APPENDIX B-2

Rules for Translating
Level 2 Environmental Attribute Values
To
Level 3 Biometrics for Chinook Salmon

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Introduction

This document is an appendix to the report entitled "Columbia River Multi-Species Framework Project Coarse Screening Analysis—Progress Report" Although it can be treated as a stand-alone document for the sake of reviewing the rules presented here, the reader will better understand its conceptual basis and application if it is used as a supplement to the main report.

This document presents the rules used to translate Level 2 Environmental Attribute values into Level 3 Biological Performance Attribute values (biometrics) for chinook salmon. We applied these rules in the EDT analysis of Columbia River chinook presented in the main report. We are currently developing comparable rule sets for bull trout, steelhead trout, coho salmon, and chum salmon. A similar process has been applied for analyzing performance measures for selected species of wildlife in the Columbia Basin.

The rules have been developed for use within the Multi-Species Framework, which provides a structure for relating the performance of different species to the environmental (or ecological) conditions in which they live. Data and information used in the Framework are organized through the Ecological Information Structure (Figure 1). The purpose of the Information Structure is to identify and organize hypotheses—or assumptions—about the environment, key ecological functions, and biological performance for the species being analyzed. It serves to document the rationale for how well management actions are expected to move the ecosystem closer to achieving the vision (goals) for the basin. EDT is an analytical method that emphasizes the need for having explicit operating hypotheses on which to base management decisions.

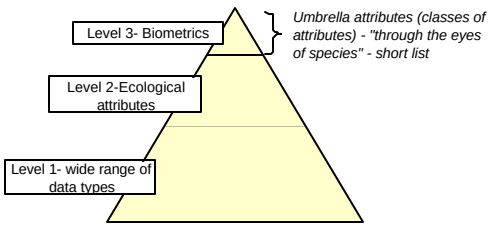

Figure 2.

The Information Structure and associated data categories are defined at three levels of organization (Figures 1). Levels 1 and 2 together characterize the environment, or ecosystem, as it can be described by data of different types. It is assumed that this characterization provides all of the necessary information about the environment needed to analyze biological performance as a consequence of the effects of environment. The Level 3 category is also a characterization of the environment, but “through the eyes of the species” being analyzed. This category describes biological performance in relation to the state of the ecosystem described by the Level 2 Environmental Attributes. Together, the three levels of data/information can be thought of as a data pyramid, with Levels 2 and 3 built upon their next lower level (Figure 2).

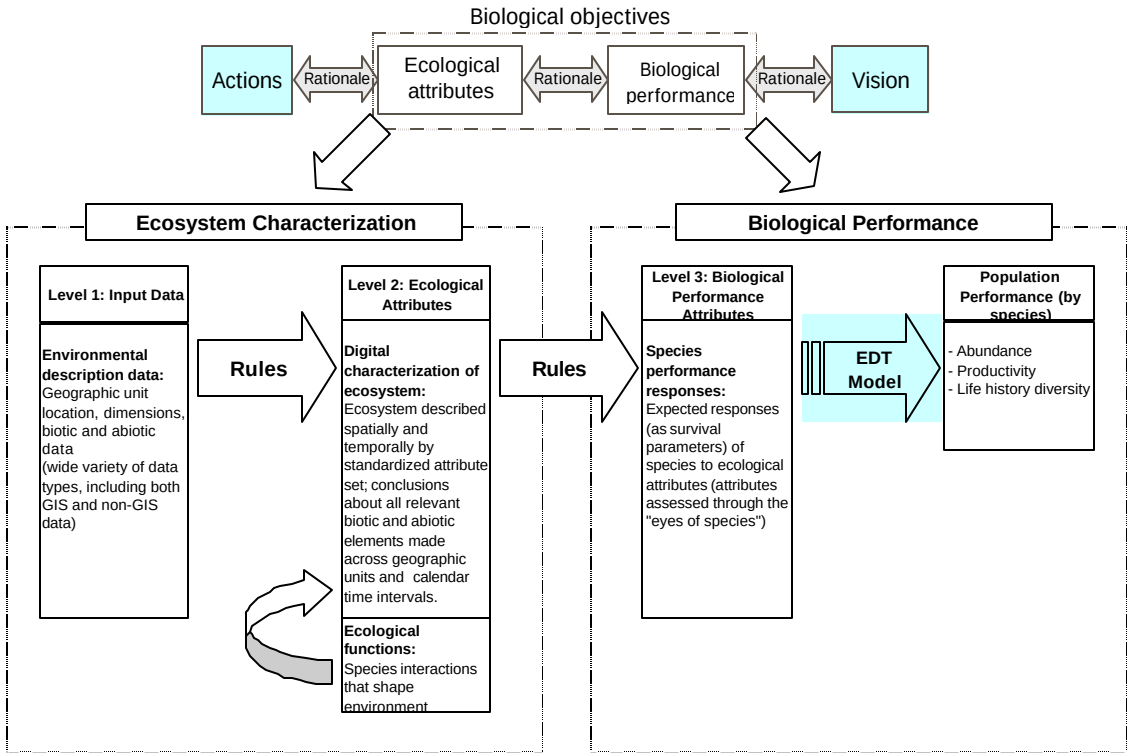

Figure 1. Ecological Information Structure.

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The Information Structure provides a way of summarizing and synthesizing a wide range of environmental input data (referred to as Level 1 input data) into a standardized set of environmental attributes (Table 1). These attributes, called Level 2 Environmental Attributes, represent a sort of digital characterization of the ecosystem. They describe the condition of the environment (both abiotic and biotic elements) encountered by various species. In concept, a set of Level 2 Environmental attributes can be described for analyzing any species.

The rules presented in this document are used to translate this characterization of the ecosystem expressed in the Level 2 attributes into survival-related performance measures for a single species, chinook salmon. They describe our assumptions about how environmental conditions affect these performance measures, or biometrics, for chinook salmon. These biometrics are also defined through a set of attributes, called Biological Performance Attributes (Table 3), which act as sort of "umbrella attributes" that group similar Level 2 environmental attributes together. In this case, however, the Biological Performance Attributes are assessed "through the eyes of the species" and define species sensitivity to one or more Level 2 Environmental Attributes. Level 3 biometrics are life-stage specific for the species of interest; chinook salmon life stages are defined in Table 3.

At this time, we have only developed rules for relating environmental conditions to chinook performance within freshwater. Consequently, Level 2 Environmental Attributes have only been defined to date for freshwater environments only, not for estuarine or marine environments. Interest exists among different entities to undertake a similar process for developing attributes and rules for estuarine and marine environments but to date no effort to do so has been initiated.

The rules presented here should be considered provisional—they are currently under review and refinements are expected. Moreover, we believe the rules should periodically be reviewed and refined through an on-going process as new information or understanding becomes available. We suggest that some type of formal process be established for this purpose. We think the rules should be a primary focus of attention by scientists with different expertise, providing the region with a common "state-of-understanding" about the effects of different attributes on species survival by life stage. Uncertainty about the rules will always exist to some extent, but when described it can help identify research needs, particularly for those attributes found to be most critical to species performance in the region.

The main body of this document is organized into two parts following the Introduction. Part I, "Rule Derivation, Structure and Presentation Format", describes how the rules were derived and structured, along with an explanation of the format for presentation. Part II provides the rules.

Four appendices are included to this document. Appendix 1 gives a description of the Level 2 Environmental Attributes. Each of the 45 attributes is defined and described with regard to its ecological role, some of the factors affecting its condition, and its general importance to salmonid fishes of the Pacific Northwest. This material will be helpful to individuals reviewing the Level 2 attribute values and for gaining an understanding of the role of these attributes within the rules. Also, the material will be useful in the process of updating Level 2 information through the **Assessment Review** that the Northwest Power Planning Council is initiating in mid 2000.

Appendices 2-4 consist of tables referenced in the section "Rule Derivation, Structure and Presentation Format."

Table 1. Level 2 Environmental Attributes. All attributes except length can be treated as categorical.

Name	Definition
Alkalinity	Alkalinity of water (conductivity can be used as a surrogate) (at moderate flows)
Bed scour	Average depth and frequency of scour on small-cobble/gravel riffles during high flow events. Frequent indicates at least one event every 1-2 years. 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 7 inch diameter), large cobble (7 to 11.9 inch diameter), boulder (>11.9 inch diameter).
Benthos diversity and production	Measure of the diversity and production of the benthos community.
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.
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.
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.
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.
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.
Dissolved oxygen	Average dissolved oxygen within the water column for the specified time interval.
Embeddedness	The extent that larger cobbles or gravel are surrounded by or covered by fine sediment.
Fine sediment	Percentage of fine sediment within pool-tailouts and riffles.
Fish community richness	Measure of the richness of the fish community (no. of fish taxa).

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Name	Definition
Fish pathogens	The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.
Fish species introductions	Extent of introductions of exotic fish species in the vicinity of the stream reaches under consideration.
Flow - change in interannual variability in high flows	A measure of between year variation in magnitude of high flow levels and/or the extent of change in overall high flow level during a month relative to an undisturbed watershed of comparable size, geology, and geography (or as would have existed in the pristine state).
Flow - changes in interannual variability in low flows	A measure of between year variation in the severity of low flow discharge during a month. Variation in low flows as applied here is relative to an undisturbed watershed of comparable size, geology, and geography (or as would have existed in the pristine state).
Flow - Intra daily (diel) variation	Varibility in flow level during a daily period. This attribute is informative mainly for regulated rivers or when flow patterns are influenced by storm water runoff.
Flow - intra-annual flow pattern	The average extent of intra-annual flow variation during a month -- a measure of a stream's "flashiness" during a season.
Gradient	Average gradient of the main channel of the reach over its entire length.
Habitat type - backwater pools	Percentage of the wetted channel surface area comprising backwater pools.
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.
Habitat type - large cobble/boulder riffles	Percentage of the wetted channel surface area comprising large cobble/boulder riffles.
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.
Habitat type - pool tailouts/glides	Percentage of the wetted channel surface area comprising pool tailouts and glides.
Habitat type - primary pools	Percentage of the wetted channel surface area comprising pools, excluding beaver ponds.
Habitat type - small cobble/gravel riffles	Percentage of the wetted channel surface area comprising small cobble/gravel riffles.
Harassment	The relative extent of poaching and/or harassment of fish within the stream reach.
Hatchery fish outplants	The magnitude of hatchery fish outplants made into the drainage over the past 10 years.
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.
Hydrologic regime - regulated	The change in the natural hydrograph caused by the operation of hydroelectric facilities in a watershed. Definition does not take into

Name	Definition
	account daily flow fluctuations (See Flow-Intra-daily Variation attribute)
Icing	Extent (magnitufe and frequency) of icing events.
Metals - in water column	The extent of dissolved heavy metals within the water column.
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.
Miscellaneous toxic pollutants - water column	The extent of miscellaneous toxic pollantants (other than heavy metals) within the water column.
Nutrient enrichment	The amount of nutrient enrichment consisting of such items as ammonia, nitrogen, phosphorous.
Obstructions to fish migration	Obstructions to fish passage by physical barriers (not dewatered channels or hinderances to migration caused by pollutants or lack of oxygen).
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).
Riparian function	A measure of riparian function that has been altered within the reach.
Salmon Carcasses	Relative abundance of andromous salmonid carcasses within watershed (e.g., HUC 5 level) that can serve as nutrient sources for juvenile salmonid production.
Temperature - daily maximum (by month)	Maximum water temperatures within the stream reach reach during a month.
Temperature - daily minimum (by month)	Minimum water temperatures within the stream reach reach during a month.
Temperature - spatial variation	The extent of water temperature variation within the reach as influenced by inputs of groundwater.
Turbidity	The relative extent of turbidity episodes within the stream reach.
Water withdrawals	The number and relative size of water withdrawals in the stream reach.
Wood	The amount of wood within the reach. Note definition of "large wood" under terms/clarification.

Table 2. Level 3 Biological Performance Attributes (biometrics). The measure of these attributes is in relation to the relative survival or performance of the focus species by life stage. These attributes act as "umbrella attributes", combining the effects of similar Level 2 attributes on the species. Effects measured by these attributes are assessed relative to fully fit individuals when present in optimal environmental conditions.

Attribute	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 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 predators species on the relative survival or performance of the focus species, apart from

Attribute	Definition
	the influence of the amount of cover habitat used by the focus species.
Salinity	The effect of the concentration of salts within the reach 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 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.

Table 3. Chinook salmon life stages for analyzing the biological performance of the species. Only life stages relevant to freshwater are shown.

Attribute	Definition
Spawning	Period of active spawning, beginning when fsh move on to spawning beds and initiate redd digging and ending when gametes are released.
Egg incubation	Egg incubation and alevin development; stage begins at the moment of the release of gametes by spawners and ends at fry emergence.
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 (note: this behavior typifies the pattern of feeding/rearing by spring chinook in headwater stream reaches).
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 (note: fish displaying strong smolt characteristics typify this life stage).
Inactive	Largely inactive or semi-dormant fish age 0 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 (note: fish displaying strong smolt characteristics typify this life stage).
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.

Part I - Rule Derivation, Structure and Presentation Format

The purpose of the rules presented here is to translate Level 2 Environmental Attribute values into survival-related performance measures for chinook salmon. The rules are assumptions about how environmental conditions affect these performance measures.

The rules are based on an extensive set of "translation examples" put together by Chris Frissell, with further input obtained from the BioRules Work Group.[1] We reformatted the information from these data sets into the rule sets applied here for chinook salmon, taking into account refinements made through the process in definitions and index values of the Level 2 Environmental Attributes. The rules should be considered as still in a state of development and refinement; further review of the rules will help ensure their adequacy and consistency with up-to-date thinking and research.

The survival-related performance measures, or biometrics, derived by the rules are defined through the Level 3 Biological Performance Attributes. These attributes act as sort of "umbrella attributes" that group similar Level 2 Environmental Attributes together, serving to explicitly define the sensitivity of the species to one or more of the Level 2 attributes through each Level 3 attribute. Whereas 45 Level 2 Environmental Attributes are used to characterize the environment (Table 1), 17 Level 3 Performance Attributes are used in defining biological response to the environment (Table 2).

The Level 3 biometrics are life-stage specific. Therefore, we formulated a rule set for each Level 3 Performance Attribute, one rule for each life stage. With eleven life stages applicable to chinook salmon in freshwater (Table 3), a total of 176 rules are presented (note: rules were not formulated for the Level 3 attribute Salinity, as they were not needed for the current analysis of the freshwater environment[2]). Rules are presented in alphabetical order for Level 3 attributes following this narrative.

The rules fall into two classes, each requiring a different format for presentation. The first class consists of those that address environmental ***quality*** attributes. These attributes directly affect the *productivity* of a population. The second class consists of rules that determine the Level 3 attribute Key Habitat, a measure of habitat ***quantity*** used by the species of interest. This attribute operates in concert with environmental quality attributes to affect the *capacity* of the environment for the species. We describe rule structure and presentation format for each rule class in the following two sections.

Rules for Environmental Quality Attributes

The rules for deriving Level 3 biometrics for attributes associated with environmental quality produce estimates of *relative survival* for a life stage. Life stage relative survival is the proportion of the survival that we assume would occur when environmental quality conditions are optimal for survival over an entire life stage. Thus a relative survival value of 1.0 would be

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[1] The BioRules Work Group consisted of Bob Bilby, Pete Bisson, Chris Frissell, Larry Lestelle, and Dale McCullough.
[2] As noted in the Introduction, rules presented here address the freshwater environment only.

expected to produce the highest (on average) survival that could occur during the life stage having a sterotypical duration for that life stage. In this case, the actual survival for the life stage would be equivalent to what we call the *benchmark survival*.[3] The estimated survival for a life stage, therefore, is simply the product of relative survival and benchmark survival.

The rules are structured in a way to identify the contributions of various Level 2 Environmental Attributes to reducing relative survival from a value of 1.0. More simply, the rules define the *assumed* extent that various Level 2 attributes prevent environmental conditions from being considered optimal for survival.

Each Level 2 Environmental Attribute is indexed to a set of values from 0 to 4, where the range of index values span a spectrum of environmental conditions (see example below for intra-gravel fine sediment). Conditions associated with index values for Level 2 Environmental Attributes are described in Appendix 2. The indexing system allows for both continuous or integer values for the attributes. Integer values were assumed to represent the midpoint of conditions for attributes having a range of conditions associated with one value, as in the sediment example shown.[4]

Example rating definitions for Fine Sediment (intra-gravel fine sediment within pool-tailouts and riffles)

Value	*Value definition*
0	<6% fines <0.85 mm particle size
1	>6% and <11% fines <0.85 mm particle size
2	>11% and <18% fines <0.85 mm particle size
3	>11% and <30% fines <0.85 mm particle size
4	>30% fines <0.85 mm particle size

Generally, there is a consistent direction to attribute values, where 0 or low values are often associated with pristine conditions, and higher values tend to occur under managed conditions. This pattern varies for a few attributes, especially those describing stream flow conditions. In this case, a rule often employed a "reset" of the index values in order to create a direction to the values, where low values would tend to represent conditions prior to watershed development.

The rules were formulated by first identifying the specific Level 2 Environmental Attributes that could strongly, moderately, or weakly cause the Level 3 biometric (relative survival) to be reduced below the optimal environmental condition for survival. These Level 2 attributes are referred to as the Primary, Secondary, and Tertiary environmental attributes affecting biological performance, respectively. In all cases, we defined only one Primary Level 2 Environmental Attribute as affecting a single Level 3 Performance Attribute. The Secondary and Tertiary Level 2 attributes were treated as modifiers to the effect of the Primary attribute. More than one

[3] Benchmark survivals are discussed in more detail in _____.
[4] When generating Level 2 attribute values for the basin, integer values frequently meant that only a broad categorical conclusion could be reached about an environmental attribute, as reflected in the range of values shown for the sediment example. In these cases, the rule would interpret an integer to represent the midpoint.

Secondary and Tertiary Level 2 attributes were applied as assumed relevant. The associations between Level 2 and Level 3 attrributes are identified for each life stage in Appendix 3.

We then defined explicit relationships between each Level 2 Environmental Attribute and the Level 3 Performance Attribute for each attribute association listed in Appendix Table 2, as illustrated in Figure 3. As noted earlier, the relationships are based on "translation examples" put together by Chris Frissell, with additional input obtained from the BioRules Work Group, and finally, they were reformatted into their current form consistent with refinements in attribute definitions.

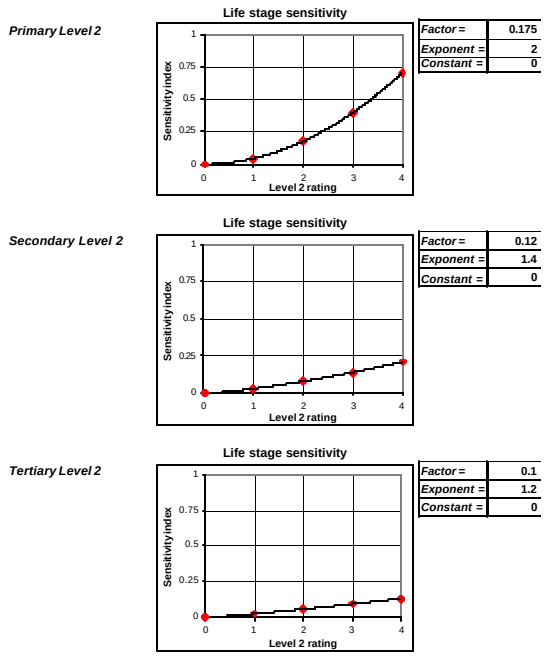

Figure 3. Examples of relationships between Level 2 Environmental Attribute ratings (Primary, Secondary, and Tertiary) and sensitivity indexes for one Level 3 Performance Attribute.

Each relationship used to define sensitivity (*SensitivityIndex*) of a Level 3 attribute to a single Level 2 Environmental Attribute *i* was given the form

$$SensitivityIndex_i = F * \left(\frac{Level2}{4} \right)^E + C$$

where *F* is a factor, *E* is an exponent, *C* is a constant, and *Level2* is the Level 2 Environmental Attribute Index value.

Most relationships were assumed to be strongly curvilinear for Primary Level 2 attributes and some Secondary attributes, having extremely little sensitivity to index values of 1, then rapidly increasing at values >2.

Sensitivity of a Level 3 attribute *j* to all associated Level 2 attributes *i* was then defined by adding the sensitivities for the Primary, Secondary, and Tertiary attributes, and converting the sum to relative survival (*RelSurv*) for the life stage, as seen in the following equation

$$RelSurv_j = 1 - \left(\sum SensitivityIndex_i \right)^{2.7}$$

where the exponent 2.7 is used to shape the function so that low Level 2 attribute index values (e.g., values of 1) added from multiple Level 2 attributes retain a minor effect on relative survival but with rapidly increasing effect as the total sensitivity index increases to higher values. [5]

The foregoing equations produce what might be thought of as *partial* relative survival values because they reflect only the mortality components contributed by each Level 3 Performance Attribute. Relative survival for a life stage *k* due to the combination of all Level 3 Performance Attributes is simply the product of relative survivals associated with each attribute as seen below

$$RelSurv_k = \prod RelSurv_j$$

The parameters that define each relationship were manually selected in order to achieve consistency with the "translation examples" noted above, together with updated information from the BioRules Work Group and literature determined to be relevant. In shaping these relationships, we found it useful to compare estimates that could be derived for actual life stage survival (density-independent survival here) to literature values where applicable. Estimated actual life stage survival is simply the product of the derived relative survival and benchmark survival. Benchmark survival values for chinook salmon used in the analysis are provided in Appendix 4.

The format for the presentation of rules for each Level 3 Performance Attribute is explained in Figure 4. For each rule, the Primary, Secondary, and Tertiary Level 2 Environmental Attributes

[5] We have found that the exponent 2.7 produces results consistent with the "translation examples" noted in the text and with a large body of habitat rating values provided to us in earlier studies.

are clearly labeled, accompanied by a brief rationale. The rationale is assigned a Level of Proof to indicate the relative amount of evidence supporting how the attribute was applied in the rule. Four levels of proof were assigned (Table 4). Each rule is accompanied by four examples of Level 2 ratings to illustrate the effect on relative survival associated with each Level 3 attribute.

Table 4. Levels of proof assigned to the use of Level 2 Environmental Attributes in 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

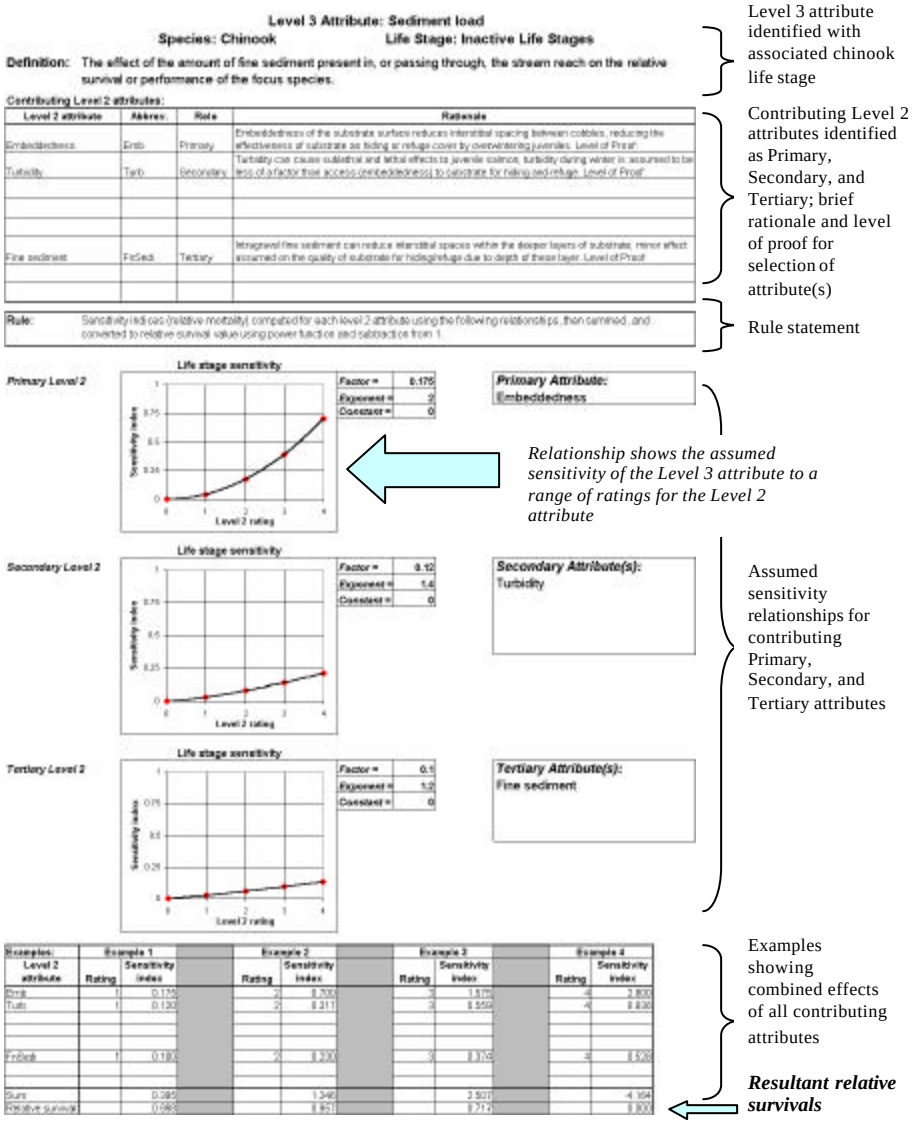

Figure 4. Format for rule presentation for Level 3 Biological Performance Attributes describing environmental quality. An example rule is shown (size reduced for display).

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Rules for Habitat Quantity Attributes

The rules for deriving the Level 3 biometric for habitat quantity produce estimates of the percent of wetted channel surface area comprised of Key Habitat used by the focus species. Key Habitat is defined as the primary habitat type(s) utilized by the focus species during a particular life stage. Preference for habitat types changes with life stages. Some life stages, like egg incubation, occur almost entirely within two habitat types (i.e., pool-tailouts/glides and riffles), while other life stages, like actively migrating fish, use all habitat types. Level 2 Environmental Attributes for habitat types are found in Table 1; habitat type attributes are those beginning with "Habitat Type."

The use of habitat types by individual life stages of chinook salmon is not necessarily "all" or none", 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 were formulated by assigning weights to each habitat type by Chris Frissell and Larry Lestelle to represent relative levels of preference. The weights were assigned based on information contained within relevant literature and personal observation. As with the rules for assessing environmental quality, the weights are assumptions that will require futher refinement.

Percent Key Habitat (*%KeyHab*) for any life stage 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 format for the presentation of rules for the Level 3 Key Habitat attribute is explained in Figure 5. For each rule, the preference weight is shown for each habitat type accompanied by a brief rationale. The rationale is assigned a Level of Proof to indicate the relative amount of evidence supporting the assigned weight. Levels of proof are those listed in Table 4. Each rule is accompanied by three examples showing different combinations of habitat types and resultant estimates of Key Habitat.

Level 3 Attribute: Key Habitat

Species: Chinook **Life Stage: Spawning**

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 six Level 2 Ecological Attributes (see table below) that quantify stream habitat types.

Contributing Level 2 attributes:

Level 2 attribute	Abbrev.	Weight	Rationale
Habitat type - backwater pools	HbBckPls	0.00	Chinook spawning does not occur in backwater pools. Level of Proof:
Habitat type - beaver ponds	HbBvrPnds	0.00	Chinook spawning does not occur in beaver ponds. Level of Proof:
Habitat type - large cobble/boulder riffles	HbLrgCbl	0.00	Substrate size is typically too large for chinook spawning in large cobble/boulder riffles. Level of Proof:
Habitat type - primary pools	HbPls	0.00	Chinook spawning does not typically occur in pools (pool tailouts are included as a separate habitat type). Level of Proof:
Habitat type - small cobble/gravel riffles	HbSmlCbl	0.50	Chinook spawn heavily on riffles with substrate sizes suitable for nest building, as occurs in this habitat type. Level of Proof:
Habitat type - pool tailouts/glides	HbPlTals	0.75	Chinook spawning densities are typically greatest on pool-tailouts. (Note: rule may need to be adjusted due to weighting toward glides) Level of Proof:

Examples:	Example 1			Example 2			Example 3		
Level 2 attribute	Percent of reach	Weight	Weighted percent	Percent of reach	Weight	Weighted percent	Percent of reach	Weight	Weighted percent
Habitat type - backwater pools	15	0.00	0.0	5	0.00	0.0	0	0.00	0.0
Habitat type - beaver ponds	15	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	60	0.00	0.0	30	0.00	0.0	20	0.00	0.0
Habitat type - small cobble/gravel riffles	2.5	0.50	1.3	35	0.50	17.5	25	0.50	12.5
Habitat type - pool tailouts/glides	12.5	0.75	9.4	5	0.75	3.8	5	0.75	3.8
Sum	100		10.6	100		22.5	100		16.3

Level 3 attribute identified with associated chinook life stage

Rule statement

Weights assigned to Level 2 habitat type attributes for computing an overall relative amount of Key Habitat; brief rationale and level of proof

Examples showing % Key Habitat for different habitat type composition

Resultant % Key Habitat

Figure 5. Format for rule presentation for the Level 3 Biological Performance Attribute Key Habitat. An example rule is shown (size reduced for display).

Part II - Rules

Rule for Translation to Level 3 Biometric

Channel Stability

Definition: 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.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Chemicals (Toxic Substances)

Definition: 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.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Competition with Hatchery Fish

Definition: 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.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Competition with Other Species

Definition: The effect of competition with other species on the relative survival or performance of the focus species; competition might be for food or space.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Flow

Definition: The effect of the amount of stream flow, or the 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.

Rule for Translation to Level 3 Biometric

Food

Definition: The effect of the amount, diversity, and availability of food that can support the focus species on the its relative survival or performance.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Habitat Diversity

Definition: The effect of the extent of habitat complexity within a stream reach on the relative survival or performance of the focus species.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Harassment

Definition: 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.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Key Habitat

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.

Rule for Translation to Level 3 Biometric

Obstructions

Definition: 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.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Oxygen

Definition: The effect of the concentration of dissolved oxygen within the stream reach on the relative survival or performance of the focus species.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Pathogens

Definition: 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.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Predation

Definition: The effect of the relative abundance of predator species on the relative survival or performance of the focus species.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Salinity

Definition: The effect of the concentration of salts within the reach on the relative survival or performance of the focus species.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Sediment Load

Definition: 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.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Temperature

Definition: The effect of water temperature within the the stream reach on the relative survival or performance of the focus species.

2/13/02 1:45 PM

Rule for Translation to Level 3 Biometric

Withdrawals (or Entrainment)

Definition: The effect of entrainment (or injury by screens) at water withdrawal structures within the stream reach on the relative survi val or performance of the focus species. This effect does not include dewatering due to water withdrawals, which is covered by the flow attribute.

2/13/02 1:45 PM