 6. Relationship between ratings for Level 2 Fine Sediment and sensitivity of eggs and alevins, derived by converting the relationship in Figure 5.

Examples of results obtained by applying the rule described here for all hydrologic regimes except groundwater dominated are provided in Table 4.

Table 4. Example results obtained for the rule incubation-Level 3 Survival Factor “Sediment Load” for chinook and coho salmon.

Life stage: egg incubation						
Attribute		Example				
		A	B	C	D	E
Fine sediment (intragravel)(Primary)	Rating	0	1	2	3	4
	Sensitivity	0	0	0.370	0.650	0.849
Relative productivity		1.00	1.00	0.63	0.35	0.15
Benchmark survival		0.6	0.6	0.6	0.6	0.6
Absolute survival		0.60	0.60	0.38	0.21	0.09

⁸ / The rule for the effects of fine sediment is the same in the current set of rules whether the dominant particle size is <1mm or >1 and <6 mm. We formulated the breakpoints in the definitions that use sand sized particles by matching the effects of the larger particle sizes from Irving and Bjornn (Irving and Bjornn 1984) with those of Tagart (Tagart 1984) that used the size class <1mm.

Example 2: Resident rearing life stages – multiple Environmental Attributes based on empirically derived index with inferences for synergy

This example involves two Attributes acting synergistically to produce a total sensitivity associated with sediment during the active rearing stage. The rule is based on an empirically derived index for sensitivity to suspended sediment, the primary Environmental Attribute in this case, and an assumed synergistic effect with temperature. This example illustrates how some rules combine a well documented sensitivity relationship with more qualitative information to derive an overall effect ascribed to a single Level 3 Factor.

Effects of suspended sediment, either as turbidity or suspended solids⁹, on fish are well documented (summarized in Bash and others 2001). Suspended sediments can affect fish behavior and physiology and result in stress and reduced survival. Temperature acts synergistically to increase the effect of suspended sediment (Newcombe and Jensen 1996, Bash and others 2001).

The severity of effect of suspended sediment increases as a function of both sediment concentration and exposure time, or dose (Newcombe and Jensen 1996, Bash and others 2001). Newcombe and Jensen (1996) performed a meta-analysis of data contained in 80 published and documented reports to assess the effects of dose on fish responses, including numerous studies involving salmonids. The analysis yielded empirical equations that relate biological response to duration of exposure and suspended sediment, including two that specifically address salmonids. The authors synthesized the results of their scale of severity (SEV) into likely outcomes for fish species (adapted in Table 4). We aligned our rating system of 0-4 to their scale, consistent with our intent to span the general range of effects across our rating scale as described earlier (Table 5).

We interpret Table 5 as seen in Figure 7 -- giving a relationship between life stage survival and SEV (based on discussion in Newcombe and Jensen, we assume these results apply to actively rearing fish, as well as adult prespawners). Figure 7 is then easily converted to a relationship between our rating scale of 0-4 and life stage sensitivity (Figure 8).

The SEV index is easily computed by expressing suspended sediment in mg/l (which can be estimated from turbidity NTUs) and making a reasoned assumption about the percent of time during the worst case month (on average) when that concentration is attained. Further discussion on how this Attribute is to be rated can be found in Lestelle (2004)

⁹ / The correlate suspended sediment is described either as turbidity or suspended solids, though the latter is preferred. Turbidity is an optical property of water where suspended solids, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered. It is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids or suspended sediment concentration—both as mg/l. Technically, turbidity is not normally considered as suspended sediment, but we treat them together since they are usually well correlated.

Table 5. Scale of severity (SEV) index of ill effects associated with excess suspended sediment (adapted from Newcombe and Jensen 1996) and corresponding Level 2 Suspended Sediment ratings used in rule formulation.

SEV	Description of effect	Level 2 SS rating
Nil effect		0
0	No behavioral effects	
Behavioral effects		
1	Alarm reaction	
2	Abandonment of cover	
3	Avoidance response	1
Sublethal effects		
4	Short-term reduction in feeding rates; short term reduction in feeding success	
5	Minor physiological stress; increase in rate of coughing;	
6	Moderate physiological stress	
7	Impaired homing	2
8	Indications of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition	
Lethal and para-lethal effects		
9	Reduced growth rate; reduced fish density	
10	0-20% mortality; increased predation	
11	>20 – 40% mortality	3
12	>40 – 60% mortality	
13	>60 – 80% mortality	4
14	>80 – 100% mortality	

Although it is readily accepted that higher temperatures act through synergism to increase the effect of suspended sediment, the extent of the effect has not yet been quantified in a manner to be included directly in the SEV index (Newcombe and Jensen 1996). The authors of the SEV state that the effect probably has to do with temperature-related patterns of oxygen saturation, respiration rate, and metabolic rate of fishes. From our review, we conclude that a noticeable effect of synergy between suspended sediment and temperature is needed in the rule to recognize this effect. We therefore assumed what is likely a conservative synergistic effect, setting the sensitivity to temperature (maximum) in the rule to add approximately 20-25% greater effect with intermediate temperature ratings when they occur with intermediate suspended sediment ratings.

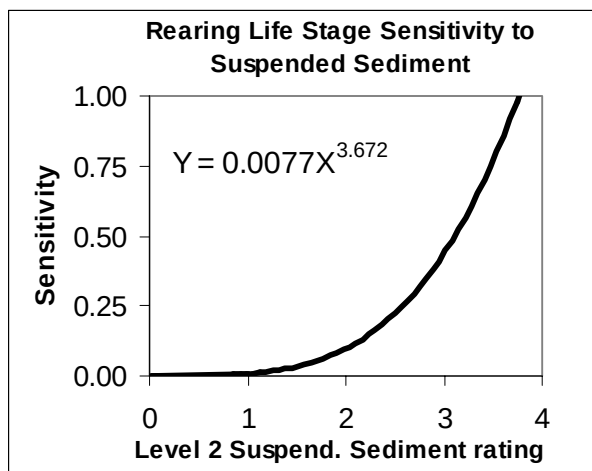


Figure 7. Relationship between scale of severity (SEV) index for suspended sediment (SS) and percent survival in rearing and prespawning life stages for salmonids – interpreted from Newcombe and Jensen (1996).

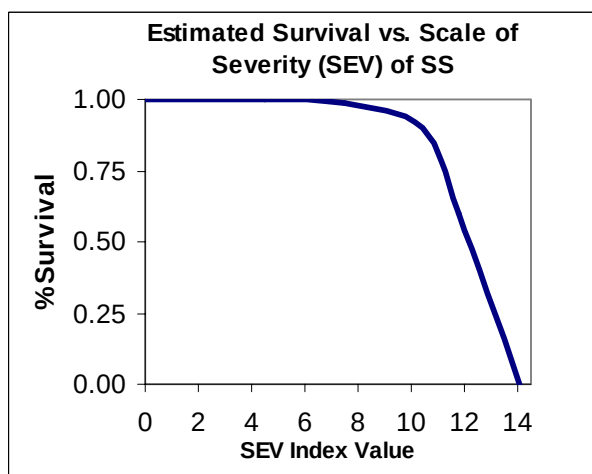


Figure 8. Relationship between ratings for Level 2 Suspended Sediment (SS) and sensitivity of salmonids during active rearing stages, derived by converting the relationship in Figure 7.

An additional note on the effect of sediment during the active rearing stage is warranted. Bjornn and Reiser (1991) summarize findings of several studies that suggest that embeddedness may further increase the effect of overall sedimentation during active rearing stages. Bjornn and Reiser conclude however that the effect likely occurs largely through reduced benthos as food for chinook. We concur with this interpretation—we address the effect of reduced benthos through the Level 3 factor food and not through sediment load.

Examples of results obtained by applying the rule described here are provided in Table 6.

Table 6. Example results obtained for the rule 0-age resident rearing-Level 3 Sediment Load for chinook and coho salmon and steelhead trout.

Life stage: 0-age resident rearing						
Attribute		Example				
		A	B	C	D	E
Suspended sediment (Primary)	Rating	2	2	3	3	3
	Sensitivity	0.098	0.098	0.436	0.436	0.436
Temperature (max)(Modifier)	Rating	0	2	0	2	3
	Sensitivity	0	0.001	0	0.001	0.005
Relative productivity		0.90	0.84	0.56	0.42	0.29
Benchmark survival		0.7	0.7	0.7	0.7	0.7
Absolute survival		0.63	0.59	0.40	0.29	0.20

Example 3: Inactive life stage – multiple Environmental Attributes based on a weight of evidence approach, including synergy

As in the previous case, this example involves two Environmental Attributes, assumed to act in synergy to produce a total sensitivity associated with sediment during the inactive rearing stage. The rule is based on a weight of evidence from several studies on the impact of substrate embeddedness on overwintering juveniles conducted over the past three decades. In addition, the rule incorporates a synergistic effect for suspended sediment, here acting as a modifying Attribute to embeddedness.

Embeddedness describes the extent that interstitial spaces between cobble and gravel on the substrate surface is filled with fine particles. Some species of salmonids use the voids between cobbles as hiding cover during the inactive (overwintering) life stage. It is well documented that the capability of the substrate to hold juvenile salmonids during winter diminishes as the substrate becomes more embedded (Bjornn and Reiser 1991) implying that overall habitat quality during this life stage declines with sedimentation. Further, the overall sensitivity to fine sediment during this stage can include effects of suspended sediment, as described above for the active rearing stages. Here, however, fish in the inactive stage are much less sensitive to suspended sediment (Noggle 1978), apparently because of reduced respiratory and metabolic requirements. We therefore allowed for some added effect of suspended sediment and assumed that it would operate to increase sensitivity identified with embeddedness in this case.

Efforts to quantify effects of embeddedness on overwintering juvenile chinook are based in large part on studies by Bjornn and others (1977). and Hillman and others (1987). Both studies reported that juvenile densities were reduced by more than half when cobble substrate became highly embedded. Juveniles are known to emigrate at the onset of winter from areas of high embeddedness and to keep moving until suitable substrate is found (Bjornn 1978). We are not aware of any studies in which mortality was specifically assessed in relation to

embeddedness, though it is believed to increase under such conditions (Waters 1995). Presumably, some fish emigrate because survival of fish remaining in embedded substrates is lower than for migrants that successfully find better habitat. Moreover, if emigrants do not find suitable substrates (as must sometimes occur because the extent of sedimentation has increased over pristine conditions), their penalty might be an even greater reduction in survival than those that do not migrate from poor quality habitat.

Lacking a quantitative relationship to apply, we drew on Chapman and McLeod's (1987) interpretation of the Bjornn and others (1977) and Hillman and others (1987) studies. They concluded that a reduction in winter habitat must occur at embeddedness levels somewhere between 0% and 66% and at that level or higher that such areas would be made unusable by overwintering fish. They also stated: "We have no doubt that functional relationships exist between embeddedness and winter holding capacity of the substrate for salmonids, and that those relationships differ by fish size and perhaps by species."

We conclude from the foregoing that it is reasonable to hypothesize a functional relationship between the survival of fish that attempt to overwinter in embedded stream reaches and the degree of embeddedness. We hypothesize that the relationship between survival and embeddedness would show little effect up to about 66% embeddedness, and then exhibit a very rapid decrease in survival above that level (Figure 9). We recast the relationships in Figure 9 in terms of sensitivity corresponding to the Level 2 embeddedness ratings (Figure 10). We assumed that the sensitivities of chinook and steelhead to embeddedness during this life stage are the same. Chinook (Chapman and Bjornn 1969, Hillman and others 1987) and steelhead (Bjornn 1971, Bustard and Narver 1975, Everest and others 1986) both rely extensively on cobbles for overwintering cover.

In contrast to chinook and steelhead, coho use substrate for overwintering cover much less often, preferring undercut banks, rootwads, and off-channel habitat (Bustard and Narver 1975), Peterson and Reid 1984). When they do use substrate, they prefer unembedded cobbles to those that are embedded (Bustard and Narver 1975b). We conclude from this that coho are much less sensitive to embedded cobbles during winter than chinook and steelhead and formulated a rule accordingly (Figures 9 and 10).

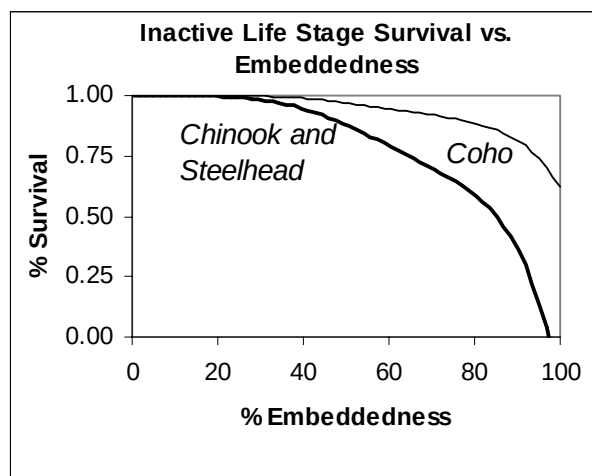


Figure 9. Relationships between survival and embeddedness for juvenile chinook, steelhead, and coho during the inactive (overwintering) life stage. The relationships are hypothesized based on general conclusions in Chapman and McLeod (1987).

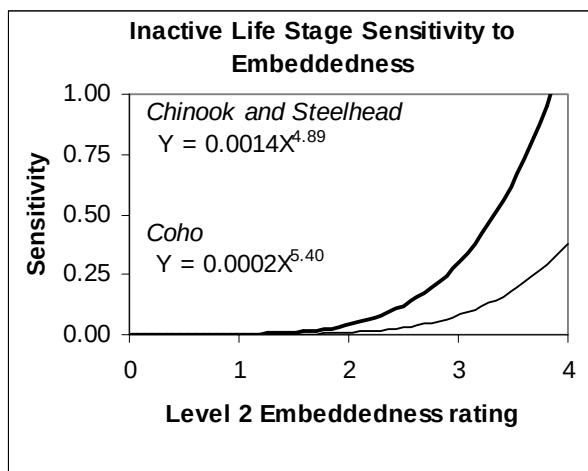


Figure 10. Relationships between ratings for Level 2 Embeddedness and sensitivity for juvenile chinook, steelhead, and coho during the inactive (overwintering) life stage—assumed based on general conclusions in Chapman and McLeod (1987). Coho sensitivity is shown with the thin line.

Additional mortality due to sedimentation could also occur if pulses of suspended sediment are sufficiently high. The tolerance of juvenile salmonids to suspended sediment during winter is known to be much higher than during periods of active rearing, likely due to a reduced state of activity. Still, some added effect associated with high SS doses is expected. We treat this potential effect as operating in a synergistic manner with embeddedness. If embeddedness is low, then the effect that might be ascribed to high suspended sediment doses should be much lower than if embeddedness is high, when fish should be more exposed to suspended sediment. We consider exposure here in the sense that fish would be more likely to enter the water column when embeddedness is high, instead of remaining in a resting state within the substrate when embeddedness is low. Hence a higher state of activity should make them more vulnerable to suspended sediment.

Examples of results obtained by applying the rule described here are provided in Table 7.

Table 7. Example results obtained for the rule inactive (overwintering)-Level 3 Sediment Load for chinook salmon.

Life stage: Inactive (overwintering)						
Attribute		Example				
		A	B	C	D	F
Embeddedness (Primary)	Rating	2	2	3	3	3
	Sensitivity	0.041	0.041	0.299	0.299	0.299
Suspended sediment (Modifier)	Rating	0	2	0	2	3
	Sensitivity	0	0.008	0	0.008	0.128
Relative productivity		0.96	0.86	0.70	0.44	0
Benchmark survival		0.7	0.7	0.7	0.7	0.7
Absolute survival		0.67	0.61	0.49	0.31	0

SECTION 4. RULES FOR ESTIMATING KEY HABITAT

Key Habitat is defined as the primary habitat type(s) utilized by a species during a particular life stage. Preference for habitat types changes with life stages. Some life stages, like egg incubation, occur almost entirely within three habitat types (i.e., pool-tailouts, glides and riffles), while other life stages, like actively migrating fish, use all habitat types.

The use of habitat types by individual life stages is not necessarily "all or nothing", however. For example, resident rearing by 0-age juvenile chinook does not occur equally in those habitat types that are utilized, some types that show use appear to be more preferred than others, while other types show almost no use.

The rules for Chinook and coho salmon and for certain life stages for steelhead trout were formulated by assigning weights to each habitat type to represent relative levels of preference based on patterns reported in the literature and in consultation with knowledgeable biologists. In addition, a different type of rule was applied to estimating key habitat for rearing juvenile steelhead, described later in this section. Literature used in formulating conclusions on habitat utilization are listed below:

- Chinook: Everest and Chapman (1972), Healey (1991), and Hayman and others (1996)
- Coho: Bisson and others.(1988b), Sandercock (1991), Nicklelson and others (1992a, 1992b)
- Steelhead: Hartman (1965), Bisson and others (1988a), Johnson and others (1988), Bjornn and Reiser (1991)

Percent Key Habitat (%KeyHab) for any life stage (except as noted below) was computed to be the sum of the weighted percentages of habitat types i within a geographic unit, as follows

$$\%KeyHab = \sum \%HabType_i * Weight_i$$

where $\%HabType_i$ is the percent of wetted channel surface area comprised of habitat type i and $Weight_i$ is the preference weight for habitat type i in the appropriate life stage. The habitat weights are easily derived from densities measured empirically for different habitat types, such as data on fish per square meter obtained by electrofishing in different seasons.

The format for the presentation of rules for the Level 3 Key Habitat attribute is shown in Figure 11.

In contrast to chinook and coho salmon, juvenile steelhead are known to use all habitat types for rearing. We therefore employed a relationship described by Johnson and others (1988) to compute a factor for adjusting downward percent key habitat, assuming that the percent key habitat is 100% at the maximum possible density (benchmark density) for each rearing life stage. The relationship estimates the rearing density of steelhead juveniles based on stream flow (or width in the absence of flow data) and channel gradient.

Level 3 -- Key Habitat									
Species: Chinook		Life Stage: Incubation							
Definition: The relative quantity (%) of the primary habitat type(s) utilized by the focus species during a life stage; quantity is expressed as percent of wetted surface area of the stream channel. Environmental quality attributes characterize the quality of this habitat for the focus species.									
Rule: The quantity of Key Habitat in a stream reach is computed from reach channel length, channel width, and percent of Key Habitat within the reach. Percent Key Habitat is estimated from habitat type composition based on a weighted sum of seven Level 2 Environmental Attributes (see table below) that quantify stream habitat types.									
Contributing Level 2 attributes:									
Level 2 attribute	Abbrev.	Weight	Rationale	Level of Proof					
Habitat type - backwater pools	HbBckPls	0.00	Eggs placed by spawners; weighting same as for Spawning. Chinook spawning does not occur in backwater pools.	1					
Habitat type - beaver ponds	HbBvrPnds	0.00	Eggs placed by spawners; weighting same as for Spawning. Chinook spawning does not occur in beaver ponds.	1					
Habitat type - large cobble/boulder riffles	HbLrgCbl	0.00	Eggs placed by spawners; weighting same as for Spawning. Substrate size typically too large for chinook spawning in large cobble/boulder riffles.	2					
Habitat type - primary pools	HbPls	0.00	Eggs placed by spawners; weighting same as for Spawning. Chinook spawning does not typically occur in pools.	2					
Habitat type - small cobble/gravel riffles	HbSmlCbl	0.60	Eggs placed by spawners; weighting same as for Spawning. Chinook spawn heavily on riffles with substrate sizes suitable for nest building.	1					
Habitat type - glides	HbGlide	0.40	Chinook spawn in swifter areas of glides, similar to pool-tailouts in characteristics.	1					
Habitat type - pool tailouts	HbPITails	0.80	Chinook spawning densities are typically greatest on pool-tailouts.	1					
Examples:									
Level 2 attribute	Example 1			Example 2			Example 3		
	Percent of reach	Weight	Weighted percent	Percent of reach	Weight	Weighted percent	Percent of reach	Weight	Weighted percent
Habitat type - backwater pools	10	0.00	0.0	5	0.00	0.0	0	0.00	0.0
Habitat type - beaver ponds	10	0.00	0.0	0	0.00	0.0	0	0.00	0.0
Habitat type - large cobble/boulder riffles	5	0.00	0.0	20	0.00	0.0	50	0.00	0.0
Habitat type - primary pools	40	0.00	0.0	32	0.00	0.0	20	0.00	0.0
Habitat type - small cobble/gravel riffles	15	0.60	9.0	35	0.60	21.0	25	0.60	15.0
Habitat type - glides	10	0.40	4.0	4	0.40	1.6	2.5	0.40	1.0
Habitat type - pool tailouts	10	0.80	8.0	4	0.80	3.2	2.5	0.80	2.0
Sum	100		21.0	100		25.8	100		18.0

Figure 11. Example of the use of Key Habitat in EDT for the Incubation life stage of Chinook salmon. The Weight is an assumption about the relative preference of the habitat types for the life stage. The lower box shows an example of the weighted percent Key Habitat given a description for a stream reach: $\%KeyHab = \sum \%HabType_i * Weight_i$

The rearing density for yearling parr *ParrDensity* is calculated from the equation

$$ParrDensity = 26.335 \times Flow^{-0.25} \times \%Gradient \times e^{(-0.1447 \times \%Gradient)}$$

where *Flow* is the low flow in cfs and *%Gradient* is the channel slope. The assumed maximum possible parr density was computed at a gradient of 4%. The adjustment factor *KeyHabAdj* to key habitat then is simply

$$KeyHabAdj = ParrDensity \div BenchmarkDensity$$

where *BenchmarkDensity* is the benchmark density for the appropriate life stage.

SECTION 5. RULES FOR ESTIMATING FOOD

Food is a Level 3 factor that modifies both productivity and capacity. In EDT, food affects survival through both density-dependent and density independent effects and is an essential element of both habitat quantity and quality. For this reason, Food appears in the Rules Viewer as both a habitat quality factor affecting Productivity (Food re: productivity) and a habitat quantity attribute affecting Capacity (Food re: capacity).

A. Food (re:Capacity)

The importance of food to population performance is a truism so evident that it is often ignored in analyzing salmonid population response to environmental change. The nascent understanding of the role of salmon carcasses in affecting basic stream productivity and food abundance for juvenile salmonids (Cederholm and others 2001, Stockner 2003) has emphasized the need to include food when modeling salmonid response to habitat change.

The effects of food in EDT are based in large measure on work by Ptolemy (1993). We use the Ptolomy relationship to scale the Benchmark densities (Appendix B) to account for local conditions associated with food availability. Ptolomy developed equations for estimating maximum salmonid densities in fluvial habitats based on fish size and nutrient indicators in British Columbia streams considered to be at or near full seeding and with little or no environmental disturbance. Further studies since his original publication continue to validate the equations (Ron Ptolemy, personal communications).

Ptolemy's work is built on Allen's (1969) observations that the maximum density of a life stage of stream-dwelling salmonids within in an area of stream is a function of fish size. Allen's concept was further developed by Grant and Kramer (1990) who concluded that fish size explained 87 percent of the variation in territory size. For a given size of fish, the density that can be supported in an area of habitat would be limited by the amount of aquatic food available. Mason and Chapman (1965) and Chapman (1966) hypothesized that the spatial requirements of fish limit their density below ceilings *set by the food supply*. Mason (1976) found proof of such food limitation for juvenile coho in a field study where he supplemented the natural food abundance in a stream. Subsequent work in British Columbia with nutrient enrichment of streams has produced strong evidence for food limitations (Stockner 2003).

While the concept relating food in streams to maximum fish density is well established, a quantitative relationship linking food and density is not available. To get around this, we assume that there is a relationship between stream alkalinity and food. We then use the relationship between alkalinity and fish density developed by Ptolomy (1993) to calculate maximum fish density for different life stages. The key concept in our use of Ptolomy's equation is that while he related stream alkalinity to fish density, the actual relationship is between food and fish density. In other words, alkalinity itself has no direct impact on fish density, but rather it has an indirect impact due to its control on general stream productivity and, therefore, on food. In streams with conditions less optimal than those studied by

Ptolomy, food is also affected by the health of the benthic invertebrate population, quantity of salmon carcasses and the amount of allochthonous inputs from the riparian zone in addition to stream alkalinity. Because of this, we develop a term for use in Ptolomy's equation that incorporates a broader definition of food, and we assume that this food term affects fish density in the manner portrayed by Ptolomy for alkalinity alone in the pristine streams he studied. Ptolomy's equation for the relationship between fish density for a life stage and alkalinity is:

$$Fish_Density = 3300 \times ALKA^{0.5} \times SIZE^{-3}$$

where *Fish_Density* is measured in fish per m² of habitat, *ALKA* is alkalinity and *SIZE* is fork length in cm.¹⁰ In EDT, an index of food based on Level 2 Attributes is converted to an alkalinity term (*ALKA*) and used in Ptolomy's equation to estimate maximum fish density for a life stage. The EDT index of alkalinity based on food attributes for use in Ptolomy's equation is created in two steps: first, development of a food index based on Level 2 Attributes, and second, creating a relationship between this food index and the stream alkalinity term in Ptolomy's equation.

The index of food availability in EDT incorporates four Level 2 Environmental Attributes:

- Alkalinity—use of this attribute is based on knowledge that alkalinity affects primary and secondary productivity of streams;
- Benthic Community Richness—this attribute describes benthic diversity and is a measure of how land use affects food availability, measured by the B-IBI;
- Riparian Function—this attribute reflects potential contributions of terrestrial insects to fish food availability;
- Salmon Carcasses—this attribute defines the relative quantity of salmonid carcasses within the area.

EDT incorporates these four Attributes to derive a FOOD index for each stream as:

$$FOOD = 4 - \left[\sum_j (a_j \bullet ATT_j^{b_j}) \right]$$

where *a* and *b* are rule parameters for the Level 2 Attributes of alkalinity, benthos, riparian function, and salmon carcasses (*ATT_j*). This results in an index for Food that is scaled from 0-4 with a 0 indicating a lack of food and a 4 indicating a super abundance of food (note that this is opposite of the categorical ratings for most attributes). We then associate the range of alkalinity seen across the Pacific Northwest to our scale of 0-4 for food ratings (Figure 12). This relationship results in a value of “alkalinity” for use in Ptolomy's equation that incorporates a broad measure of food controls applicable to streams with significant anthropogenic constraints on environmental conditions. Using Ptolomy's equation with this food term, we calculate a maximum fish density for a given environmental condition.

¹⁰ / The equation differs slightly for coho for reasons given in Ptolomy (1993).

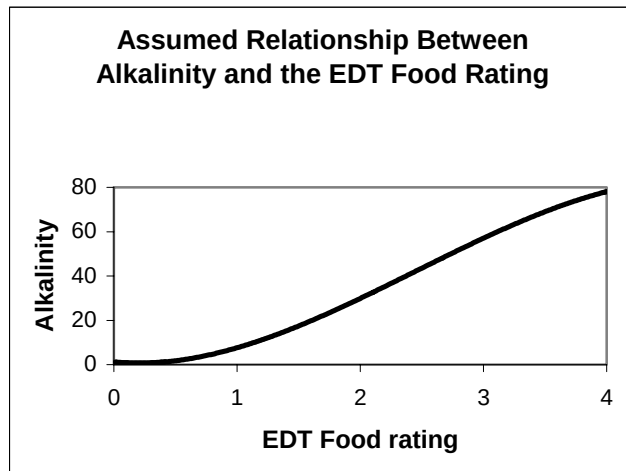


Figure 12. Assumed relationship between food rating and total alkalinity, based on the range of alkalinity values applied by Ptolemy (1993). Alkalinity here is used as a surrogate of total food availability in a stream to juvenile salmonids.

The last step in calculating the fish density is to use the density derived above, which accounts for the food availability in the stream, to adjust the Benchmark densities in Appendix B and derive the final fish density for the stream. To do this, we compute a scalar between 0 and 1 that reflects the adjustment described above to the Ptolomy estimate of density as a result of food abundance in the stream:

$$Food_Scalar = Fish_Density / Max_Density$$

where, *Fish_Density* is the fish density adjusted for food conditions in the stream that comes from the Ptolomy equation, and *Max_Density* is the fish density from the Ptolomy equation when all the food attributes are set to their maximum (best) value. Finally, *Food_Scalar* times the Benchmark density in Appendix B gives the adjusted fish density that is used to compute capacity in the stream.

B. Food (re:Productivity)

To this point in the food discussion, the results are applied in a manner that affects how food abundance affects Capacity. We also apply the food rating to adjust Productivity, consistent with evidence that suggests that food characteristics affect survival at very low population densities, i.e., in the absence of density effects. Ward and others (2003) and Wilson and others (2003) found that enrichment of food resources in oligotrophic rivers of British Columbia using fertilizers containing marine derived nutrients significantly increased survival even when populations were extremely depressed. This suggests that the quality of food resources can be enhanced in such a manner that it affects survival even when competition for food should be minor.

To estimate the effect on productivity, we apply the attribute ratings in the **Synergistic Form** of the productivity equation presented earlier. The shape of the relationship between Level 2 Attributes and Food (re:productivity) can be viewed in the Rules Viewer. The resulting survival factor F_i is allocated equally across the number of relevant life stages for the species (four life stages for Chinook and coho each and seven life stages for steelhead).

Although much research is now being focused on improving understanding about what affects food abundance in streams and how it is utilized by fish, there remains considerable uncertainty (Stockner 2003). Results of EDT incorporating effects on both capacity and productivity, however, produce results that compare favorably with how coho and steelhead populations have been found to respond to stream enrichment studies in streams in British Columbia (Ward and others 2003, Wilson and others 2003). We tested the rules by looking at how additions of salmon carcasses affect population performance. Modeling results showed that Productivity and Capacity were increased significantly by adding salmon carcasses where depleted and to an extent comparable to the findings from British Columbia.

SECTION 6. LEVEL OF PROOF

The species-habitat rules in EDT are working hypotheses based on a synthesis of existing knowledge of salmonid biological in streams of the Pacific Northwest. The existing knowledge that goes into the rules comes from a variety of sources including published, peer reviewed literature, “grey” literature that comes from contract report or other unpublished sources and from conclusions from recognized experts in the field. As a result, some of the rules are firmly grounded in existing science while others may be more speculative. To recognize this range of certainty associated with the existing scientific knowledge base, we have established four levels of proof for each Attribute Rule (Table 8). Almost all rules in EDT are currently rated a 1 or 2 proof level. This is not to say that even rules with a level of proof of 1 will not be refined as knowledge improves. Ultimately, all aspects of EDT and the rules are open to discussion and refinement. EDT is intended to be a “knowledge capture tool”—a vehicle for assembling a collective statement about how salmonid fishes experience the environment. EDT is not designed to prove anything but rather to apply existing knowledge to important watershed problems. In this way we believe that the region can make the best decisions possible at a point in time, recognizing that scientific and social uncertainties dictate the need for an adaptive approach.

Table 8. Levels of proof assigned to the use of Level 2 Environmental Attributes in EDT Species-Habitat rules.

Level of proof	Evidence
1	Thoroughly established, generally accepted, good peer-reviewed empirical evidence in its favor
2	Strong weight of evidence in support but not fully conclusive
3	Theoretical support with some evidence from experiments or observations
4	Speculative, little empirical support

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**Information Structure of
Ecosystem Diagnosis and Treatment (EDT)
and Habitat Rating Rules for
Chinook Salmon, Coho Salmon, and Steelhead Trout**

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Appendices

Appendix A. Life Stages

Appendix B. Benchmark Survival for Chinook, Coho and Steelhead

Appendix C. Level 2 Attribute Definitions

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Appendix F. L2-L3 Associations for Chinook

Appendix G. L2-L3 Associations for Coho

Appendix H. L2-L3 Associations for Steelhead

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Appendix A

Species-Specific Life Stages

Appendix Table A-1. Chinook salmon life stages within the freshwater environment.

Life stage	Description
Spawning	Period of active spawning, beginning when fish move on to spawning beds and initiate redd digging and ending when gametes are released. Note: For computational purposes, the reproductive potential associated with a spawning female is incorporated at the beginning of this stage; this potential includes sex ratio (average females per total spawners) and average fecundity per female.
Egg incubation	Egg incubation and alevin development; stage begins at the moment of the release of gametes by spawners and ends at fry emergence (losses to egg viability that occur in the instant prior to fertilization are included here).
Fry colonization	Fry emergence and initial dispersal; time period is typically very short, beginning at fry emergence and ending when fry begin active feeding associated with a key habitat.
0-age resident rearing	Rearing by age 0 fish that is largely associated with a small "home range"; these fish are generally territorial.
0-age transient rearing	Rearing by age 0 fish accompanied by directional movement (I.e., these fish do not have home ranges); these fish are non-territorial, though agonistic behavior may still be exhibited (note: this pattern typifies a 0-age fall chinook rearing pattern).
0-age migrant	Directional migration by age 0 fish that tends to be rapid and not strongly associated with feeding/rearing. This type of movement typically occurs when fish redistribute within the stream system prior to, or during, winter.
0-age inactive	Largely inactive or semi-dormant fish age fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
1-age resident rearing	Feeding/rearing by age 1 fish that is associated with a home range; these fish are often territorial.
1-age migrant	Directional migration by age 1 fish that tends to be rapid and not strongly associated with feeding/rearing. Such migrations will typically occur during either spring or fall/early winter by fish migrating seaward or as a redistribution to a different freshwater habitat (such as occurs following winter or in preparation for winter).
Migrant prespawner	Adult fish approaching sexual maturity that are migrating to their natal stream; in the ocean this stage occurs in the final year of marine life, in freshwater feeding has generally ceased.
Holding prespawner	Adult fish approaching sexual maturity that are largely stationary and holding, while en route to their spawning grounds; distance to the spawning grounds from holding sites may be short or long.

Appendix Table A-2. Coho salmon life stages within the freshwater environment.

Life stage	Description
Spawning	Period of active spawning, beginning when fish move on to spawning beds and initiate redd digging and ending when gametes are released. Note: For computational purposes, the reproductive potential associated with a spawning female is incorporated at the beginning of this stage; this potential includes sex ratio (average females per total spawners) and average fecundity per female.
Egg incubation	Egg incubation and alevin development; stage begins at the moment of the release of gametes by spawners and ends at fry emergence (losses to egg viability that occur in the instant prior to fertilization are included here).
Fry colonization	Fry emergence and initial dispersal; time period is typically very short, beginning at fry emergence and ending when fry begin active feeding associated with a key habitat.
0-age resident rearing	Rearing by age 0 fish that is largely associated with a small "home range"; these fish are generally territorial.
0-age migrant	Directional migration by age 0 fish that tends to be rapid and not strongly associated with feeding/rearing. This type of movement typically occurs when fish redistribute within the stream system prior to, or during, winter.
0-age inactive	Largely inactive or semi-dormant fish age fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
1-age resident rearing	Feeding/rearing by age 1 fish that is associated with a home range; these fish are often territorial.
1-age migrant	Directional migration by age 1 fish that tends to be rapid and not strongly associated with feeding/rearing. Such migrations will typically occur during either spring or fall/early winter by fish migrating seaward or as a redistribution to a different freshwater habitat (such as occurs following winter or in preparation for winter).
Migrant prespawner	Adult fish approaching sexual maturity that are migrating to their natal stream; in the ocean this stage occurs in the final year of marine life, in freshwater feeding has generally ceased.
Holding prespawner	Adult fish approaching sexual maturity that are largely stationary and holding, while en route to their spawning grounds; distance to the spawning grounds from holding sites may be short or long.

Appendix Table A-3. Steelhead trout life stages.

Life stage	Description
Spawning	Period of active spawning, beginning when fish move on to spawning beds and initiate redd digging and ending when gametes are released. Note: For computational purposes, the reproductive potential associated with a spawning female is incorporated at the beginning of this stage; this potential includes sex ratio (average females per total spawners) and average fecundity per female.
Egg incubation	Egg incubation and alevin development; stage begins at the moment of the release of gametes by spawners and ends at fry emergence (losses to egg viability that occur in the instant prior to fertilization are included here).
Fry colonization	Fry emergence and initial dispersal; time period is typically very short, beginning at fry emergence and ending when fry begin active feeding associated with a key habitat.
0-age resident rearing	Rearing by age 0 fish that is largely associated with a small "home range"; these fish are generally territorial.
0-age migrant	Directional migration by age 0 fish that tends to be rapid and not strongly associated with feeding/rearing. This type of movement typically occurs when fish redistribute within the stream system prior to, or during, winter.
0-age inactive	Largely inactive or semi-dormant fish age fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
1-age resident rearing	Feeding/rearing by age 1 fish that is associated with a home range; these fish are often territorial.
1-age migrant	Directional migration by age 1 fish that tends to be rapid and not strongly associated with feeding/rearing. Such migrations will typically occur during either spring or fall/early winter by fish migrating seaward or as a redistribution to a different freshwater habitat (such as occurs following winter or in preparation for winter).
1-age inactive	Largely inactive or semi-dormant fish age 1 fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
2+-age resident rearing	Feeding/rearing by age 2 and older fish that is associated with a home range; these fish are often territorial.
2+-age migrant	Directional migration by age 2 and older fish that tends to be rapid and not strongly associated with feeding/rearing. Such migrations will typically occur during either spring or fall/early winter by fish migrating seaward or as a redistribution to a different freshwater habitat (such as occurs following winter or in preparation for winter).
2+-age inactive	Largely inactive or semi-dormant fish age 2 and older fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
Migrant prespawner	Adult fish approaching sexual maturity that are migrating to their natal stream; in the ocean this stage occurs in the final year of marine life, in freshwater feeding has generally ceased.
Holding prespawner	Adult fish approaching sexual maturity that are largely stationary and holding, while en route to their spawning grounds; distance to the spawning grounds from holding sites may be short or long.

Appendix B

Benchmark Survival for Chinook, Coho and Steelhead

Benchmarks

The EDT method associates survival with habitat. The productivity and capacity values derived in the EDT process are characteristics of the environment by time and location as interpreted “though the eyes of salmon” by species and life stage (Mobrand et al. 1997). The procedure for deriving these productivity and capacity values involves what we refer to as a shaping of survival conditions over time and space, as salmon might experience them in completing their life cycle. The shaping of survival conditions is done with reference to a defined set of “benchmark” conditions.

From literature we can identify habitat requirements by life stage for the species. We can take it a step further and describe optimal conditions and the expected survival and density limits by life stage. We refer to the survival and density values associated with optimal conditions as reference benchmarks. Thus benchmarks provide us with a set of descriptions for optimal conditions expressed as productivity survival, maximum densities, and habitat characteristics for each life stage. These conditions constitute what can be thought of “as good as it gets” for survival of the species in nature. We have employed a set of benchmark values derived from reviewing relevant sources of information, including discussions with scientists having expertise in survival of salmonids by life stage under various conditions.

The systematic shaping of survival conditions using the habitat rating procedures is intended to assure that productivity and capacity values for each life history segment along a trajectory are: a) bounded by the biological limits of the species, b) scaled consistently across time, space, and life stage, and c) scaled consistently with the benchmark values.

It is important to keep in mind that benchmark or optimal conditions are different from template (pre-development) conditions. Template conditions were not always optimal for salmon survival. The benchmark descriptions serve as a point of reference for both the patient and template and for all watersheds.

Appendix Table B-1. Benchmark assumptions for fall chinook, spring chinook, coho, summer steelhead, and winter steelhead.

Species	Life stage	Stereotypical duration (weeks)	Productivity	Density (fish/m2)
Fall chinook	Spawning	1	1.00	0.22
	Egg incubation	25	0.57	400.00
	Fry colonization	2	0.75	5.75
	0-age resident rearing	30	0.70	1.60
	0-age transient rearing	8	0.36	0.50
	0-age migrant	2	0.96	30.00
	0-age inactive	19	0.70	0.30

Appendix Table B-1 continued. Benchmark assumptions for fall chinook, spring chinook, coho, summer steelhead, and winter steelhead.

Species	Life stage	Stereotypical duration (weeks)	Productivity	Density (fish/m2)
	1-age resident rearing	30	0.90	0.20
	1-age migrant	2	0.98	30.00
	Migrant prespawner	8	0.93	1.00
Spring chinook	Holding prespawner	8	0.98	1.00
	Spawning	1	1.00	0.22
	Egg incubation	23	0.60	400.00
	Fry colonization	2	0.75	5.75
	0-age resident rearing	30	0.70	1.60
	0-age transient rearing	8	0.36	0.50
	0-age migrant	2	0.96	30.00
	0-age inactive	19	0.70	0.30
	1-age resident rearing	30	0.90	0.20
	1-age migrant	2	0.98	30.00
	Migrant prespawner	4	0.90	1.00
	Holding prespawner	4	0.99	1.00
Coho	Spawning	1	1.00	0.33
	Egg incubation	18	0.60	300.00
	Fry colonization	2	0.80	9.60
	0-age resident rearing	25	0.75	1.88
	0-age migrant	2	0.96	30.00
	0-age inactive	20	0.70	0.88
	1-age resident rearing	8	0.95	0.50
	1-age migrant	2	0.98	30.00
	Migrant prespawner	4	1.00	2.00
	Holding prespawner	4	1.00	1.00
Summer steelhead	Spawning	1	1.00	0.33
	Egg incubation	7	0.70	400.00
	Fry colonization	2	0.75	25.62
	0-age resident rearing	16	0.78	2.52
	0-age migrant	2	0.98	30.00
	0-age inactive	20	0.70	1.13
	1-age resident rearing	28	0.85	0.25

Appendix Table B-1 continued. Benchmark assumptions for fall chinook, spring chinook, coho, summer steelhead, and winter steelhead.

Species	Life stage	Stereotypical duration (weeks)	Productivity	Density (fish/m2)
	1-age migrant	2	0.98	30.00
	1-age inactive	20	0.85	0.21
	2+-age resident rearing	28	0.90	0.11
	2+-age migrant	2	0.99	30.00
	2+-age inactive	20	0.93	0.11
	Migrant prespawner	12	0.98	1.00
	Holding prespawner	26	0.98	1.00
Winter steelhead	Spawning	1	1.00	0.33
	Egg incubation	7	0.70	400.00
	Fry colonization	2	0.75	25.62
	0-age resident rearing	16	0.78	2.52
	0-age migrant	2	0.98	30.00
	0-age inactive	20	0.70	1.13
	1-age resident rearing	28	0.85	0.25
	1-age migrant	2	0.98	30.00
	1-age inactive	20	0.85	0.21
	2+-age resident rearing	28	0.90	0.11
	2+-age migrant	2	0.99	30.00
	2+-age inactive	20	0.93	0.11
	Migrant prespawner	3	1.00	1.00
	Holding prespawner	8	1.00	1.00

Appendix C

Level 2 Environmental Attributes

Appendix Table C-1. Level 2 Environmental Attributes (or ecological attributes).

Code	Attribute	Definition
Alka	Alkalinity	Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO ₃ or CaCO ₃ .
BdScour	Bed scour	Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).
BenComRch	Benthos diversity and production	Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of Oregon RiverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).
ChLngth	Channel length	Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a categories but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.
WidthMx	Channel width - month maximum width (ft)	Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.
WidthMn	Channel width - month minimum width (ft)	Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.
ConfineHdro	Confinement - Hydromodifications	The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cutoff due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.
Confine	Confinement - natural	The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.
DisOxy	Dissolved oxygen	Average dissolved oxygen within the water column for the specified time interval.
Emb	Embeddedness	The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.
FnSedi	Fine sediment	Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.
FshComRch	Fish community richness	Measure of the richness of the fish community (no. of fish taxa, i.e., species).

Appendix Table C-1 continued. Level 2 Environmental Attributes (or ecological attributes).

Code	Attribute	Definition
FshPath	Fish pathogens	The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.
FSPIntro	Fish species introductions	Extent of introductions of exotic fish species in the vicinity of the stream reaches under consideration.
FlwHigh	Flow - change in average annual peak flow	The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as T_{Qmean} , see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q_{2yr}).
FlwLow	Flow - change in average annual low flow	The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.
FlwDielVar	Flow - Intra daily (diel) variation	Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.
FlwIntraAnn	Flow - intra-annual flow pattern	The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric T_{Qmean} , see Konrad [2000]), or inferred from patterns corresponding to watershed development.
Grad	Gradient	Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.
HbBckPls	Habitat type - backwater pools	Percentage of the wetted channel surface area comprising backwater pools.
HbBvrPnds	Habitat type - beaver ponds	Percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat.
HbGlide	Habitat type - glide	Percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.
HbLrgCbl	Habitat type - large cobble/boulder riffles	Percentage of the wetted channel surface area comprising large cobble/boulder riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).
HbOfChFctr	Habitat type - off-channel habitat factor	A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.
HbPITails	Habitat type - pool tailouts.	Percentage of the wetted channel surface area comprising pool tailouts.
HbPls	Habitat type - primary pools	Percentage of the wetted channel surface area comprising pools, excluding beaver ponds
HbSmICbl	Habitat type - small cobble/gravel riffles	Percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).
Harass	Harassment	The relative extent of poaching and/or harassment of fish within the stream reach.

Appendix Table C-1 continued. Level 2 Environmental Attributes (or ecological attributes).

Code	Attribute	Definition
HatFOutp	Hatchery fish outplants	The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.
HydroRegimeNatural	Hydrologic regime - natural	The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.
HydroRegimeReg	Hydrologic regime - regulated	The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).
Icing	Icing	Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.
MetWatCol	Metals - in water column	The extent of dissolved heavy metals within the water column.
MetSedSls	Metals/Pollutants - in sediments/soils	The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.
MscToxWat	Miscellaneous toxic pollutants - water column	The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.
NutEnrch	Nutrient enrichment	The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.
Obstr	Obstructions to fish migration	Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).
PredRisk	Predation risk	Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).
RipFunc	Riparian function	A measure of riparian function that has been altered within the reach.
SalmCarcass	Salmon Carcasses	Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs the upper mainstem, or in mainstem areas vs major tributary drainages.
TmpMonMx	Temperature - daily maximum (by month)	Maximum water temperatures within the stream reach during a month.
TmpMonMn	Temperature - daily minimum (by month)	Minimum water temperatures within the stream reach during a month.
TmpSptVar	Temperature - spatial variation	The extent of water temperature variation (cool or warm water depending upon season) within the reach as influenced by inputs of groundwater or tributary streams, or the presence of thermally stratified deep pools.

Appendix Table C-1 continued. Level 2 Environmental Attributes (or ecological attributes).

Code	Attribute	Definition
Turb	Turbidity	The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$, where, X = duration in hours, Y = mg/l, $a = 1.0642$, $b = 0.6068$, and $c = 0.7384$. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.
Wdrwl	Water withdrawals	The number and relative size of water withdrawals in the stream reach.
WdDeb	Wood	The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

Appendix D

Definitions of Level 2 Environmental Attribute Index Values

Appendix Table D-1. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
Alka	Alkalinity	Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO ₃ or CaCO ₃ .	Very low (average value typically would be 0-5 mg/l)	Moderately low (average value typically would be 5-10 mg/l)	Moderately high (average value typically would be 10-40 mg/l)	High (average value typically would be 40-100 mg/l)	Very high (average value typically would be 100-300 mg/l)
BdScour	Bed scour	Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).	Average depth of scour >0 cm and <2 cm	Average depth of scour >2 cm and <10 cm	Average depth of scour >10 cm and <18 cm	Average depth of scour >18 cm and <24 cm	Average depth of scour >24 cm and <40 cm

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
BenComRch	Benthos diversity and production	Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of Oregon RiverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).	(1) Simple EPT index -- Macroinvertebrates abundant; multiple species of families Ephemeroptera, Plecoptera, and Trichoptera are present. OR (2) B-IBI (10 metrics) -- ≥ 45 Comparable to least disturbed reference condition; overall high taxa diversity, particularly of mayflies, stoneflies, caddisflies, long-lived clinger, and intolerant taxa. Relative abundance of predators high. OR (3) BORIS score -- Minimal impairment in benthic community — < 1 standard deviation from the reference mean AND considered "ideal or good watershed and stream condition for reference condition."	(1) Simple EPT index -- Intermediate OR (2) B-IBI (10 metrics) -- ≥ 37 and < 45 . Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of mayflies, stoneflies, and caddisflies; proportion of tolerant taxa increases. OR (3) BORIS score -- Minimal impairment in benthic community — < 1 standard deviation from the reference mean AND considered "marginal watershed and stream condition for reference condition."	(1) Simple EPT index -- Macroinvertebrates common or abundant but 1-2 families among Ephemeroptera, Plecoptera, and Trichoptera are not present. OR (2) B-IBI (10 metrics) -- ≥ 27 and < 37 . Total taxa reduced—particularly intolerant, long-lived, stonefly, and clinger taxa. Relative abundance of predator declines; proportion of tolerant taxa continues to increase. OR (3) BORIS score -- Moderate impairment in benthic community — > 1 and < 2 standard deviations from the reference mean.	(1) Simple EPT index -- Intermediate. OR (2) B-IBI (10 metrics) -- ≥ 17 and < 27 . Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few stoneflies or intolerant taxa present; dominance by three most abundant taxa often very high. OR (3) BORIS score -- Severe impairment in benthic community — > 2 and < 2.5 standard deviations from the reference mean.	(1) Simple EPT index -- Macroinvertebrates are present only at extremely low densities and/or biomass. OR (2) B-IBI (10 metrics) -- < 17 . Overall taxa diversity very low and dominated by a few highly tolerant taxa; mayfly, stonefly, caddisfly, clinger, long-lived and intolerant taxa largely absent. Relative abundance of predators very low. OR (3) BORIS score -- Extremely severe impairment in benthic community — > 2.5 standard deviations from the reference mean.
ChLngth	Channel length	Length of the primary channel contained with the stream reach -- Note: this attribute will not be given by a categories but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.					
WidthMx	Channel width - month maximum width (ft)	Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.	< 15 ft	> 15 ft and < 60 ft	> 60 ft and < 100 ft	> 100 ft and < 360 ft	> 360 ft

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
WidthMn	Channel width - month minimum width (ft)	Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.	< 15 ft	> 15 ft and < 60 ft	> 60 ft and < 100 ft	> 100 ft and 360 ft	> 360 ft

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
ConfineHdro	Confinement – Hydromodifications	The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cutoff due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.	The stream channel within the reach is essentially fully connected to its floodplain. Very minor structures may exist in the reach that do not result in flow constriction or restriction. Note: this describes both a natural condition within a naturally unconfined channel as well as the natural condition within a canyon.	Some portion of the stream channel, though less than 10% (of the sum of lengths of both banks), is disconnected from its floodplain along one or both banks due to man-made structures or ditching.	More than 10% and less than 40% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.	More than 40% and less than 80% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.	Greater than 80% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
Confine	Confinement - natural	The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.	Reach mostly unconfined by natural features -- Average valley width > 4 channel widths.	Reach comprised approximately equally of unconfined and moderately confined sections.	Reach mostly moderately confined by natural features -- Average valley width 2 - 4 channel widths.	Reach comprised approximately equally of moderately confined and confined sections.	Reach mostly confined by natural features -- Average valley width < 2 channel widths.
DisOxy	Dissolved oxygen	Average dissolved oxygen within the water column for the specified time interval.	> 8 mg/L (allows for all biological functions for salmonids without impairment at temperatures ranging from 0-25 C)	> 6 mg/L and < 8 mg/L (causes initial stress symptoms for some salmonids at temperatures ranging from 0-25 C)	> 4 and < 6 mg/L (stress increased, biological function impaired)	> 3 and < 4 mg/L (growth, food conversion efficiency, swimming performance adversely affected)	< 3 mg/L
Emb	Embeddedness	The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.	< 10% of surface covered by fine sediment	> 10 and < 25 % covered by fine sediment	> 25 and < 50 % covered by fine sediment	> 50 and < 90 % covered by fine sediment	> 90% covered by fine sediment

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
FnSedi	Fine sediment	Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.	Particle sizes <0.85 mm: < 6% OR Particle sizes <6.3 mm: <10%	Particle sizes <0.85 mm: > 6% and < 11% OR Particle sizes <6.3 mm: >10% and <25%	Particle sizes <0.85 mm: > 11% and < 18% OR Particle sizes <6.3 mm: >25% and <40%	Particle sizes <0.85 mm: > 18% and < 30% OR Particle sizes <6.3 mm: >40% and <60%	Particle sizes <0.85 mm: > 30% fines OR Particle sizes <6.3 mm: >60%
FshComRch	Fish community richness	Measure of the richness of the fish community (no. of fish taxa, i.e., species).	2 or fewer fish taxa	3-7 fish taxa	8-17 fish taxa	18-25 fish taxa	> 25 fish taxa
FshPath	Fish pathogens	The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.	No historic or recent fish stocking in drainage and no known incidences of whirling disease, C. shasta, IHN, or IPN	Historic fish stocking, but no fish stocking records within the past decade, or sockeye population currently existing in drainage, or known incidents of viruses among kokanee populations within the watershed.	On-going periodic, frequent, or annual fish stocking in drainage or known viral incidents within sockeye, chinook, or steelhead populations in the watershed.	Operating hatchery within the reach or in the reach immediately downstream or upstream	Known presence of whirling disease or C. shasta within the watershed.
FSPIntro	Fish species introductions	Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.	No non-native species reported or known to be in the sub-drainage of interest.	1-2 non-native species reported or known to be in the sub-drainage of interest.	3-7 non-native species reported or known to be in the sub-drainage of interest.	8-14 non-native species reported or known to be in the sub-drainage of interest.	15 or more non-native species reported or known to be in the sub-drainage of interest.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
FlwHigh	Flow - change in average annual peak flow	The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as $T_{Q_{mean}}$, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q_{2yr}).	Peak annual flows expected to be strongly reduced relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >40% and <100% decrease in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known by regulated flow levels. This condition is associated with flow regulation or water diversion projects.	Peak annual flows expected to be moderately reduced relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >20% and <40% decrease in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known by regulated flow levels. This condition is associated with flow regulation or water diversion projects.	Peak annual flows expected to be comparable to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR <20% change in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state); OR <5% reduction in average $T_{Q_{mean}}$ compared to the undeveloped watershed state.	Peak annual flows expected to be moderately increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >20% and <40% increase in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state); OR >5% and <15% reduction in average $T_{Q_{mean}}$ compared to the undeveloped watershed state. This condition exemplified in some forested watersheds with high road density that experience significant rain on snow events, as the North Fork Stillaguamish River (Pess et al. <i>in review</i>). Note: many managed forested watersheds in the Pacific Northwest exhibit slight, if any, increases in peak annual flows since logging commenced (see Ziemer and Lisle 1998).	Peak annual flows expected to be strongly increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >40% and <110%+ increase in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state); OR >15% and <45% reduction in average $T_{Q_{mean}}$ compared to the undeveloped watershed state. This condition exemplified in watersheds with significant urbanization (e.g., >20%).

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
FlwLow	Flow - change in average annual low flow	The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.	Average daily low flows expected to be strongly increased compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >75% increase in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.	Average daily low flows expected to be moderately increased compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >20% and <75% increase in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.	Average daily low flows expected to be comparable to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR <20% change in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state).	Average daily low flows expected to be moderately reduced compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >20% and <50% reduction in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.	Average daily low flows expected to be severely reduced compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >50% and <=100% reduction in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
FlwDielVar	Flow - Intra daily (diel) variation	Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.	Essentially no variation in discharge during an average 24-hr period during season or month. This characterizes conditions not influenced by flow ramping or accelerated storm runoff. This rating also would apply to small suburban-urbanized drainages with impervious surfaces of <10% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Slight to low variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) slight to low ramping condition associated with flow regulation, averaging <2 inches change in stage per hour. This condition has both slight to low rates of change in flow and high frequency with which it occurs. This rating also would apply to small suburban-urbanized drainages with impervious surfaces of ~10-25% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Low to moderate variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) low to moderate ramping condition associated with flow regulation, averaging >2 inches and <6 inches change in stage per hour. This condition has both moderate to high rates of change in flow and high frequency with which it occurs. This rating also would apply to small suburban-urbanized drainages with impervious surfaces of ~25-40% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Moderate to high variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) moderate to high ramping condition associated with flow regulation, averaging between 6 inches to 12 inches change in stage per hour. This condition has both moderate to high rates of change in flow and high frequency with which it occurs. This rating also would apply to small suburban to urbanized drainages with impervious surfaces of ~40-50% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Extreme variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) extreme ramping condition associated with flow regulation, averaging between 12 inches to 24 inches change in stage per hour. This condition is both extreme in the rate of change in flow and the frequency with which it occurs. This rating would apply to small, heavily urbanized drainages with impervious surfaces of 50-80% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.
FlwIntraAnn	Flow - intra-annual flow pattern	The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric T_{Qmean} , see Konrad [2000]), or inferred from patterns corresponding to watershed development.	Storm runoff response (rates of change in flow) expected to be slowed greatly relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >15% increase in average T_{Qmean} compared to the undeveloped watershed state or as known by regulated flow levels. This condition is associated with flow regulation.	Storm runoff response (rates of change in flow) expected to be moderately slower relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >5% and <15% increase in average T_{Qmean} compared to the undeveloped watershed state or as known by regulated flow levels. This condition is associated with flow regulation.	Storm runoff response (rates of change in flow) comparable to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR <5% reduction in average T_{Qmean} compared to the undeveloped watershed state.	Storm runoff response (rates of change in flow) expected to be moderately increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >5% and <15% reduction in average T_{Qmean} compared to the undeveloped watershed state. This condition exemplified in some managed forested watersheds with high road density, likely most evident in small drainages.	Storm runoff response (rates of change in flow) expected to be strongly increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >15% and <45% reduction in average T_{Qmean} compared to the undeveloped watershed state. This condition exemplified in watersheds with significant urbanization.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
Grad	Gradient	Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.	0 - 0.1%	>0.10% and <0.5%	>0.5% and <1%	>1% and <2%	>2% and <4%
HbBckPls	Habitat type - backwater pools	Percentage of the wetted channel surface area comprising backwater pools.	0 - <0.25% of wetted surface area encompasses this habitat type	>0.25% and <5% of wetted surface area encompasses this habitat type	>5% and <25% of wetted surface area encompasses this habitat type	>25% and <50% of wetted surface area encompasses this habitat type	>50% of wetted surface area encompasses this habitat type
HbBvrPnds	Habitat type - beaver ponds	Percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat.	0 - <0.25% of wetted surface area encompasses this habitat type	>0.25% and <5% of wetted surface area encompasses this habitat type	>5% and <25% of wetted surface area encompasses this habitat type	>25% and <50% of wetted surface area encompasses this habitat type	>50% of wetted surface area encompasses this habitat type

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
HbGlide	Habitat type - glide	Percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.	0 - <0.25% of wetted surface area encompasses this habitat type	>0.25% and <5% of wetted surface area encompasses this habitat type	>5% and <25% of wetted surface area encompasses this habitat type	>25% and <50% of wetted surface area encompasses this habitat type	>50% of wetted surface area encompasses this habitat type
HbLrgCbl	Habitat type - large cobble/boulder r riffles	Percentage of the wetted channel surface area comprising large cobble/boulder riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et a. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).	0 - <0.25% of wetted surface area encompasses this habitat type	>0.25% and <5% of wetted surface area encompasses this habitat type	>5% and <25% of wetted surface area encompasses this habitat type	>25% and <50% of wetted surface area encompasses this habitat type	>50% of wetted surface area encompasses this habitat type

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
HbOfChFctr	Habitat type - off-channel habitat factor	A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.	No off-channel habitat present	>0 X and < 0.05 X	>0.05 X and < 0.25 X	>0.25 X and < 0.5 X	>0.5 X
HbPITails	Habitat type - pool tailouts.	Percentage of the wetted channel surface area comprising pool tailouts.	0 - <0.25% of wetted surface area encompasses this habitat type	>0.25% and <5% of wetted surface area encompasses this habitat type	>5% and <25% of wetted surface area encompasses this habitat type	>25% and <50% of wetted surface area encompasses this habitat type	>50% of wetted surface area encompasses this habitat type
HbPls	Habitat type - primary pools	Percentage of the wetted channel surface area comprising pools, excluding beaver ponds	0 - <0.25% of wetted surface area encompasses this habitat type	>0.25% and <5% of wetted surface area encompasses this habitat type	>5% and <25% of wetted surface area encompasses this habitat type	>25% and <50% of wetted surface area encompasses this habitat type	>50% of wetted surface area encompasses this habitat type
HbSmICbl	Habitat type - small cobble/gravel riffles	Percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).	0 - <0.25% of wetted surface area encompasses this habitat type	>0.25% and <5% of wetted surface area encompasses this habitat type	>5% and <25% of wetted surface area encompasses this habitat type	>25% and <50% of wetted surface area encompasses this habitat type	>50% of wetted surface area encompasses this habitat type
Harass	Harassment	The relative extent of poaching and/or harassment of fish within the stream reach.	Reach is distant from human population centers, no road access or no local concentration of human activity.	Reach is distant from human population centers, but with partial road access or little local concentration of human activity.	Reach is near human population center, but has limited public access (through roads or boat launching sites).	Extensive road and/or boat access to the reach with localized concentrations of human activity.	Reach is near human population center or has extensive recreational activities, and has extensive road access and/or opportunities for boat access.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
HatFOutp	Hatchery fish outplants	The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.	No stocking records in the past decade.	No more than two instances of fish releases in the past decade in the drainage.	Fish releases made into the drainage every 1-3 years at isolated locations within the drainage.	Fish releases made at multiple sites in the drainage, but only in 1-3 years during the past decade. When the species released is the same as focus species, chance for some superimposition can occur here.	Fish releases made every 1-3 years and at multiple sites in the drainage. When the species released is the same as focus species, superimposition can occur here.
HydroRegime Natural	Hydrologic regime - natural	The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.	Groundwater-source-dominated; strongly buffered peak flows (as in a springbrook or in river like the Metolius in central Oregon)	Spring snowmelt dominated, non-glacial; temporally consistent and moderate peak and low flows	Rain-on-snow transitional; consistent spring peak and low flows with inconsistent and flashy winter or early spring rain-on-snow peaks	Rainfall-dominated; flashy winter and early spring peaks, consistently low summer flows and variable spring and fall flows.	Glacial runoff system; high, turbid low flows, generally buffered peak flows except with occasional outburst floods and infrequent rain-on-snow events
HydroRegime Reg	Hydrologic regime - regulated	The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).	No artificial flow regulation occurs upstream to affect hydrograph.	Project operations have not changed median flows between months or season as the project is operated as a run-of-river facility, or project storage is < 15 days of the annual mean daily flow of the river.	Project operations have not changed median flows between months or season as the project is operated as a run-of-river facility, or project storage is > 15 and < 30-days of the annual mean daily flow of the river.	Project operations have resulted in a measurable shift in median flows between months or seasons. The project provides limited flood control during periods of high run-off (winter or spring). The project's reservoir is operated each year to store more than 30 but less than 60-days of the annual mean daily flow of the river.	Project operations have resulted in a major shift in median flows between months or seasons. The project is operated to provide significant flood control during high run-off periods (winter or spring). The project's reservoir is operated each year to store more than 60-days of the annual mean daily flow of the river.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
Icing	Icing	Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.	Anchor ice and icing events do not occur.	Some anchor ice may occur infrequently, having little or no impact to physical structure of stream, in-stream structure, and stream banks/bed.	Likelihood for some anchor ice and/or icing events is moderate to high each year and effects on stream, in-stream structure, and stream banks/beds is considered low to moderate.	Likelihood for anchor ice and/or icing events is high each year, having effects on stream, in-stream structure, and stream banks/beds that differ widely within the reach--from low to high across the reach.	Likelihood of severe anchor ice or overbank ice jams is high each year, having major and extensive effects on stream, in-stream structure, and stream banks across the reach.
MetWatCol	Metals - in water column	The extent of dissolved heavy metals within the water column.	No toxicity expected due to dissolved heavy metals to salmonids under prolonged exposure (1 month exposure assumed).	May exert some low level chronic toxicity to salmonids (1 month exposure assumed).	Consistently chronic toxicity expected to salmonids (1 month exposure assumed).	Usually acutely toxic to salmonids (1 month exposure assumed).	Always acutely toxic to salmonids (1 month exposure assumed).
MetSedSls	Metals/Pollutants - in sediments/soils	The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.	Metals/pollutants at natural (background) levels with no or negligible effects on benthic dwelling organisms or riparian vegetation (under continual exposure).	Deposition of metals/pollutants in low concentrations such that some stress symptoms occur to benthic dwelling organisms or riparian vegetation root/shoot growth is impaired (under continual exposure).	Stress symptoms increased or biological functions moderately impaired to benthic dwelling organisms; or few areas within the riparian zone present where no vegetation exists (slickens); ecotonal to these areas occupied only by tolerant species; horizons containing metals/pollutant concentrations influencing root growth and composition are common within the riparian corridor.	Growth, food conversion, reproduction, or mobility of benthic organisms severely affected; or large areas of the riparian zone devoid of vegetation; ecotonal areas occupied only by metals/pollutant-tolerant species; few areas in the riparian zones which are unaffected.	Metals/pollutant concentrations in sediments/soils are lethal to large numbers of the benthic species and/or riparian zone is practically devoid of vegetation.
MscToxWat	Miscellaneous toxic pollutants - water column	The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.	No substances present that may periodically be at or near chronic toxicity levels to salmonids.	One substance present that may only periodically rise to near chronic toxicity levels (may exert some chronic toxicity) to salmonids.	More than one substance present that may periodically rise to near chronic toxicity levels or one substance present > chronic threshold and < acute threshold (consistently chronic toxicity) to salmonids.	One or more substances present > acute toxicity threshold but < 3X acute toxicity threshold (usually acutely toxic) to salmonids.	One or more substances present with > 3X acute toxicity (always acutely toxic) to salmonids.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
NutEnrch	Nutrient enrichment	The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.	Unenriched streams (corresponding to benthic chlorophyll a values 0.5-3 mg/m2). Nutrient levels typical of oligotrophic conditions (small supply of nutrients, low production of organic matter, low rates of decomposition, and high DO). No enrichment is occurring nor is suspected. Green filamentous algae may be present at certain times of year, particularly in unshaded areas.	Very small amount of enrichment suspected to be occurring through land use activities (corresponding to benthic chlorophyll a values 3-20 mg/m2). Green filamentous algae present in summer months in unshaded reaches.	Nutrient levels typical of oligotrophic conditions (small supply of nutrients, low production of organic matter, low rates of decomposition, and high DO). Some enrichment known to be occurring (corresponding to benthic chlorophyll a values 20-60 mg/m2), often associated with failing septic tanks or runoff from areas of heavy fertilizer usage. Dense mats of green or brown filamentous algae present in summer months.	Eutrophic (abundant nutrients associated with high level of primary production, frequently resulting in oxygen depletion). Very obvious enrichment of reach is occurring from point sources or numerous non-point sources (corresponding to benthic chlorophyll a values 60-600 mg/m2). Large, dense mats of green or brown filamentous algae will be present during summer months.	Super enrichment of reach is strongly evident. Known, major point sources of organic waste inputs, such as runoff from large feedlot operation, wash water from farm products processing, or significant sewage facilities with inadequate treatment (corresponding to benthic chlorophyll a values 600-1200 mg/m2). In most severe cases, filamentous bacteria abundant, associated with low D.O. and hydrogen sulfide. In less severe cases, large dense mats of green or brown filamentous algae generally cover the substrate.
Obstr	Obstructions to fish migration	Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen). Note: Rating here is used as a flag in the database. The nature of the obstruction is required to be defined more carefully in a follow-up form.	None documented or inferred.	One or barriers to juvenile migrants at certain flow levels.	One or barriers to juvenile migrants at all flow levels.	One or barriers to juvenile migrants at all flow levels and barrier(s) to adult migration at certain flow levels.	One or more barriers to all fish migration at all flow levels.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
PredRisk	Predation risk	Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).	Many or most native predators are depressed or rare, none are greatly increased over natural levels, and there is expected a significant numerical survival advantage to fish as a result compared to historical predator abundance.	Some native predators are moderately depressed, none are greatly increased over natural levels, and there is expected some small to moderate numerical survival advantage to fish as a result compared to historical predator abundance.	Diversity and per-capita abundance of predators exists so that predation risk is at near-natural level and distribution.	Moderate increase in population density or moderately concentrated population of predator species exists due to artifacts of human alteration of the environment (e.g., top-down food web effects, habitat manipulations) compared to historical condition.	Excessive population density or concentrated population of predator species exists due to artifacts of human alteration of the environment (e.g., top-down food web effects, habitat manipulations) compared to historic condition.
RipFunc	Riparian function	A measure of riparian function that has been altered within the reach.	Strong linkages with no anthropogenic influences.	>75-90% of functional attributes present (overbank flows, vegetated streambanks, groundwater interactions typically present).	50-75% functional attribute rating- significant loss of riparian functioning- minor channel incision, diminished riparian vegetation structure and inputs etc.	25-50% similarity to natural conditions in functional attributes- many linkages between the stream and its floodplain are severed.	< 25% functional attribute rating: complete severing of floodplain-stream linkages
SalmCarcass	Salmon Carcasses	Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs the upper mainstem, or in mainstem areas vs major tributary drainages.	Super abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >800.	Very abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >400 and < 800.	Moderately abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >200 and < 400.	Not abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >25 and <200.	Very few or none -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) <25.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
TmpMonMx	Temperature - daily maximum (by month)	Maximum water temperatures within the stream reach during a month.	Warmest day < 10 C	Warmest day > 10 C and < 16 C	> 1 d with warmest day 22-25 C or 1-12 d with > 16 C	> 1 d with warmest day 25-27.5 C or > 4 d (non-consecutive) with warmest day 22-25 C or > 12 d with > 16 C	> 1 d with warmest day 27.5 C or 3 d (consecutive) > 25 C or > 24 d with > 21 C
TmpMonMn	Temperature - daily minimum (by month)	Minimum water temperatures within the stream reach during a month.	Coldest day > 4 C	< 7 d with < 4 C and minimum > 1 C	1 to 7 d < 1 C	8 to 15 days < 1 C	> 15 winter days < 1 C
TmpSptVar	Temperature - spatial variation	The extent of water temperature variation (cool or warm water depending upon season) within the reach as influenced by inputs of groundwater or tributary streams, or the presence of thermally stratified deep pools.	Super abundant sites of groundwater discharge into surface waters (primary source of stream flow), tributaries entering reach, or deep pools that provide abundant temperature variation in reach.	Abundant sites of groundwater discharge into surface waters, tributaries entering reach, or deep pools that provide abundant temperature variation in reach.	Occasional sites of groundwater discharge into surface waters, tributaries entering reach or deep pools that provide intermittent temperature variation in reach.	Infrequent sites of groundwater discharge into surface waters, tributaries entering reach or deep pools that provide infrequent temperature variation in reach.	No evidence of temperature variation in reach.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
Turb	Turbidity	The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$, where, $X = \text{duration in hours}$, $Y = \text{mg/l}$, $a = 1.0642$, $b = 0.6068$, and $c = 0.7384$. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.	SEV Index ≤ 4.5 Clear with infrequent (short duration-- several days per year) concentrations of low concentrations (< 50 mg/l) of suspended sediment. No adverse effects on biota of these low doses.	SEV Index >4.5 and ≤ 7.5 Occasional episodes (days) of low to moderate concentrations (<500 mg/L), though very short duration episodes (hours) may occur with of higher concentrations (500 to 1000). These concentrations are always sublethal to juvenile and adult salmonids-though some behavioral modification may occur.	SEV Index >7.5 and ≤ 10.5 Occasional episodes of moderate to relatively high concentrations (>500 and <1000 mg/L), though shorter duration episodes (<1 week) may occur with higher concentrations (1000-5000 mg/L). The higher concentrations stated can be expected to result in major behavioral modification, severe stress, severely reduced forage success and direct mortality.	SEV Index >10.5 and ≤ 12.5 On-going or occasional episodes (periodic events annually lasting weeks at a time) of high concentrations of suspended sediment (>5000 and <10000 mg/L), or shorter duration episodes lasting hours or days of higher concentrations. These conditions result in direct, high mortality rates.	SEV Index >12.5 Extended periods (month) of very high concentrations (>10000 mg/L). These represent the most extreme severe conditions encountered and result in very high mortality of fish species.

Appendix Table D-1 continued. Level 2 Environmental Attributes and associated rating definitions.

Code	Attribute	Definition	Index Value 0	Index Value 1	Index Value 2	Index Value 3	Index Value 4
Wdrwl	Water withdrawals	The number and relative size of water withdrawals in the stream reach.	No withdrawals.	Very minor water withdrawals with or without screening (entrainment probability considered very low).	Several of significant water withdrawals along reach though all sites known or believed to be screened with effective screening devices. (Note: one site that withdraws substantial portion of flow without screening falls into this category.)	Several sites of significant water withdrawals along reach without screening or screening believed to be ineffective. (Note: one site that withdraws substantial portion of flow without screening falls into this category.)	Frequent sites of significant water withdrawals along reach without screening or screening believed to be ineffective.
WdDeb	Wood	The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.	A complex mixture of single large pieces and accumulations consisting of all sizes, decay classes, and species origins; cross-channel jams are present where appropriate vegetation and channel conditions facilitate their existence; large wood pieces are a dominant influence on channel diversity (e.g., pools, gravel bars, and mid-channel islands) where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 3-10 pieces/CW, 25-50 ft -- 3-10 pieces/CW, 50-150 ft -- 7-30 pieces/CW, 150-400 ft -- 20-50 pieces/CW in conjunction with large jams in areas where accumulations might occur, >400 ft -- 15-37 pieces/CW in conjunction with large jams in areas where accumulations might occur.	Complex array of large wood pieces but fewer cross channel bars and fewer pieces of sound large wood due to less recruitment than index level 1; influences of large wood and jams are a prevalent influence on channel morphology where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 2-3 pieces/CW, 25-50 ft -- 2-4 pieces/CW, 50-150 ft -- 3-7 pieces/CW, 150-400 ft -- 10-20 pieces/CW (excluding large jams) in conjunction with large jams in areas where accumulations might occur, >400 ft -- 8-15 pieces/CW (excluding large jams) in conjunction with large jams in areas where accumulations might occur.	Few pieces of large wood and their lengths are reduced and decay classes older due to less recruitment than in index level 1; small debris jams poorly anchored in place; large wood habitat and channel features of large wood origin are uncommon where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 1-2 pieces/CW, 25-50 ft -- 1-2 pieces/CW, 50-150 ft -- 1-3 pieces/CW, 150-400 ft -- 10-20 pieces/CW without large jams in areas where accumulations might occur, >400 ft -- 8-15 pieces/CW without large jams in areas where accumulations might occur.	Large pieces of wood rare and the natural function of wood pieces limited due to diminished quantities, sizes, decay classes and the capacity of the riparian streambank vegetation to retain pieces where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 0.33-1 pieces/CW, 25-50 ft -- 0.33-1 pieces/CW, 50-150 ft -- 0.33-1 pieces/CW, 150-400 ft -- 3-10 pieces/CW without large jams in areas where accumulations might occur, >400 ft -- 2-8 pieces/CW without large jams in areas where accumulations might occur.	Pieces of LWD rare. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- <0.33 pieces/CW, 25-50 ft -- <0.33 pieces/CW, 50-150 ft -- <0.33 pieces/CW, 150-400 ft -- <3 pieces/CW with accumulations where they might occur, >400 ft -- <2 pieces/CW with no accumulations where they might occur.

Appendix E

Level 3 Survival Factors

Appendix Table E-1. Level 3 Survival Factors.

Factor	Definition
Channel stability	The effect of stream channel stability (within reach) on the relative survival or performance of the focus species; the extent of channel stability is with respect to its streambed, banks, and its channel shape and location.
Chemicals	The effect of toxic substances or toxic conditions on the relative survival or performance of the focus species. Substances include chemicals and heavy metals. Toxic conditions include low pH.
Competition (with hatchery fish)	The effect of competition with hatchery produced animals on the relative survival or performance of the focus species; competition might be for food or space within the stream reach.
Competition (with other species)	The effect of competition with other species on the relative survival or performance of the focus species; competition might be for food or space.
Flow	The effect of the amount of stream flow, or the pattern and extent of flow fluctuations, within the stream reach on the relative survival or performance of the focus species. Effects of flow reductions or dewatering due to water withdrawals are to be included as part of this attribute.
Food	The effect of the amount, diversity, and availability of food that can support the focus species on the its relative survival or performance.
Habitat diversity	The effect of the extent of habitat complexity within a stream reach on the relative survival or performance of the focus species.
Harassment	The effect of harassment, poaching, or non-directed harvest (i.e., as can occur through hook and release) on the relative survival or performance of the focus species.
Key habitat	The relative quantity of the primary habitat type(s) utilized by the focus species during a life stage; quantity is expressed as percent of wetted surface area of the stream channel.
Obstructions	The effect of physical structures impeding movement of the focus species on its relative survival or performance within a stream reach; structures include dams and waterfalls.
Oxygen	The effect of the concentration of dissolved oxygen within the stream reach on the relative survival or performance of the focus species.
Pathogens	The effect of pathogens within the stream reach on the relative survival or performance of the focus species. The life stage when infection occurs is when this effect is accounted for.
Predation	The effect of the relative abundance of predator species on the relative survival or performance of the focus species.
Sediment load	The effect of the amount of the amount of fine sediment present in, or passing through, the stream reach on the relative survival or performance of the focus species.
Temperature	The effect of water temperature with the stream reach on the relative survival or performance of the focus species.
Withdrawals (or entrainment)	The effect of entrainment (or injury by screens) at water withdrawal structures within the stream reach on the relative survival or performance of the focus species. This effect does not include dewatering due to water withdrawals, which is covered by the flow attribute.

Appendix F

**Associations used in translating Level 2 Environmental Attribute
values to Level 3 Survival Factor values through
rule sets for chinook salmon**

Appendix Table F-1. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
Spawning	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - Intra daily (diel) variation						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Small cobble/gravel riffles	Pool tailouts	Glides				
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	no effects						
Incubation	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals/Pollutants - in sediments/soils	Metals - in water column				

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - Intra daily (diel) variation						
	Food	no effects						
	Habitat diversity	No effect						
	Harassment	Harassment						
	Key Habitat	Small cobble/gravel riffles	Pool tailouts	Glides				
	Obstructions	No effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	No effect						
	Sediment load	Fine sediment						
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	No effects						
Fry colonization	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effects						
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow - change in intra-annual variability (flow flashiness)	Riparian function	Wood

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood	Icing	
	Harassment	no effects						
	Key Habitat	Backwater pools	Beaver ponds	Primary pools	Pool tailouts	Glides	Small cobble/gravel riffles	Large cobble riffles
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Embeddedness					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age resident rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - changes in interannual variability in low flows	Embeddedness	Habitat type - backwater pools	Habitat type - beaver ponds	Habitat type - primary pools	Confinement - natural	Confinement - Hydromodifications
	Flow (continued)		Riparian function	Wood				
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Primary pools	Backwater pools	Glides	Pool tailouts	Beaver ponds	Large cobble riffles	Off-channel habitat (just coho)
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age transient rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - changes in interannual variability in low flows	Embeddedness	Habitat type - backwater pools	Habitat type - beaver ponds	Habitat type - primary pools	Confinement - natural	Confinement - Hydromodifications
	Flow (continued)		Riparian function	Wood				
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Key Habitat	Primary pools	Backwater pools	Glides	Pool tailouts	Beaver ponds	Large cobble riffles	
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	no effects						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	no effects						
	Key Habitat	<all habitat types applied equally>						
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age Inactive	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow - change in intra-annual variability (flow flashiness)	Riparian function	Wood
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment						
	Key Habitat	Primary pools	Backwater pools	Beaver ponds	Glides	Large cobble riffles just chinook		
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily minimum (by	Hatchery fish outplants		

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
					month)			
	Sediment load	Embeddedness	Turbidity (susp. sed.)					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
1-age resident rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow - change in intra-annual variability (flow flashiness)	Riparian function	Wood
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Primary pools	Backwater pools	Glides	Pool tailouts	Beaver ponds	Large cobble riffles	
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
1-age migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	no effects						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	no effects						
	Key Habitat	<all habitat types applied equally>						
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
Prespawning migrant	Channel stability	no effects						

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - changes in interannual variability in low flows						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - Hydromodifications	Riparian function	Wood			
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	KeyHabitat	<all habitat types applied equally>						
	Obstructions	Obstructions to fish migration ²						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	no effects						
Prespawning holding	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						

Appendix Table F-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for chinook salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Competition (with other species)	no effects						
	Flow	Flow - changes in interannual variability in low flows	Embeddedness	Habitat type - backwater pools	Habitat type - beaver ponds	Habitat type - primary pools	Confinement - natural	Confinement - Hydromodifications
	Flow (continued)		Riparian function	Wood				
	Food	no effects						
	Habitat diversity	Gradient	Confinement - Hydromodifications	Riparian function	Wood			
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Primary pools	Glides	Large cobble riffles				
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	no effects						

Appendix G

**Associations used in translating Level 2 Environmental Attribute
values to Level 3 Survival Factor values through
rule sets for coho salmon**

Appendix Table G-1. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
Spawning	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - Intra daily (diel) variation						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Small cobble/gravel riffles	Pool tailouts	Glides				
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	no effects						
Incubation	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals/Pollutants - in sediments/soils	Metals - in water column				

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - Intra daily (diel) variation						
	Food	no effects						
	Harassment	Harassment						
	Key Habitat	Small cobble/gravel riffles	Pool tailouts	Glides				
	Obstructions	No effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Sediment load	Fine sediment						
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	No effects						
Fry colonization	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effects						
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow - change in intra-annual variability (flow flashiness)	Riparian function	Wood
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood	Icing	

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Harassment	no effects						
	Key Habitat	Backwater pools	Beaver ponds	Primary pools	Pool tailouts	Glides	Small cobble/gravel riffles	Large cobble riffles
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Embeddedness					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age resident rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - changes in interannual variability in low flows	Embeddedness	Habitat type - backwater pools	Habitat type - beaver ponds	Habitat type - primary pools	Confinement - natural	Confinement - Hydromodifications
	Flow (continued)		Riparian function	Wood				
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Primary pools	Backwater pools	Glides	Pool tailouts	Beaver ponds	Large cobble riffles	Off-channel habitat

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Key Habitat (continued)		Small cobble/gravel riffles					
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	no effects						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	no effects						
	Key Habitat	<all habitat types applied equally>						
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age Inactive	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow - change in intra-annual variability (flow flashiness)	Riparian function	Wood
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment						
	Key Habitat	Primary pools	Backwater pools	Beaver ponds	Glides	Off-channel habitat		
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily minimum (by	Hatchery fish outplants		

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
					month)			
	Sediment load	Embeddedness	Turbidity (susp. sed.)					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
1-age resident rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow - change in intra-annual variability (flow flashiness)	Riparian function	Wood
	Food	Alkalinity	Salmon Carcasses	Benthos diversity and production	Riparian function			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Primary pools	Backwater pools	Glides	Pool tailouts	Beaver ponds	Large cobble riffles	Small cobble/gravel riffles
	Key Habitat (continued)		Off-channel habitat					
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by					

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
			month)					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
1-age migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	no effects						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	no effects						
	Key Habitat	<all habitat types applied equally>						
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
Prespawning migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - changes in interannual variability in low flows						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - Hydromodifications	Riparian function	Wood			
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	KeyHabitat	<all habitat types applied equally>						
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	no effects						
Prespawning holding	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				

Appendix Table G-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for coho salmon.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	Flow - changes in interannual variability in low flows	Embeddedness	Habitat type - backwater pools	Habitat type - beaver ponds	Habitat type - primary pools	Confinement - natural	Confinement - Hydromodifications
	Flow (continued)		Riparian function	Wood				
	Food	no effects						
	Habitat diversity	Gradient	Confinement - Hydromodifications	Riparian function	Wood			
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	Key Habitat	Primary pools	Glides	Large cobble riffles				
	Obstructions	no effects						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	no effects						

Appendix H

**Associations used in translating Level 2 Environmental Attribute
values to Level 3 Survival Factor values through
rule sets for steelhead**

Appendix Table H-1. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
Spawning	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	Flow - Intra daily (diel) variation						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	KeyHabitat	Habitat type- small cobble/gravel riffles	Habitat type- pool tailouts	Habitat type-glides				
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
Incubation	Channel stability	Bed scour	Icing	Riparian function	Wood	Confinement - Hydromodifications	Flow - change in interannual variability in high flows	Flow - intra-annual flow pattern
	Chemicals	Miscellaneous toxic pollutants - water	Metals/Pollutants - in sediments/soils	Metals - in water column				

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
		column						
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	Flow - Intra daily (diel) variation	Flow - change in interannual variability in low flows					
	Food	no effects						
	Habitat diversity	No effect						
	Harassment	Harassment						
	KeyHabitat	Habitat type- small cobble/gravel riffles	Habitat type- glides	Habitat types- pool tailouts				
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	No effect						
	Sediment load	Fine sediment						
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
Fry colonization	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow - intra-annual flow pattern	Riparian function	Wood
	Food	Alkalinity	Benthos diversity	Riparian function	Salmon Carcasses			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood	Icing	
	Harassment	no effects						
	KeyHabitat	Habitat type- backwater pools	Habitat type- beaver ponds	Habitat type- large cobble/boulder riffles	Habitat type- primary pools	Habitat type- small cobble/gravel riffle	Habitat type- glides	Habitat type- pool tailouts
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Embeddedness					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age resident rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - changes in interannual variability in low flows	Embeddedness	Riparian function	Wood	Confinement - Hydromodifications	Confinement - natural	Confinement - Hydromodifications

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Food	Alkalinity	Benthos Diversity	Riparian function	Salmon Carcasses			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	KeyHabitat	All habitat types incorporated						
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	No effect						
	Food	no effects						
	Habitat diversity	Riparian function	Confinement - natural	Confinement - Hydromodifications	Wood			
	Harassment	No effect						

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Key Habitat	Habitat type- backwater pools	Habitat type- beaver ponds	Habitat type- glides	Habitat type-large cobble/boulder riffles	Habitat type- pool tailouts	Habitat type- primary pools	Habitat type- small cobble/gravel riffles
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
0-age Inactive	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow-intra-annual flow pattern	Riparian function	Wood
	Food	Benthos diversity and production	Alkalinity	Riparian function	Salmon Carcasses			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood	Icing	
	Harassment	Harassment						
	KeyHabitat	All habitat types incorporated						
	Obstructions	Obstructions to fish migration						

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily minimum (by month)	Hatchery fish outplants		
	Sediment load	Embeddedness	Turbidity (susp. sed.)					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
1-age resident rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity and production	Riparian function	Salmon Carcasses		
	Flow	Flow - change in interannual variability in high flows	Confinement - natural	Confinement - Hydromodifications	Gradient	Flow- intra-annual flow pattern	Riparian function	Wood
	Food	Alkalinity	Benthos diversity	Riparian function	Salmon Carcasses			
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood	Icing	
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	KeyHabitat	All habitat types incorporated						
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
1-age migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	no effects						
	Competition (with other species)	no effects						
	Flow	no effects						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood	Icing	
	Harassment	Harassment						
	KeyHabitat	Habitat type- backwater pools	Habitat type- beaver ponds	Habitat type- glides	Habitat type- large cobble/boulder riffles	Habitat type-pool tailouts	Habitat type- primary pools	Habitat type- small cobble/gravel riffles
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature - daily maximum (by month)	Hatchery fish outplants		
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Temperature	Temperature - daily minimum (by month)	Temperature - spatial variation					
	Withdrawals	Water withdrawals						
1-age inactive	Channel stability	Bed Scour	Icing	Riparian Function	Wood			
	Chemicals	Misc toxic pollutants- water column	Metals/Pollutants- in sediments/soils	Metals- in water column				
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	Flow- change in interannual variability in high flows	Confinement-Hydromodifications	Confinement-natural	Gradient	Flow- intra-annual flow pattern	Riparian function	Wood
	Food	Alkalinity	Salmon Carcasses	Benthos diversity	Riparian function			
	Habitat diversity	Gradient	Confinement-Hydromodifications	Confinement-natural	Riparian Function	Wood		
	Harassment	No effect						
	KeyHabitat							
	Obstructions							
	Oxygen	Dissolved Oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature- daily Max (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature- daily Min (by month)	Hatchery fish outplants		
	Sediment load	Embeddedness	Turbidity					
	Temperature	Temperature- daily Min (by month)	Temperature-spatial variation					
	Withdrawals	Water withdrawals						

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
2+ age resident rearing	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Misc toxic pollutants- water column	Metals/Pollutants- in sediments/soils	Metals- in water column				
	Competition (with hatchery fish)	Hatchery fish outplants	Alkalinity	Benthos diversity	Riparian function	Salmon Carcasses		
	Competition (with other species)	Fish community richness	Alkalinity	Benthos diversity	Riparian function	Salmon Carcasses		
	Flow	Flow- change in interannual variability in high flows	Confinement- Hydromodifications	Confinement- natural	Gradient	Flow- intra-annual flow pattern	Riparian function	Wood
	Food	Alkalinity	Salmon Carcasses	Benthos diversity	Riparian function			
	Habitat diversity	Gradient	Confinement- Hydromodifications	Confinement- natural	Riparian function	Wood		
	Harassment	Harassment	Habitat type- primary pools	Riparian function	Turbidity	Wood		
	KeyHabitat							
	Obstructions							
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature- daily Max (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature- daily Max (by month)			
	Sediment load	Turbidity	Temperature- daily Max (by month)					
	Temperature	Temperature- daily Max (by month)	Temperature- daily Min (by month)	Temperature- spatial variation				
	Withdrawals	Water withdrawals						
2+ age migrant	Channel stability	No effect						
	Chemicals	Misc toxic pollutants- water column	Metals/Pollutants- in sediments/soils	Metals- in water column				

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	No effect						
	Food	No effect						
	Habitat diversity	Riparian function	Confinement-Hydromodifications	Confinement-natural	Wood			
	Harassment	No effect						
	Key Habitat	Habitat type-backwater pools	Habitat type-beaver ponds	Habitat type- glides	Habitat type- large cobble/boulder riffles	Habitat type- pool tailouts	Habitat type- primary pools	Habitat type- small cobble/gravel riffles
	Obstructions							
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature- daily Max (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature- daily Max (by month)	Hatchery fish outplants		
	Sediment load	Turbidity	Temperature- daily Max (by month)					
	Temperature	Temperature- daily Max (by month)	Temperature-spatial variation					
	Withdrawals	Water withdrawals						
2+ age inactive	Channel stability	Bed scour	Icing	Riparian function	Wood			
	Chemicals	Misc toxic pollutants- water column	Metals/Pollutants- in sediments/soils	Metals- in water column				
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	Flow- change in interannual variability in high	Confinement-Hydromodifications	Confinement-natural	Gradient	Flow- intra-annual flow pattern	Riparian function	Wood

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
		flows						
	Food	Alkalinity	Salmon Carcasses	Benthos diversity	Riparian function			
	Habitat diversity	Gradient	Confinement-Hydromodifications	Confinement-natural	Riparian function	Wood		
	Harassment	No effect						
	KeyHabitat							
	Obstructions							
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature- daily Max (by month)	Nutrient enrichment			
	Predation	Predation risk	Fish community richness	Fish species introductions	Temperature- daily Min (by month)	Hatchery fish outplants		
	Sediment load	Embeddedness	Turbidity					
	Temperature	Temperature- daily Min (by month)	Temperature-spatial variation					
	Withdrawals	Water withdrawals						
Prespawning migrant	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effect						
	Competition (with other species)	No effect						
	Flow	Flow - changes in interannual variability in low flows						
	Food	no effects						
	Habitat diversity	Gradient	Confinement - natural	Confinement - Hydromodifications	Riparian function	Wood		

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	KeyHabitat	Habitat type-backwater pools	Habitat type-beaver ponds	Habitat type- glides	Habitat type- large cobble/boulder riffles	Habitat type- pool tailouts	Habitat type-primary pools	Habitat type-small cobble/gravel riffles
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	No effects						
Prespawning holding	Channel stability	no effects						
	Chemicals	Miscellaneous toxic pollutants - water column	Metals - in water column	Metals/Pollutants - in sediments/soils				
	Competition (with hatchery fish)	No effects						
	Competition (with other species)	No effects						
	Flow	Flow - changes in interannual variability in low flows	Embeddedness	Habitat type - backwater pools	Habitat type - beaver ponds	Habitat type - primary pools	Confinement - natural	Confinement - Hydromodifications
	Flow (cont)		Riparian function	Wood				
	Food	no effects						
	Habitat diversity	Gradient	Confinement - Hydromodifications	Riparian function	Wood			

Appendix Table H-1 continued. Associations used in translating Level 2 Environmental Attribute values to Level 3 Survival Factor values through rule sets for steelhead trout.

Life stage	Level 3 Survival Factor	Level 2 Environmental Attribute						
		Primary	Modifying	Modifying	Modifying	Modifying	Modifying	Modifying
	Harassment	Harassment	Habitat type - primary pools	Riparian function	Turbidity (susp. sed.)	Wood		
	KeyHabitat	Habitat type- primary pools	Habitat type- glides	Habitat type- large cobble/boulder riffles				
	Obstructions	Obstructions to fish migration						
	Oxygen	Dissolved oxygen						
	Pathogens	Fish pathogens	Fish species introductions	Temperature - daily maximum (by month)	Nutrient enrichment			
	Predation	Predation risk						
	Sediment load	Turbidity (susp. sed.)	Temperature - daily maximum (by month)					
	Temperature	Temperature - daily maximum (by month)	Temperature - spatial variation					
	Withdrawals	No effect						

Literature Cited in Appendices

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