Entiat EDT Watershed Analysis

Final Report

February 2003

Prepared for

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Submitted by

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1.0 INTRODUCTION

This document presents the initial EDT diagnosis for planning restoration and protection of salmon habitat in watersheds within the Entiat River, Washington. The diagnosis is based on an assessment of the relative contributions of geographic areas, and the environmental factors operative within each, to the performance of naturally produced chinook salmon.

Salmon survival depends on the condition of diverse habitats along the aquatic landscape. The quality and quantity of habitats from gravel beds in headwater streams to eel grass beds in nearshore marine areas can all affect the performance of salmon populations. Protecting or restoring these habitats in a strategic manner will require locally based solutions, suited to the needs of each watershed. This can only be achieved through coordinated multi-jurisdictional efforts based on a rational process for identifying and prioritizing actions aimed at those factors that most affect salmon survival.

Resource planners associated with the Entiat River have initiated such a process. They seek to develop a rational basis for guiding and coordinating salmon conservation and recovery actions within the Entiat watershed. To this end, they are applying an analytical approach called Ecosystem Diagnosis and Treatment (EDT)—a habitat-based procedure for relating environmental conditions to the performance of salmon populations. EDT captures a wide range of information and makes it accessible to planners, decision-makers and scientists in the form of a working hypothesis for salmon performance within the ecosystem. The Yakima Nation contracted with Mobrand Biometrics, Inc. (MBI) to apply the method in analyzing conditions in the Entiat watershed with respect to chinook performance and to derive a strategic assessment of action priorities. This document presents the preliminary results of these analyses.

1.1 Project Objectives

The project, as contracted to MBI, had two primary objectives:

1. To complete a watershed assessment in the Entiat for the focus species, assessing current and historic measures of population performance relative to habitat conditions, and to derive strategic priorities for protection and restoration actions.
2. To assist planners with developing sets of candidate actions for the Entiat basins—each action identified with respect to its strategic priority—and to analyze possible benefits to the focus species.

1.2 Project Overview

The project consists of two phases—corresponding to the two objectives: 1) watershed assessment and 2) analysis of action alternatives. Combined, both phases provide an overall set of strategic priorities for recovery and protection planning within the Entiat River.

In the assessment phase, we characterized baseline reference conditions with regard to both environmental conditions and population performance measures. We structured the assessment to draw conclusions at basin, subbasin, and stream reach scales. We characterized two baseline reference scenarios: predevelopment or historic conditions and current conditions. The comparison of these scenarios forms the basis of the diagnostic conclusions about how the basins and associated salmon performance have been altered by human development. The historic reference scenario also serves to define the natural limits to potential recovery actions within the basins.

To perform the assessment, a team composed of people knowledgeable about the Entiat River assembled baseline information on habitat and human-use factors and fish life history patterns. For each stream reach, the team estimated a set of habitat parameters using the assembled data and information. Habitat parameters for the Columbia River, Columbia estuary and marine were obtained from the Northwest Power Planning Council' Multi-Species Framework Project (NWPPC, in press). We analyzed the data sets from species-specific life history perspectives in order to describe population performance in relation to habitat and human-use factors. These characterizations of the environment and resultant species performance constitute the working hypothesis for the ecosystem—guiding the strategic assessment and the near-term and long-range salmon recovery planning.

In the final step of the assessment phase, we derived hypothesis-driven strategic priorities for conservation and recovery actions. These priorities identify the relative importance of geographic areas for protection or restoration (or both) and the associated environmental factors. This information is needed for both near-term and long-range action planning as planning committees and various stakeholders seek to identify, prioritize, implement, and monitor conservation and recovery actions.

In the action analysis phase, action alternatives were posed as experimental hypotheses to be tested through an adaptive management program. We assisted Entiat planners and other basin stakeholders in prioritizing near-term conservation actions to protect and restore the ecosystem processes and functions that create and maintain habitat for salmonid species. Criteria for identifying and prioritizing action recommendations included (but were not limited to) the following: benefits for salmon habitat and salmon recovery, cost-effectiveness, and technical feasibility.

1.3 Use of the EDT Method

Ecosystem Diagnosis and Treatment (EDT) is an analytical method relating habitat features and biological performance to support conservation and recovery planning (Lichatowich et al. 1995; Lestelle et al. 1996; Mobrand et al. 1997; Mobrand et al. 1998). It acts as an analytical framework that brings together information from empirical observation, local experts, and other models and analyses.

EDT emphasizes the importance of a science-based approach to recovery planning. Fundamental to the scientific method is the use of an explicit conceptual framework within which information about the natural system is gathered, organized, and analyzed. A logical linkage between actions and events within the watershed and their effect on values and objectives must be presumed and explicitly addressed—a requirement of EDT.

EDT differs from models often used in fish and wildlife management and offers important features that can augment conventional methods. EDT is best described as a scientific model (see Hilborn and Mangel 1997). A scientific model attempts to explain the mechanisms behind observed phenomena to form an overall hypothesis. This contrasts with conventional statistical models that provide correlation-based predictions of events without necessarily explaining the underlying mechanism. As a scientific model, EDT constructs a working hypothesis of a watershed as a basis for planning and for comparison of alternative futures. This hypothesis provides metrics to gauge progress and testable hypotheses to refine knowledge. EDT helps us understand and describe the inevitable complexity of ecological systems in order to plan effective recovery strategies. A statistical model, on the other hand, seeks to reduce complexity to a small number of predictive or correlated variables. A scientific model like EDT provides the hypothesis while a statistical model can provide the test. The hypothesis is the rationale that links actions and expected outcome.

Validation of a scientific model as a planning tool means establishing its applicability and utility to the problem at hand. We suggest three criteria or questions for judging the usefulness of such a model: 1) Does it produce results that are consistent with what we observe; 2) How well does it explain what we observe; and 3) Is it useful for guiding future actions?

The EDT method has been widely applied throughout the Pacific Northwest in a variety of rivers. Most noteworthy for the Entiat assessment, EDT is being used by the NWPPC as the primary analytical tool to develop and assess subbasin plans in Columbia Basin. The Entiat assessment will complement this regional effort.

1.4 Document Organization

This document is organized into three sections:

1.0 Introduction

2.0 The EDT Method as Applied to Entiat River
—a description of the principal parts of the EDT method as it as has been applied in this analysis

3.0 The Assessment
—the assessment of the Entiat watershed with respect to the performance of Chinook

4.0 Restoration and Protection Scenarios

Three appendices accompany this report:

A. The EDT Analytical Model

B. Ecological Attributes and Related Survival Factors

C. Stream Reach Analysis for Chinook Performance

2.0 THE EDT METHOD AS APPLIED TO ENTIAT WATERSHED

This chapter describes the basic components of the EDT method as it was applied in the Entiat analysis. A more complete description of the conceptual design and application of EDT can be found at http://www.edthome.org. Additional information is also provided in Appendix A of this document.

The EDT method consists of three components:

- *Conceptual and Information Framework*—a way of organizing information to describe a watershed ecosystem for analyzing biological performance
- *Analytical Model*—a tool used to analyze environmental information and draw conclusions about the ecosystem
- *Step-by-Step Procedure*—the steps followed in applying EDT; these are described as applied in the Entiat analysis

2.1 Conceptual and Information Framework

2.1.1 The Framework Concept

The conceptual framework consists of three major elements: the vision, the set of biological objectives, and the strategies for moving the watershed toward the vision (Figure 2.1). The **vision** describes a set of desired future conditions with regard to biological, economic, and social values. In an ESA context, these desired conditions address recovery objectives for salmon species. The **biological objectives** describe the vision with respect to the characteristics of the environment and associated biological performance of species under those conditions. The **strategies** are those actions intended to achieve the biological objectives. This simple framework forms the core of the EDT method—it is the framework that has been adopted by the Northwest Power Planning Council for planning recovery actions in the Columbia Basin.

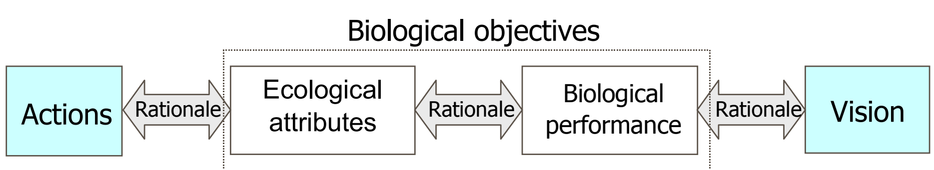

Figure 2.1. The EDT conceptual framework.

This framework is the pathway for linking various potential watershed actions to desired outcomes. It provides the rationale for identifying how actions are transferred through the ecosystem into resource outcomes. The framework explains possible consequences of actions in a manner consistent with existing knowledge and information, and it requires that assumptions necessary to watershed planning be identified—thus it becomes a vehicle for learning and communicating.

2.1.2 Ecological Information Structure

The Information Structure and associated data categories are defined at three levels of organization. Together, these can be thought of as an information pyramid in which each level builds on information from the lower level (Figure 2.2). As we move up the through the three levels, we take an increasingly organism-centered view of the ecosystem. Levels 1 and 2 together characterize the environment, or ecosystem, as it can be described by different types of data (Figure 2.3). This provides the characterization of the environment needed to analyze biological performance for a species. The Level 3 category is a characterization of that same environment from a different perspective: "through the eyes of the focal species" (Mobrand et al. 1997). This category describes biological performance in relation to the state of the ecosystem described by the Level 2 ecological attributes.

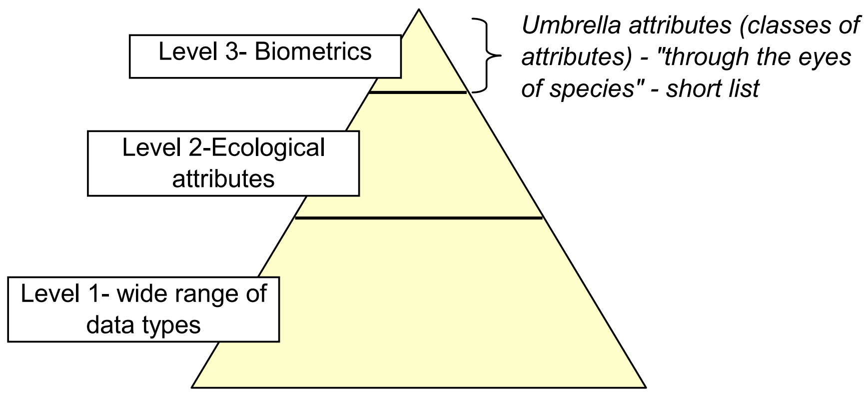

Figure 2.2. Data/information pyramid—information derived from supporting levels.

The organization and flow of information begins with a wide range of environmental data (Level 1 data) that describe a watershed, including all of the various types of empirically based data available. These data include reports and unpublished data. Level 1 data exist in a variety of forms and pedigrees. The Level 1 information is then summarized or synthesized into a standardized set of attributes (Level 2 ecological attributes, see Table 2.1) that refine the basic description of the watershed. The Level 2 attributes are descriptors that specify physical and biological characteristics about the environment relevant to the derivation of the survival and habitat capacity factors for the specific species in Level 3. Definitions for Level 2 and Level 3 attributes are given in Appendix B, together with a matrix showing associations between the two levels.

The Level 2 attributes represent conclusions that characterize conditions in the watershed at specific locations, during a particular time of year (season or month), and for an associated management scenario. Hence an attribute value is an assumed conclusion by site, time of year, and scenario. These assumptions become operating hypotheses for these attributes under specific scenarios. Where Level 1 data are sufficient, these Level 2 conclusions can be derived through simple rules. However, in many cases, experts are needed to provide knowledge about geographic areas and attributes where Level 1 data are incomplete. Regardless of the means whereby Level 2 information is derived, the characterization it provides can be ground-truthed and monitored over time through an adaptive process.

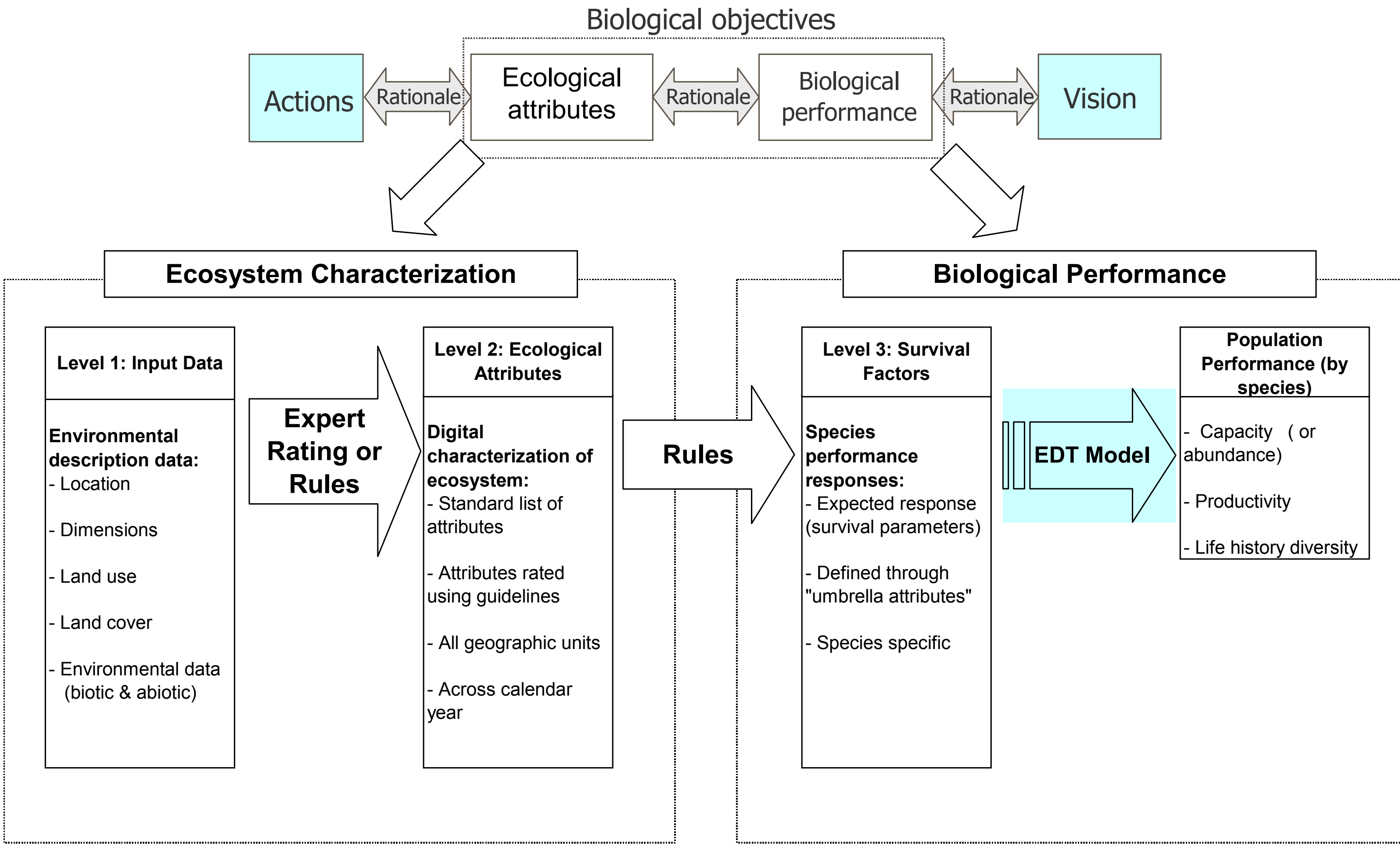

Figure 2.3. Ecological Information Structure.

Table 2.1. Hierarchical organization of Ecological Attributes (Level 2) by categories of major stream corridor features. Corresponding salmonid Survival Factors (Level 3) are shown associated with groups of Level 2 attributes (other associations may also be used in conversion rules). Associations can differ by species and life stage. See Appendix B for association matrices.

Ecological Attributes (Level 2)		Related Survival Factors (Level 3)
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 stability Channel width Habitat diversity Key habitat Obstructions Sediment load
	Channel width - month maximum width	
	Channel width - month minimum width	
	Gradient	
2.2 Confinement	Confinement - hydromodifications	
	Confinement - natural	
2.3 Habitat type	Habitat type - backwater pools	
	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	
3 Water Quality		
3.1 Chemistry	Alkalinity	Chemicals (toxic substances) Oxygen Temperature
	Dissolved oxygen	
	Metals - in water column	
	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	

Table 2.1 continued. Hierarchical organization of Ecological Attributes (Level 2).

Ecological Attributes (Level 2)		Related Survival Factors (Level 3)
4 Biological Community		
4.1 Community effects	Fish community richness	Competition with hatchery fish Competition with other fish Food Harassment Pathogens Predation
	Fish pathogens	
	Fish species introductions	
	Harassment	
	Hatchery fish outplants	
	Predation risk	
	Salmon carcasses	
4.2 Macroinvertebrates	Benthos diversity and production	

In the Entiat process, conclusions regarding Level 2 attribute conditions were derived by a group of natural resource-related professionals with knowledge of the watersheds of interest. These individuals had expertise in such disciplines as fish habitat, hydrology, geomorphology, water quality, and civil engineering.

The link between Level 2 attributes and Level 3 factors is made through sets of rules. The rules translate the Level 2 characterization of the environment into biological performance by life stage for a focus species. Biological performance describes how a species reacts to characteristics of its environment in terms of survival (productivity) and capacity. The rules are defined through the Level 3 Survival Factors (Table 2.1), which act as "umbrella attributes" grouping Level 2 attributes together.

A separate set of biological rules for doing the conversion from Level 2 to Level 3 has been derived for each species of salmon. The rules are provisional—they are currently being reviewed through a formal process in the region. They are a characterization of our understanding of the relation between the environment and salmon survival at the current time. We expect that the rules will be refined through the review process. Additional information on the rules and the review process can be found at http://www.edthome.org.

The Level 3 Survival Factors serve as the input to the EDT model for estimating population response measures. These measures are the currency for formulating and comparing strategic priorities and sets of conservation and recovery actions.

The remaining component that is incorporated into the Information Structure is the set of candidate actions to be considered for implementation. Actions—defined through assumptions about effectiveness, dispersal of effect, and time lag to achieve full effect—are evaluated by examining how they result in changes to Level 2 attributes, which in turn affect Level 3 factors and population performance measures. In the Entiat process, assumptions about action effectiveness were made with the aid of a working group of civil engineers and biologists. These assumptions represent objectives for the actions that can, if implemented, be monitored for effectiveness.

2.2 Analytical Model

The tools essential for applying the EDT method have been assembled into the EDT model: a repository of data, information, and knowledge, as well as a collection of analytical procedures. It includes a database that stores and documents information about the geography and physical characteristics of the watersheds of interest. Also included are databases that describe and document the biology, life history characteristics, and environmental sensitivities of a set of indicator species. The EDT model includes a module for developing alternative future scenarios by defining action strategies and targeted environmental attributes.

The EDT model makes it possible to manage the complexity and quantity of detailed information needed to use the EDT method. The model allows us to address tractable issues and problems in the context of a broad framework, which integrates a wide range of scientific disciplines. The model is a tool for achieving accountability: it expands the ability of scientists to keep track of complex relationships and opens broader horizons for creativity.

The analytical tools included in the model compute the various diagnostic indicators described and displayed elsewhere in this document. The principal output are the parameter estimates of biological performance for the fish populations of interest. These parameters are then used by the model in deriving other diagnostics of interest, such as strategic priorities for conservation and recovery actions.

We define biological performance in terms of three elements: productivity, capacity[1], and life history diversity (Figure 2.4). These measures are characteristics of the ecosystem that describe persistence, abundance, and distribution potential of a population. They are the core performance measures used by the National Marine Fisheries Service (NMFS) as part of its viable population concept (see McElhany et al. 2000). Each measure is defined briefly below.

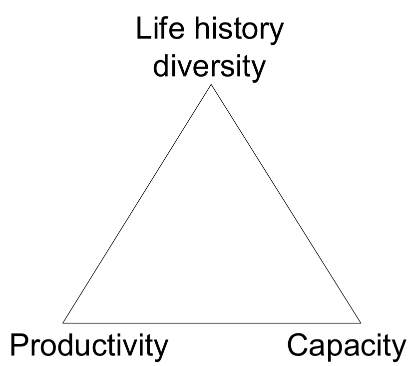

Figure 2.4. Measures of biological performance.

Productivity. This element represents the relative success of the species to complete its life cycle within the environment it experiences.[2] It determines resilience to mortality pressures,

[1] We use the terms productivity and capacity as defined by Hilborn and Walters (1992). Capacity is the maximum population size for one or more life history segments. Capacity and productivity are not independent.

[2] The productivity rate is the reproductive rate measured over a full generation that would occur at low population density, i.e., when competition for resources among the population is minimal.

such as from fishing, dams, and further habitat degradation. *Habitat quality* (including water quality) is a major determinant of a population's productivity. This performance element is especially important when efforts are being made to reverse long-term downward trends in population abundance. The model estimates productivity for the population of interest under specific management scenarios, expressed as the average number of adult progeny produced per parent spawner (at low population density). A life cycle productivity less than 1 for any part of the population is, by definition, unsustainable. As population productivity approaches 1 (e.g., values less than 2),[3] the population is clearly at risk.

Capacity. This element defines how large a population can grow within the environment it experiences, as a result of finite space and food resources. It determines the effect of this upper limit on abundance to survival and distribution. *Habitat quantity* is a major determinant of the environmental capacity to support population abundance. In the analysis presented here, we frequently refer to "abundance" rather than capacity. Here we are describing the equilibrium run size abundance (or average abundance under steady state conditions), which highly correlates with capacity. The model estimates both capacity and equilibrium abundance for the population of interest corresponding to specific management scenarios.

Life History Diversity. This element represents the multitude of pathways through space and time available to, and used by, a species in completing its life cycle. Populations that can sustain a wide variety of life history patterns are likely to be more resilient to the influences of environmental change. Thus a loss of life history diversity is an indication of declining health of a population (Lichatowich and Mobrand 1995) and perhaps its environment. The model computes an index of life history diversity as the percentage of possible life cycle pathways (i.e., life *trajectories* in space and time that members of a population might follow across the aquatic landscape) having a productivity greater than 1.

The algorithms used to calculate population parameters are based on the Beverton-Holt survival function (after Beverton and Holt 1957). All of the estimates are made for steady state conditions. The derivation of some of the key relationships used in the EDT analysis are presented in Appendix A.

2.3 Step-by-Step Procedure

The EDT method consists of a series of steps (see Lestelle et al. 1996) adapted for the Entiat analysis. The steps are outlined below:

1. Identification of goals and values
2. Resource assessment (or diagnosis)
3. Analysis of actions
4. Considerations for monitoring and implementation

Each step is described below.

[3] The life cycle productivity needed to sustain a population in the face of environmental uncertainty has not been defined.

2.3.1 Identification of Goals and Values

Watershed goals for fish resources are derived from social, cultural, political, and legal considerations in a policy environment. The EDT process does not presume agreement between the various values and goals, but it emphasizes the importance of identifying all of them. Goals and values provide the currency whereby projected outcomes of actions can be evaluated.

Many statements regarding goals and values for salmonid resources within the boundaries of the Entiat watershed have been issued by various entities and agencies. The documents published by these entities need to be reviewed in order to identify major themes within the range of statements issued. We do not suggest that these are definitive statements of goals and values for fish resources within the Entiat—merely that they reflect a basis for developing more specific and comprehensive goals with regard to salmon conservation and recovery actions.

2.3.2 Resource Assessment

During the resource assessment step we diagnosed the environmental impediments to achieving the goals and values associated with the salmon resources of the Entiat River. This step was structured to produce conclusions drawn at basin, subbasin, and stream reach scales. The assessment, thus, provides a comprehensive, analytically derived limiting factors analysis[4] of each watershed, from which we formulated strategic priorities for conservation and restoration measures.

The resource assessment consisted of two tasks: 1) baseline information assembly and 2) analysis and diagnosis.

2.3.2.1 Baseline Information Assembly

To perform the assessment, we assembled baseline information on habitat and human-use factors and fish life history patterns for the watersheds of interest and adjoining estuarine, nearshore, and deep water marine areas. We first structured the entirety of the relevant geographic areas, including marine waters, into distinct habitat reaches. We identified reaches on the basis of similarity of habitat features, drainage connectivity, and land use patterns (Table 2.2). This task required that all reaches be completely characterized by the relevant environmental attributes.

A technical work group was formed for the Entiat basin for the purpose of deriving the Level 2 attribute conclusions for the freshwater stream reaches. Expert knowledge about habitat identification, habitat processes, hydrology, water quality, and fish biology was incorporated into the process. The work groups drew upon published and unpublished data and information for the basin to complete the task.

[4] The term "limiting factors analysis" is widely used in the Pacific Northwest to refer to various types of analyses of the importance of different environmental factors to salmon performance. Often these are not analytically derived. Notably, the EDT method does provide an analytically derived analysis—one that examines the relative contributions of all factors to the loss in salmon performance.

Table 2.2. Stream reaches defined in the Entiat River, Columbia River, and marine areas.

Reach	Description
Entiat-1	Entiat-1: From Columbia River to End of slack water; Length (mi): 0.6
Entiat-2	Entiat-2: From Slack water to Fire Station Bridge; Length (mi): 2.6
Entiat-3	Entiat-3: From Fire Station Bridge to Roaring Creek; Length (mi): 3
Entiat-4	Entiat-4: From Roaring Creek to J/S Bridge; Length (mi): 2.6
Entiat-5	Entiat-5: From J/S Bridge to Mad River; Length (mi): 1.8
Entiat-6	Entiat-6: From Mad River to Mud Creek; Length (mi): 1.2
Entiat-7	Entiat-7: From Mud Creek to R/S Bridge; Length (mi): 2.2
Entiat-8	Entiat-8: From R/S Bridge to Potato Creek; Length (mi): 1.2
Entiat-9	Entiat-9: From Potato Creek to Potato Moraine; Length (mi): 0.9
Entiat-10	Entiat-10: From Potato Moraine to Stormy Creek; Length (mi): 2.2
Entiat-11	Entiat-11: From Stormy Creek to Preston Creek; Length (mi): 4.8
Entiat-12	Entiat-12: From Preston Creek to Fox Creek; Length (mi): 4.7
Entiat-13	Entiat-13: From Fox Creek to Box Canyon; Length (mi): 1.5
Entiat-14	Box Canyon
Entiat-15	Entiat 15: From Box Canyon to Silver Falls Creek; Length (mi): 1.7
Entiat-16	Entiat-16: From Silver Falls Creek to Entiat Falls; Length (mi): 2.8
Mad-1	Mad River Mouth to Tillicum Creek
Mad-2	Tillicum Creek to Pine Flat
Mad-3	Pine Flat to Camp 9
Columbia R. mainstem	Multiple reaches confluence with Entiat River to Columbia River estuary (includes dams)
Columbia R. Estuary	Columbia estuary (extends upstream to RM 49)
Marine areas	Multiple marine reaches (coastal zone and offshore reaches)

We employed a similar process for Columbia River mainstem, Columbia estuarine, and marine areas on a project working for the NWPPC assessing Columbia Basin chinook using the EDT method. For that project, we compiled information from reports and consulted experts to characterize the mainstem, estuaries and marine areas with respect to the Level 3 survival factors. A process that follows the entire ecological information structure depicted in Figure 2.3 is still being formulated for these areas. For the Entiat project being reported here, the Level 3 factors act as umbrella attributes that served the same purpose that the Level 2 attributes served for Entiat reaches.

We characterized two baseline reference scenarios for the Entiat, Columbia River, and marine area: predevelopment, or historic, conditions and current conditions. The comparison of these scenarios formed the basis for diagnostic conclusions about how the Entiat and associated salmon performance have been altered by human development. The historic reference scenario also served to define the natural limits to potential recovery actions within the basin.

2.3.2.2 Analysis and Diagnosis

We analyzed the data sets from species-specific, life history perspectives using the EDT model to estimate population performance measures in relation to the habitat and human-use factors associated with each scenario. The estimates provided an approximation of the extent that environmental change has affected performance of these salmon populations. The analysis also incorporated information on harvest and genetic fitness effects, enabling us to estimate the portion of lost performance that is due to environmental effects.

The objective of the diagnosis then became identifying the relative contributions of environmental factors to the losses in salmon performance. To accomplish this, we performed two types of analyses, each at a different scale of overall effect.

The first analysis was done *across geographic areas* relevant to populations, where each geographic area typically encompasses many reaches. This analysis, called the *Geographic Area Analysis*, identified the relative importance of each area for either restoration or protection actions. In this case, we analyzed the effect of either restoring or further altering environmental conditions on population performance.

The second analysis considered conditions within *individual stream reaches* and identified the most important factors contributing to a loss in performance corresponding to each reach. This analysis, called the *Stream Reach Analysis* (Appendix C), identified the factors (classes of Level 2 attributes) that, if appropriately moderated or corrected, would produce the most significant improvements in overall fish population performance. It identified the factors that should be considered in planning habitat restoration projects.

Together, these two analyses formed the basis for identifying strategic priorities for conservation and restoration measures within each watershed.

2.3.3 Analysis of Actions

The purpose of this step in the analysis is to identify candidate actions and analyze them for their potential benefit to the fish populations of interest.

3.0 RESOURCE ASSESSMENT

The purpose of the assessment was to diagnose the environmental impediments to achieving the goals and values associated with the salmon resources of Entiat Watershed. It was structured to draw conclusions at basin, subbasin, and stream reach scale, and provided a comprehensive, analytical limiting factors analysis of the watershed. Strategic priorities for conservation and restoration were based on this limiting factors analysis, or "diagnosis". Five separate diagnostic prescriptions for the watershed were then evaluated in terms of the performance of Entiat spring and summer Chinook, and are presented to the Entiat Watershed Workgroup as alternative management strategies.

This section is divided by chinook race or stock, as follows:

- Spring Chinook
- Summer Chinook

The results are organized into the following topics:

1. Population performance summary
2. Strategic priorities for restoration and protection measures
3. Data uncertainties
4. Assessment conclusions – geographic priorities

In Section 4, the final section of the document, we present the nature and estimated impacts of five restoration scenarios based on the "diagnosis" presented in this section.

The results for population performance measures (capacity or abundance, productivity, and life history diversity) are presented by population in both tabular and graphic displays. The reader should note that a high level of precision is not intended by the numeric outputs shown—we rounded performance values in a manner to make comparisons as simple as possible and, hopefully, minimize confusion. Abundance estimates are rounded to the nearest tenth.

A short explanation of how we address uncertainty in the assessment is warranted. The issue is: how certain are we that the factors affecting salmonid performance are correctly identified? This issue consists of two parts. The first involves certainty about the data and information used in the analysis. The second involves certainty about the analysis itself and how it is used to draw conclusions. The section summarizing assessment conclusions describes our conclusions about the first aspect. The second aspect is discussed in other sections of this document, i.e., Sections 1 and 2, as well as in other related reports that can be found at www.edthome.org.

3.1 Entiat Spring Chinook

3.1.1 Baseline Population Performance

Model results for Entiat spring chinook are based on life history assumptions summarized in Table 3.1.

Table 3.1. Life history assumptions used to model spring chinook in the Entiat River.

Stock Name:	Entiat River Spring Chinook	
Race:	Spring	
Geographic Area (spawning reaches):	Potato Moraine to Entiat Falls	
River Entry Timing (Columbia R):	March – June	
River Entry Timing (Entiat R):	May - early July	
Spawn Timing:	September	
Emergence Timing (dates):	mid February to late March	
Juvenile Life History:	Ocean type:	0%
	Stream type:	100%
Stock Genetic Fitness:		85%

After taking into account harvest and loss genetic fitness, the EDT model estimated the average spawning population size of the current spring chinook should be approximately 138 fish, with a productivity of just 2 adult returns per spawner (Figure 3.1). These performance estimates are in general agreement with observations. The Entiat Subbasin Summary (NWPPC 2002) reported a mean escapement of 175 fish for the period 1986-1995, and notes that the productivity of the population is so low as to warrant an ESA listing. The life history diversity value indicates only 35% of the historic life history pathways can be successfully used under current conditions. Removing all harvest and genetic loss effects from the analysis increased average run size to 170 fish, a 23% increase. Most of this increase was attributable to removing the assumed 15% decrease in genetic fitness from the analysis, with most of the remainder being accounted for by a ~7% total harvest rate. The analysis also suggests that the Entiat Subbasin has a much greater production potential for spring chinook than it now displays, as historical abundance is estimated at 2,557 spawners, with a productivity of 12 returning adults per spawner and a life history diversity of 93%.

3.1.2 Strategic Priorities for Entiat Spring Chinook

We assessed strategic priorities for Entiat spring chinook in three basic ways. Two of these ways emphasized the "where" of a fish management plan while the third emphasizes the "what". Places where a strategic plan should be focused were determined by identifying areas critical to preserving current production (viz., by identifying areas with high "Protection Value"), and by identifying areas with the greatest potential for restoring a significant measure of historical production (viz., by identifying areas with high "Restoration Potential"). The kinds of actions a management plan should include were determined by performing a "Reach Analysis". A Reach Analysis identifies the life stages most severely impacted (relative to historical performance) on a reach-by-reach basis, as well as the environmental conditions most responsible for the impacts. This three-part diagnosis can

Report 1 - Baseline Spawner Population Performance Parameters
Entiat Spring Chinook Baseline

Population	Scenario	Diversity index	Productivity	Capacity	Abundance
Entiat Spring Chinook	Historical	93%	12.0	2,789	2,557
	Current	35%	2.0	281	138
	Current (no Harvest or Fitness Impacts)	44%	2.1	321	170

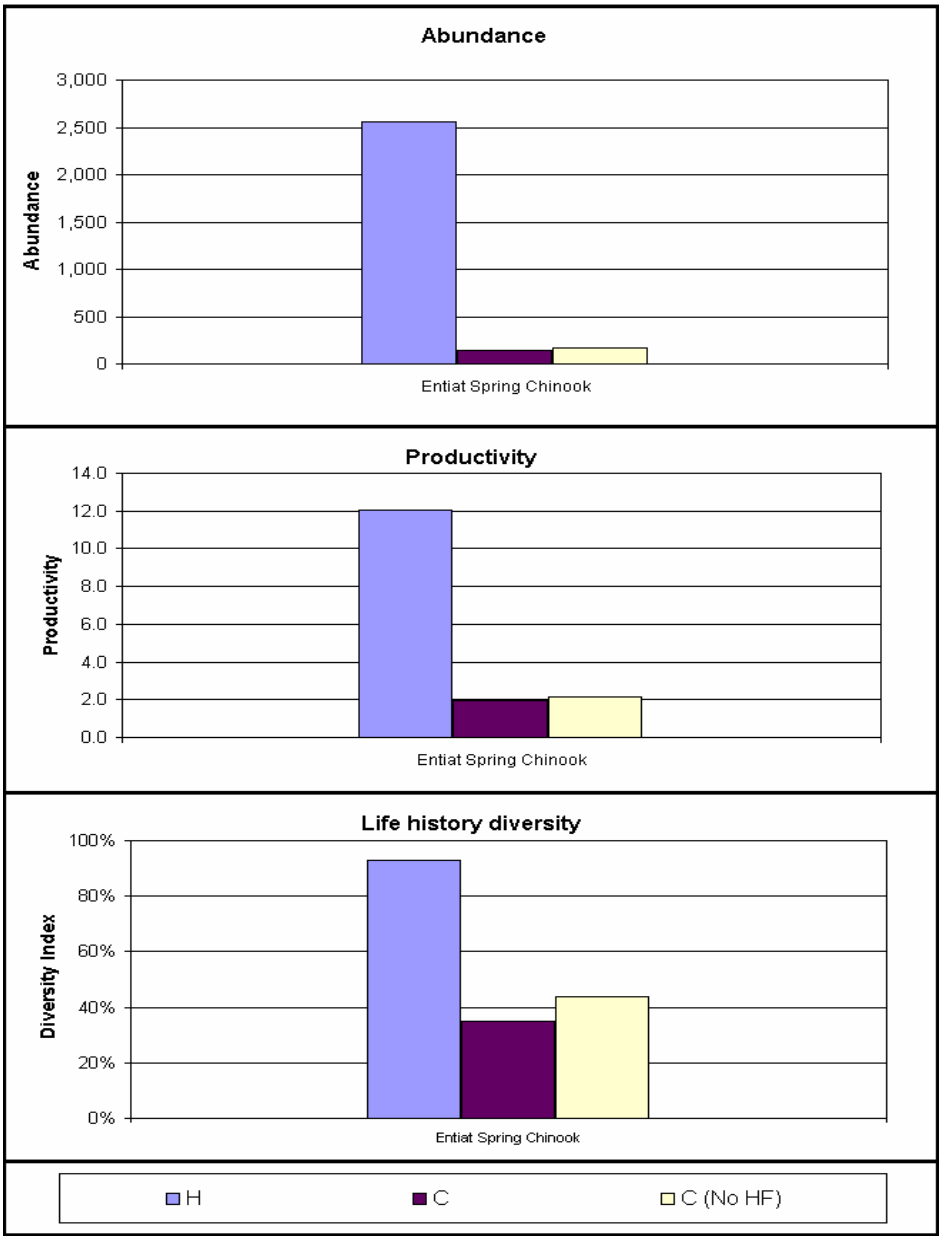

Figure 3.1. Naturally produced Entiat spring chinook based on modeling results.

then be used to develop a plan designed to protect areas critical to current production, and to implement effective restoration actions in reaches with the greatest production potential.

The first pair of charts in Appendix C describe this analysis in greater detail. The rest of the charts in Appendix C consist of the Reach Analysis for the Entiat Subbasin. The Reach Analysis is intended to serve as a reference tool to be used in all types of watershed planning related to salmon conservation and recovery.

In order to conduct the EDT analysis with sufficient precision, the Entiat drainage was first subdivided into the 24 stream segments or "reaches" identified in Table 3.2. Each reach is relatively homogenous in terms of habitat conditions. Such a detailed reach structure, however, is counterproductive for displaying results. Therefore the reaches were regrouped into the five larger "geographic areas": the lower Entiat, the lower middle Entiat, the upper middle Entiat, the upper Entiat, and the Mad River.

Table 3.2. Reaches of the Entiat River drainage defined for EDT analysis of spring chinook and summer chinook .

Reach Name	Geographic Area	Reach Location	Spawning Reach?
Entiat R-1	Lower Entiat	Columbia confluence to end of slack water (0.6 mi)	Summer Chinook
Entiat R-2	Lower Entiat	End of slack water to Fire Station Bridge (2.6 mi)	Summer Chinook
Entiat R-3	Lower Entiat	Fire Station Bridge to Roaring Creek (3.0 mi)	Summer Chinook
Entiat R-4	Lower Entiat	Roaring Creek to J/S Bridge (2.6 mi)	Summer Chinook
Entiat R-5	Lower Entiat	J/S Bridge to Mad River (1.8 mi)	Summer Chinook
Entiat R-6	Lower Middle Entiat	Mad River to Mud Creek (1.3 mi)	Summer Chinook
Entiat R-7	Lower Middle Entiat	Mud Creek to R/S Bridge (2.2 mi)	Summer Chinook
Entiat R-8	Lower Middle Entiat	R/S Bridge to potato Creek (1.2 mi)	Summer Chinook
Entiat R-9	Lower Middle Entiat	Potato Creek to Potato Moraine (0.9 mi)	Summer Chinook
Entiat R-10	Upper Middle Entiat	Potato Moraine to Stormy Creek (2.2 mi)	Summer Chinook and Spring Chinook
Entiat R-11	Upper Middle Entiat	Stormy Creek to Preston Creek (4.8 mi)	Summer Chinook and Spring Chinook
Entiat R-12	Upper Middle Entiat	Preston Creek to Fox Creek (4.7mi)	Spring Chinook

Table 3.2. Reaches of the Entiat River drainage defined for EDT analysis of spring chinook and summer chinook .

Reach Name	Geographic Area	Reach Location	Spawning Reach?
Entiat R-13	Upper Middle Entiat	Fox Creek to Box Canyon (1.5 mi)	Spring Chinook
Entiat R-14	Upper Entiat	Box Canyon	
Entiat R-15	Upper Entiat	Box Canyon to Silver Falls (1.7 mi)	Spring Chinook
Entiat R-16	Upper Entiat	Silver Falls to Entiat Falls (2.8 mi)	Spring Chinook
Mad R-1	Mad River	Mouth to Tillicum Cr	Spring Chinook
Mad R-2	Mad River	Tillicum Cr to Pine Flat	Spring Chinook
Mad R-3	Mad River	Pine Flat to Camp 9	Spring Chinook

3.1.2.1 Entiat Spring Chinook Restoration Priorities

A very large and important geographic area not shown in Table 3.2 consists of all of the Columbia mainstem reaches. Not surprisingly, these out-of-subbasin reaches ranked first in restoration potential. Reaches within the Entiat watershed were estimated to account for 38% of the total restoration potential for life history diversity, 24% of the restoration potential for productivity and 25% of the restoration potential for abundance (Figure 3.2). Such a result is to be expected for a Subbasin as far upriver as the Entiat. Beyond the unremarkable insight that seven hydroelectric projects have a large cumulative impact on production, this result suggests that improving performance of Entiat spring chinook is strongly tied to actions in the Columbia River, partly because spring chinook parr are believed to migrate out of the Subbasin and to rear in the mainstem for a considerable time before smolting (see the next section – Data Uncertainties – for additional details). Within the watershed, the upper middle Entiat ranked first overall in terms of restoration potential, and was followed by the Mad River and the lower Entiat (tied for 2nd), the lower middle Entiat and the upper Entiat (Figure 3.3). It should be noted that the Mad River had a relatively high rank primarily because of its large potential impact on life history diversity; the Mad ranks 3rd in terms of abundance and last in terms of productivity.

The factors most responsible for lost production inside the Entiat watershed are remarkably consistent within the Entiat mainstem, as are the life stages most severely impacted. Throughout the Entiat mainstem a lack of habitat diversity is easily the most important factor underlying depressed production. The second most important factor is a lack of food, especially in the upper middle Entiat, with channel stability, key habitat and flow playing distinctly lesser roles. The life stages most impacted by these conditions are almost always either fry or subyearling parr. Indeed, in 13 of the 16 mainstem Entiat reaches supporting spring chinook, the most severely impacted life stage was either fry or parr.

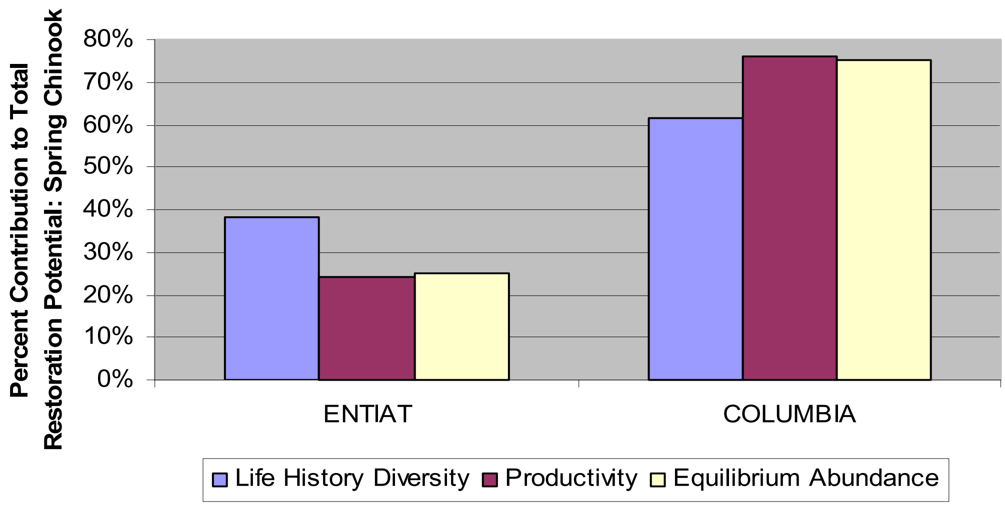

Figure 3.2 Contribution of reaches inside the Entiat Subbasin and the Columbia mainstem to the total Restoration Potential of Entiat Spring Chinook. Restoration Potential is expressed in terms of life history diversity, productivity and equilibrium abundance.

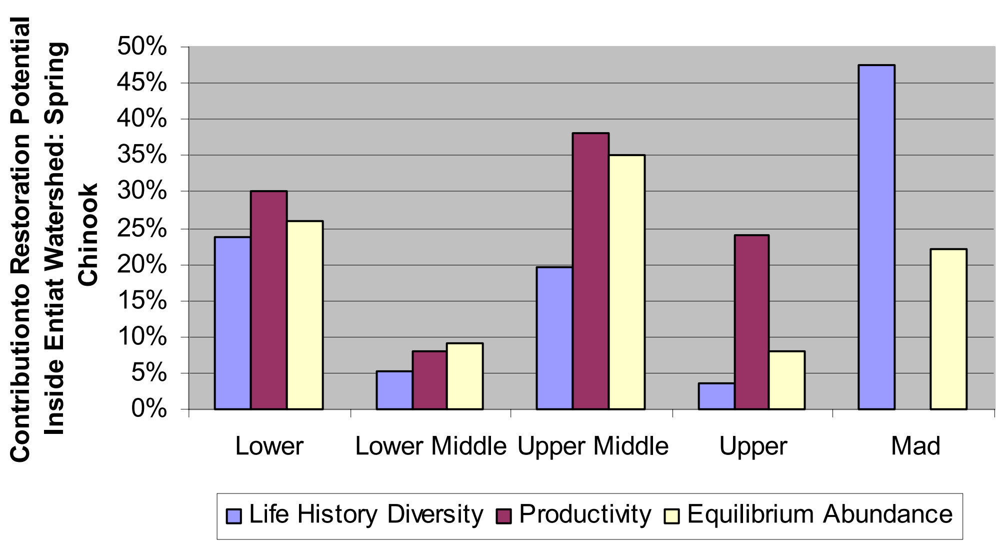

Figure 3.3 Relative Restoration Potential of geographic areas inside the Entiat Subbasin. Restoration Potential is expressed in terms of life history diversity, productivity and equilibrium abundance.

For fry and subyearling parr, habitat diversity is a function of gradient, confinement, riparian function, LWD density and icing. The Entiat mainstem is moderately steep, which depresses habitat diversity to some degree. On the other hand, channel confinement, riparian function, and LWD density are substantially degraded throughout the mainstem, and low temperatures and icing are problematic in the lower Entiat. These factors clearly play a major role in degrading habitat diversity and must be improved if spring chinook production is to be increased substantially. Food availability is a function of benthic invertebrate production, alkalinity, riparian function and salmon carcasses. While the benthic invertebrate community appears to be relatively healthy in the Entiat mainstem, and alkalinity is only moderately low, the abundance of salmon carcasses is extremely low and, as mentioned, riparian function is very poor. Thus, at risk of some oversimplification, any effective spring chinook restoration project targeting the Entiat mainstem should emphasize reducing channel confinement, improving riparian function, and increasing LWD density and the abundance of salmon carcasses.

The limiting factors and the life stages they impact most severely are somewhat different in the Mad River. The most severely impacted life stages in the Mad are adult life stages, specifically pre-spawning adults in the "holding" phase and actively spawning adults. Incubating eggs and fry are depressed to a somewhat lesser extent. Although a lack of habitat diversity plays a major role here as well, as well as a lack of channel stability, the dominant limiting environmental condition in the Mad River is water temperature. High fall water temperatures and a lack of habitat diversity significantly depress the survival of pre-spawning adults, and very low winter temperatures and a lack of spawning habitat depress the survival of incubating eggs.

The major limiting environmental factors described for Entiat spring chinook are summarized in Figure 3.4. A complete description of limiting factors by reach and life stage is found in Appendix C.

3.1.2.2 Entiat Spring Chinook Protection Priorities

Unlike restoration, the areas of highest priority for protecting spring chinook production are inside the Entiat Subbasin. Entiat reaches account for approximately 64% of the total protection value for productivity, 63% of the total protection value for abundance and 52% for life history diversity (Figure 3.5). Within the watershed, the upper middle Entiat ranked first overall in terms of protection value, and was followed by the lower Entiat, the upper Entiat, the lower middle Entiat and the Mad River (Figure 3.6). The upper middle Entiat, it should be noted, includes much of the spawning, early rearing, and adult holding habitat for Entiat spring chinook.

Much of the preceding discussion of geographic priorities for both protection and restoration is summarized in Figure 3.7. Figure 3.7 is consists of three "ladders", the left representing equilibrium abundance, the middle productivity and the right life history diversity. The width of each "rung" of these ladders represents the sum of protection value and restoration potential for a particular geographic area, the left half for protection and the right for restoration. The darker-shaded left portion of each ladder represents protection value, and the right the restoration potential. The way in which Figure 3.7 should be interpreted can best be explained by example. If one looks only at the "Upper Middle

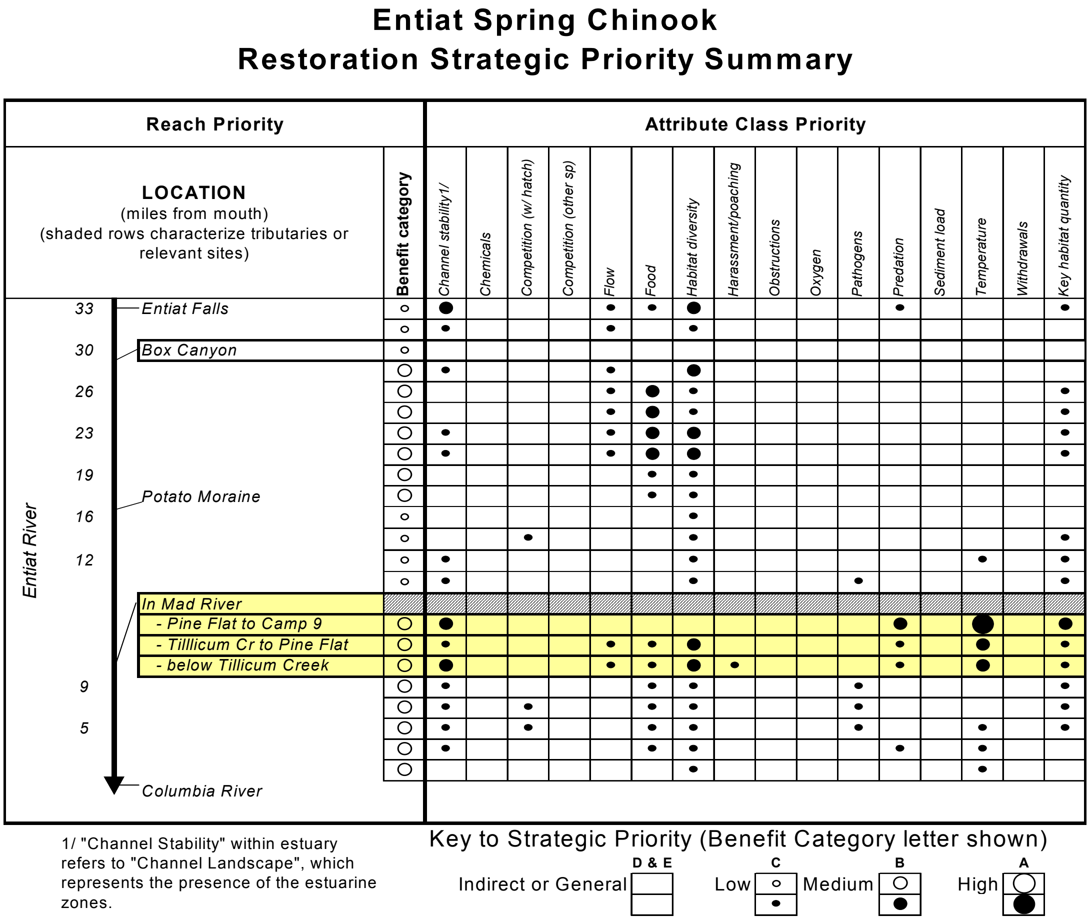

Figure 3.4. Summary of restoration strategic priorities for environmental factors (attribute classes) corresponding to geographic areas within the Entiat watershed for spring chinook salmon.

Entiat" row and the "Change in Abundance" column, one sees that the dark blue "degradation" bar extends almost to –100%, while the light blue bar extends to about +25%. The meaning of the degradation bar is that the abundance of Entiat spring Chinook population is currently almost totally depedndent on the Upper Middle Entiat (viz., would decline essentially to zero if the area were thoroughly degraded), while overall abundance would increase about 25% if the Upper Middle Entiat were to be restored to historical conditions.

In interpreting the various figures and tables of a diagnosis, planners should aware that some impacts have local causes and some do not. The causes of sediment deposition and non-normative flow conditions, for example, frequently are located upstream and/or are associated with land use. Hence identification of specific actions to rectify certain environmental conditions must consider the ultimate origin of the condition.

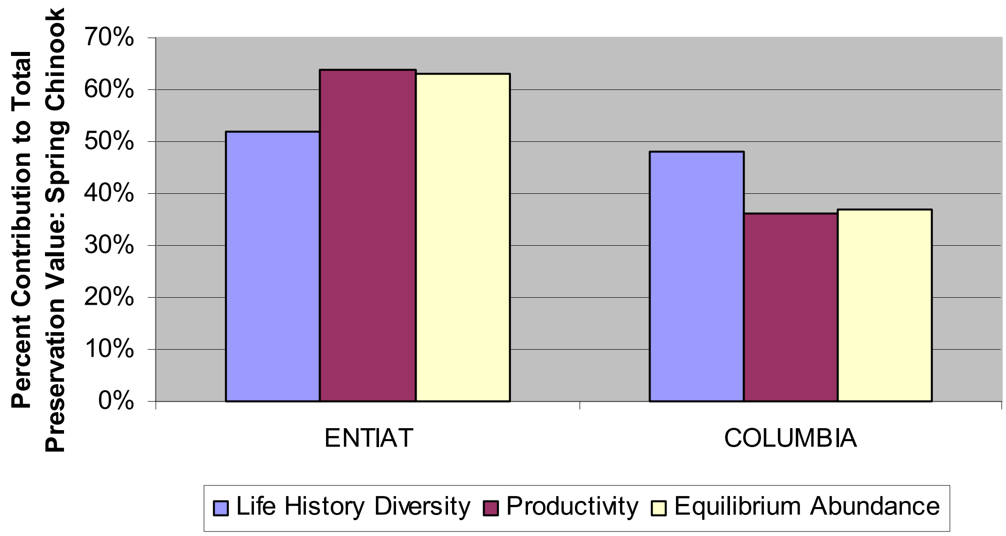

Figure 3.5 Contribution of reaches inside the Entiat Subbasin and in the Columbia mainstem to the total Preservation Value of Entiat Spring Chinook. Preservation Value is expressed in terms of life history diversity, productivity and equilibrium abundance.

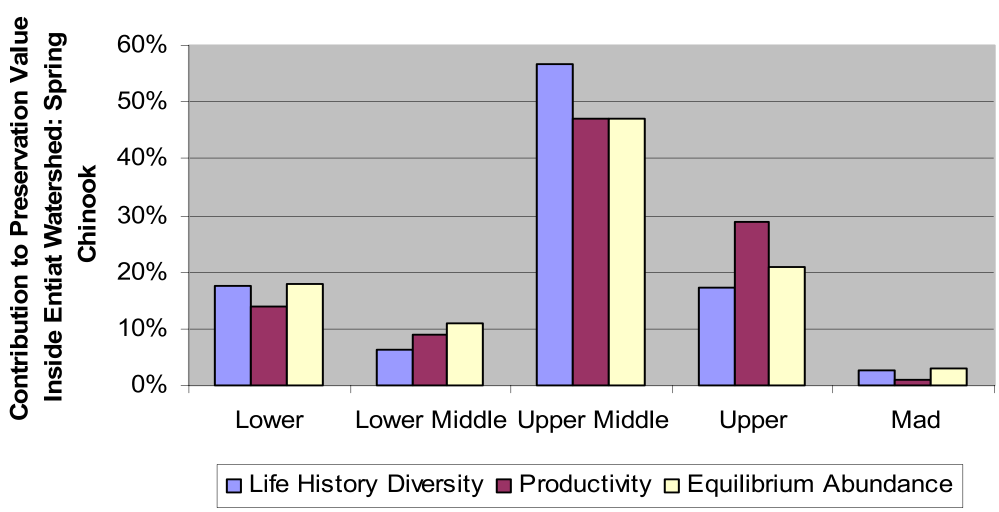

Figure 3.6 Relative contribution to Preservation Value of reaches inside the Entiat watershed. Preservation Value is expressed in terms of life history diversity, productivity and equilibrium abundance.

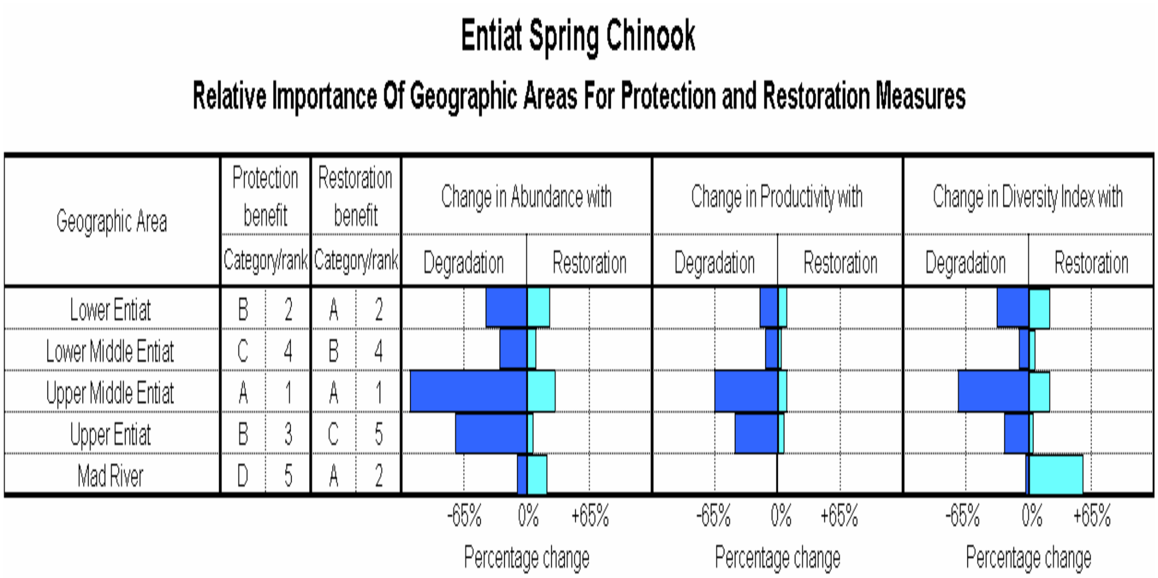

Figure 3.7. Relative importance of geographic areas for restoration and protection measures targeting Entiat spring chinook. Areas are ranked and assigned to benefit categories according to potential (A is highest) to affect population performance. Contribution of performance measures to rankings are graphed.

3.2 Entiat Summer Chinook

3.2.1 Population Performance Summaries

Model results for Entiat summer chinook are based on life history assumptions described in Table 3.3.

Table 3.3. Life history assumptions used to model summer chinook in the Entiat River.

Stock Name:	Entiat River Summer Chinook	
Race:	Summer	
Geographic Area (spawning reaches):	Mouth to Preston Creek	
River Entry Timing (Columbia R):	Mid June – early August	
River Entry Timing (Entiat R):	Mid September – mid October	
Spawn Timing:	Early October – mid November	
Emergence Timing (dates):	Early March to mid April	
Juvenile Life History:	Ocean type:	20%
	Stream type:	80%
Stock Genetic Fitness:		85%

The EDT model estimated the mean spawning population size of summer chinook to be 99 fish, with a population productivity of 1.5 adult returns per spawner and a life history diversity index of just 13% (Figure 3.8). These figures incorporate the impact of an assumed 30% harvest rate and a genetic loss of fitness impact of 15%. Historical abundance was estimated at 2,680, productivity at 10.7 and life history diversity at 100%.

This abundance estimate for the current population is substantially more than the mean observed escapement of 11 fish for the years 1987-1991 reported in the Entiat Subbasin Summary (NWPPC 2002). Equilibrium abundance is, however, a function of both carrying capacity and productivity, and if the EDT productivity estimate were only 30% smaller, observed and modeled abundance figures would be identical.

In any case, the modeling results suggest a population that may not be sustainable. A productivity of 1.5 returns per spawner indicates very little resiliency of the population to environmental variation (high flow events, etc). The life history diversity index indicates only 13% of the historic life history pathways are now self-sustaining. Thus only a few locations in the Entiat mainstem under current environmental conditions and harvest rates are likely to produce as many adult progeny as spawners.

A fair measure of the poor performance of summer chinook as modeled was attributable to the assumed harvest rate and fitness impact. Removing all harvest and fitness impacts from the analysis more than doubled the mean abundance but increased productivity by only about 67%. Productivity did not increase to the same extent as abundance because the removal of harvest and fitness upgraded many pathways from non-viable to just-viable status (viz., changed productivities from less than 1.0 to just above 1.0– see Appendix A for details).

3.2.2 Strategic Priorities for Entiat Summer Chinook

We assessed strategic priorities for summer chinook in the same manner as for spring chinook. The first pair of charts in Appendix C show how benefit categories were identified for summer chinook. The rest of the charts in Appendix C describe reach-specific strategic priorities for Entiat summer chinook restoration. As for spring chinook, the summer chinook reach analysis document is intended to be a reference tool for all types of watershed planning related to salmon conservation and recovery.

Planners should note that the results for summer chinook must be compared to those for spring chinook. Because the needs of each stock do not coincide exactly, a restoration plan should identify population-specific goals and balance priorities across stocks.

3.2.2.1 Entiat Summer Chinook Restoration Priorities

As was the case for Entiat spring chinook, the Columbia mainstem reaches ranked first in terms of restoration potential. Reaches within the Entiat Subbasin were estimated to account for 28% of the total restoration potential for life history diversity, 59% of the total for productivity and 28% of the total for abundance (Figure 3.9). Within the subbasin, the Lower Entiat ranked first overall in terms of restoration potential, and was followed by the Upper Middle Entiat and the Lower Middle Entiat (Figure 3.10).

Report 1 - Baseline Spawner Population Performance Parameters
Entiat Summer Chinook

Population	Scenario	Diversity index	Productivity	Capacity	Abundance
Entiat Summer Chinook	Historical	100%	10.7	2,955	2,680
	Current	13%	1.5	296	99
	Current (No HF)	37%	2.2	425	229

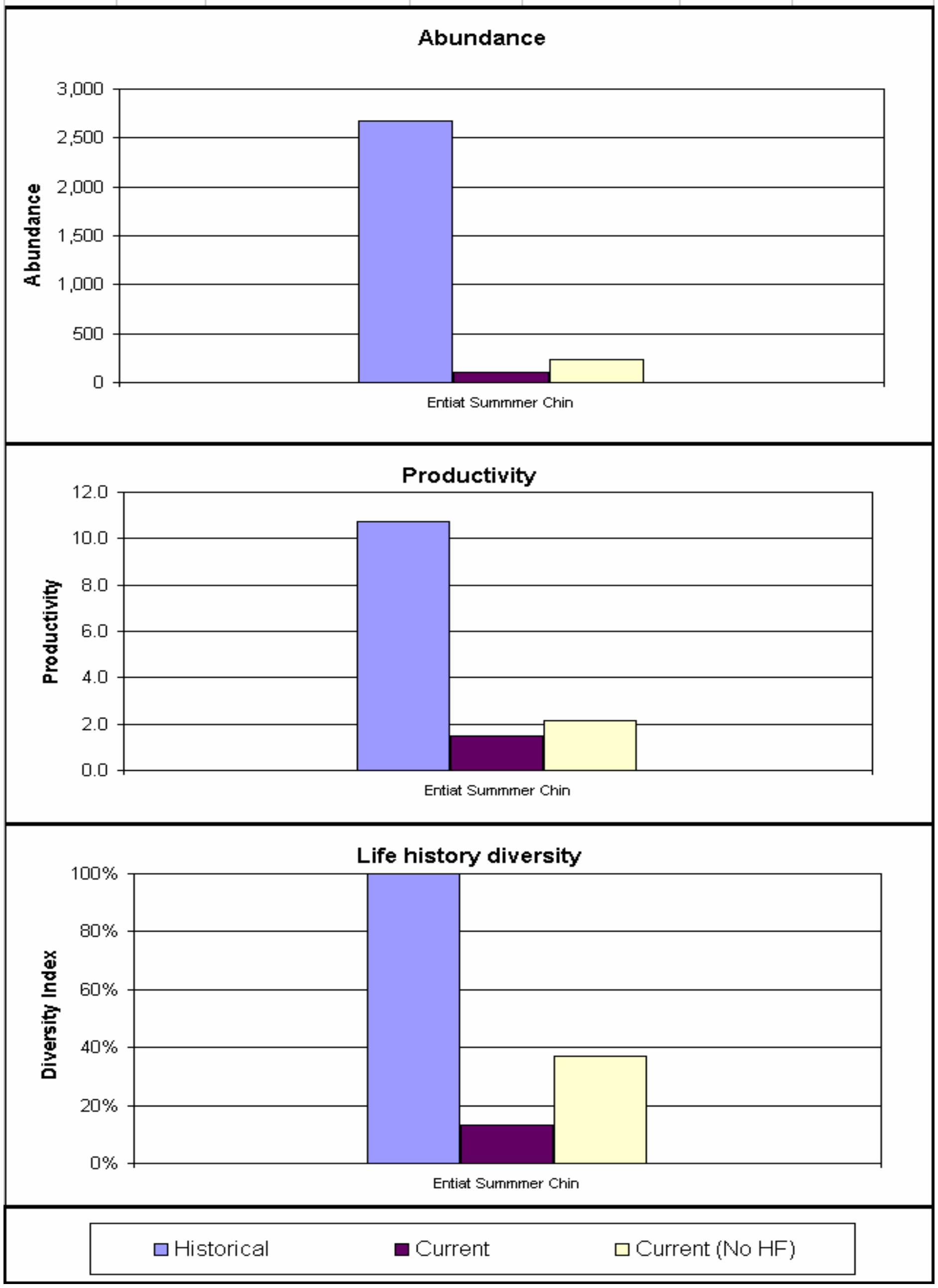

Figure 3.8. Entiat summer chinook (naturally produced) performance measures based on modeling results.

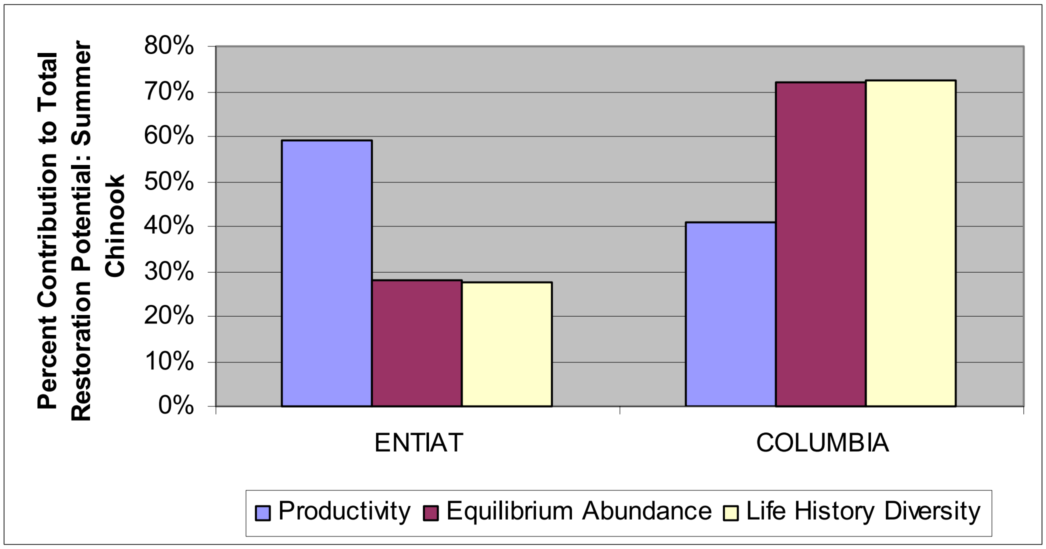

Figure 3.9 Contribution of reaches inside the Entiat Subbasin and the Columbia mainstem to the total Restoration Potential of Entiat Summer Chinook. Restoration Potential is expressed in terms of life history diversity, productivity and equilibrium abundance.

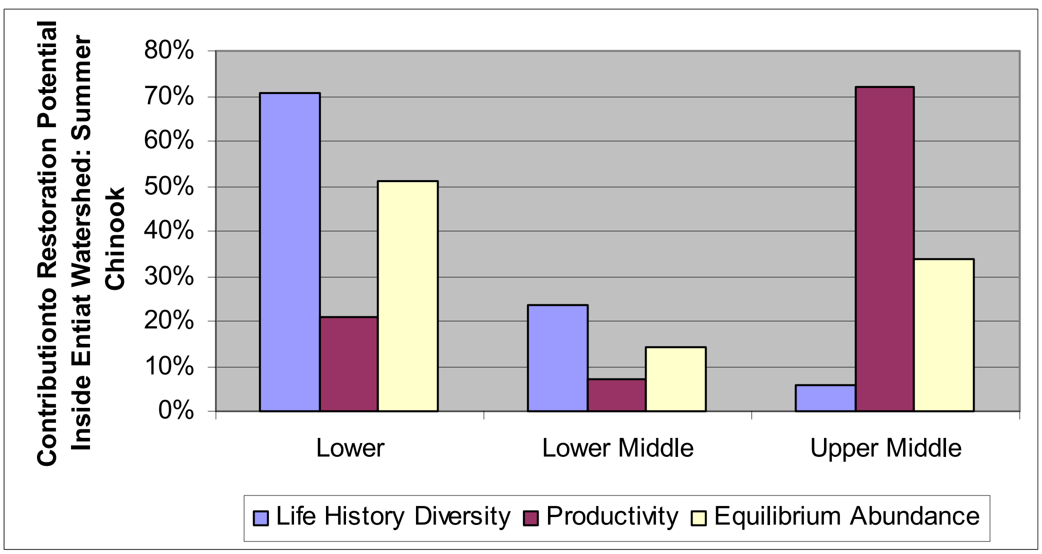

Figure 3.10 Relative Restoration Potential for Summer Chinook of geographic areas inside the Entiat Subbasin. Restoration Potential is expressed in terms of life history diversity, productivity and equilibrium abundance.

A loss of habitat diversity is clearly the most significant factor depressing summer chinook production in the Entiat Subbasin. Habitat diversity was the dominant factor in ten of the eleven reaches supporting summer chinook. Channel stability, flow, and food played distinctly lesser roles, and predation risk, temperature, sediment and key habitat had relatively minor impacts. With one exception, the life stages most impacted by these conditions were either fry or pre-spawning adults in the holding phase of their life cycle.

As previously mentioned, habitat diversity for fry is a function of gradient, confinement, riparian function, LWD density and icing. Except for icing, the same factors determine habitat diversity for holding adults. Although other habitat attributes – especially channel stability, flow and food -- play a role in depressing summer chinook production, the impact of habitat diversity is so dominant that it would distort the diagnosis to dwell upon the determinants of these factors. Moreover, impaired riparian function and a lack of LWD exacerbates four of the principle limiting factors, and confinement exacerbates three of the four. Thus, it is probably not an oversimplification to say that any effective summer chinook restoration project should emphasize reducing channel confinement, improving riparian function and increasing LWD density.

3.2.2.2 **Entiat Summer Chinook Protection Priorities**

Unlike spring chinook, the areas of highest priority for *protecting* Entiat summer chinook are also outside the subbasin. This difference is partly attributable to the fact summer chinook spawn and rear much lower in the drainage, with the result that many more juveniles migrate out of the subbasin and rear for considerably longer periods in the Columbia mainstem. To a lesser degree, it is also due to the fact 20% of Entiat summer chinook juveniles were estimated to follow an ocean-type life history, and to smolt and migrate to the ocean as subyearlings in the late spring and summer. The EDT model estimates that 30% of the total protection value for life history diversity is attributable to reaches inside the subbasin. Comparable figures for productivity and abundance are 56% and 41%, respectively (Figure 3.11). Within the subbasin, the Lower Entiat ranks first overall in terms in terms of protection value, followed by the Upper Middle Entiat and the Lower Middle Entiat (Figure 3.12).

The relative importance of geographic areas within the drainage to Entiat summer chinook for both restoration and protection measures is displayed in Figure 3.13. The same geographic areas were used for summer chinook as spring chinook (see Table 3.2).

To reiterate, the Columbia River mainstem ranked first in terms of restoration benefit. However, if summer chinook restoration is a high priority, then restoration actions in the lower Entiat River would probably benefit population performance. Although all geographic areas inside the subbasin showed a strong abundance response to protection measures, the lower Entiat clearly ranked highest. In conclusion, if summer chinook is the priority population, then strategic priorities for restoration and preservation should target the lower Entiat River.

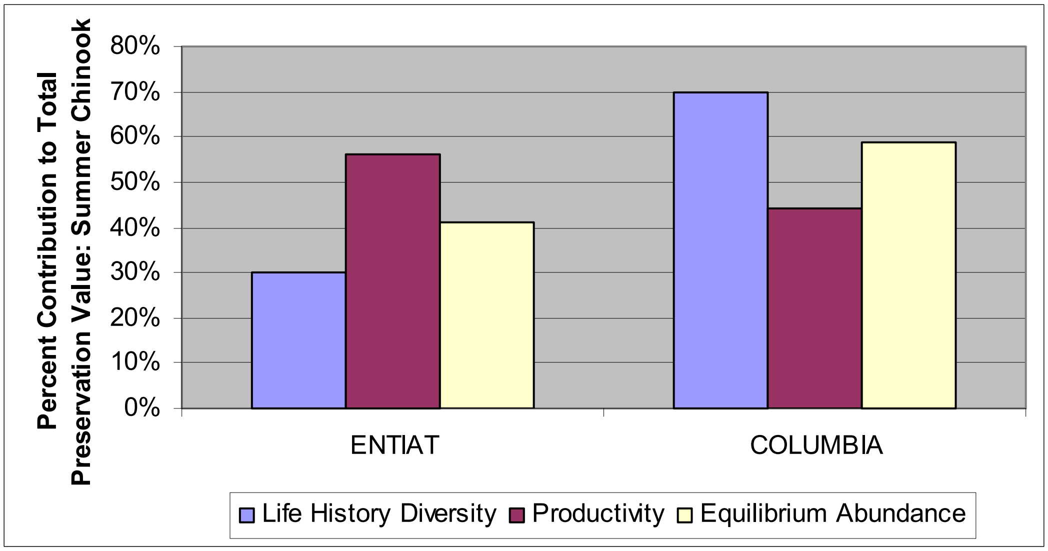

Figure 3.11. Contribution of reaches inside the Entiat Subbasin and in the Columbia mainstem to the total Preservation Value of Entiat Summer Chinook. Protection Value is expressed in terms of life history diversity, productivity and equilibrium abundance.

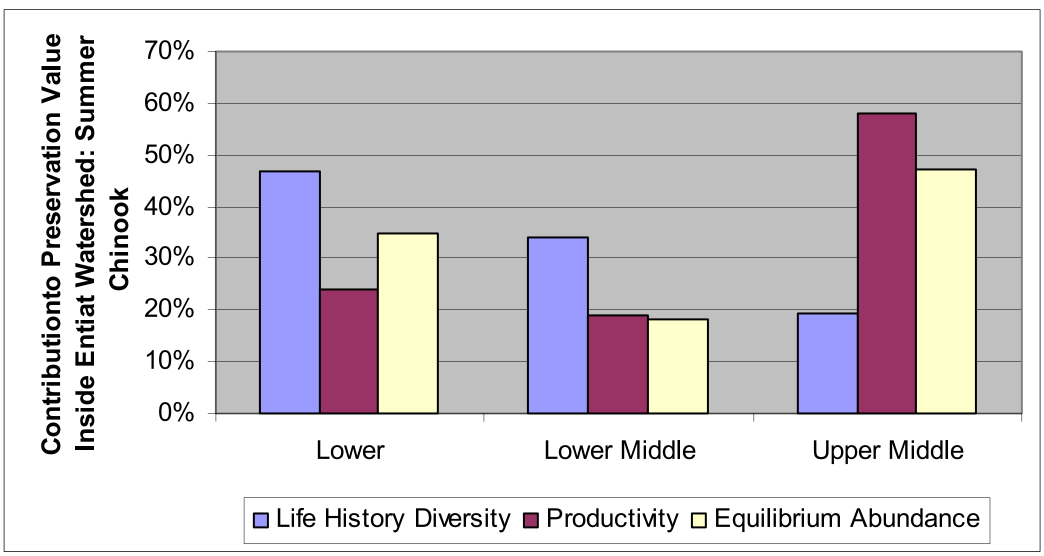

Figure 3.12. Relative contribution to Preservation Value of reaches inside the Entiat watershed. Preservation Value is expressed in terms of life history diversity, productivity and equilibrium abundance.

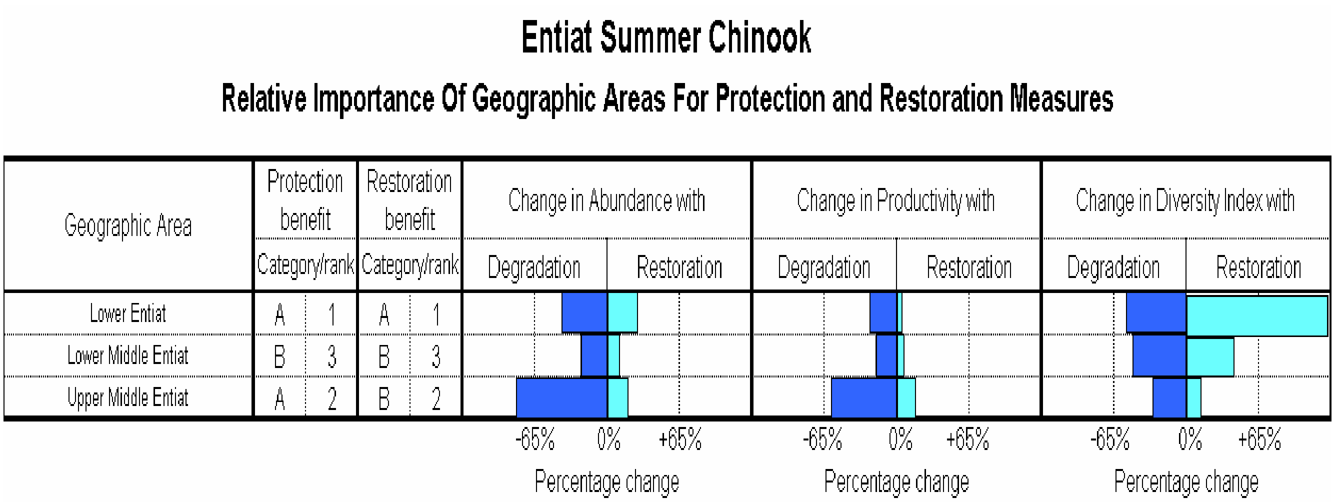

Figure 3.13. Relative importance of geographic areas for restoration and protection measures targeting Entiat summer chinook. Areas are ranked and assigned to benefit categories according to potential (A is highest) to affect population performance. Contribution of performance measures to rankings are graphed.

3.3 Data/Information Uncertainties for Entiat Watershed

This report describes results of the initial assessment of chinook performance in the Entiat River. It emphasizes conditions inside the subbasin and measures that can be taken there to improve performance of chinook salmon. In accordance with this intra-subbasin emphasis, then, the major uncertainties underlying this analysis are as follows

- Juvenile life history assumptions for spring and summer chinook must be verified. We assumed that a majority of summer chinook progeny overwinter in the Columbia River mainstem. However, in an initial modeling exercise targeting *spring* chinook, we assumed juveniles remained in the Entiat until the following spring. Results from this exercise showed very low spring chinook abundance even for the historic condition, primarily due to poor quality overwintering habitat. We next modeled a spring chinook life history in which a majority of the juveniles moved downstream during the summer and overwintered in the Columbia River mainstem like summer chinook. The results in this report are based on this revised life history pattern.

  Such an assumption for spring chinook is consistent with observations from the Yakima River. There, biologists have observed a "transient" spring chinook life history pattern, in which subyearlings migrate slowly downstream during the summer. These juveniles are thought to overwinter in the lower Yakima River mainstem (Fast et al. 1991). Importantly, these Yakima spring chinook regularly migrate over distances that, if they occurred in the Entiat River, would put most of them in the Columbia mainstem.

- Fine sediment and bed scour ratings must be reviewed. This report incorporated estimates of fine sediment levels and bed scour that had only a modest impact on the survival of incubating eggs.
- Ratings for winter conditions must be reviewed. Overwinter survival is strongly affected by cold water temperatures in December and January. Comments made by various Entiat Work Group members indicated some mainstem reaches had a strong contribution of groundwater. It is not certain that the impact of these upwelling areas was accurately captured by the analysis.

In conclusion, three attributes in particular should be verified as opportunity occurs: fine sediment, bed (substrate) scour, and the extent of groundwater sources.

Recommended verification of:
fine sediment within riffles
bed scour
distribution of springs and upwelling

4.0 RESTORATION AND PROTECTION SCENARIOS

In an EDT analysis, restoration scenarios are comprised of different combinations of distinct types of restoration actions. Each action is assumed to restore a certain degree of "normative character"[1] to the environmental attributes it affects, and multiple actions applied simultaneously have multiplicative effects. That is to say, if actions A and B each restore 20% of the historical value to some attribute, each leaves the attribute "80% unrest red". In terms of the "percent unrest red" value, the combined impact of a scenario consisting of A and B is .8 * .8, or .64, which is the same as 1 – .64 or 36% restoration.

Again, restoration scenarios in EDT are made up of distinct combinations of actions. Actions differ by the particular attributes they affect, by magnitude of impact in terms of percent restoration, and by the specific reaches in which they act. In the Entiat analysis, five types of restoration action were combined into five restoration scenarios targeting 11 of the 16 reaches of the Entiat mainstem -- Entiat River reaches 2 through 12. These scenarios included measures to protect critical habitat areas as well as to restore habitat quality and quantity. To a large degree, the Entiat scenarios were cumulative; actions taken in a scenario of lower intensity were preserved and augmented in the "next" scenario. The actions and scenarios modeled in this analysis were proposed by the Entiat Work Group, and were based partly on the EDT diagnosis and partly on a consensus among stakeholders of what was practicable.

The specific actions evaluated and the environmental impacts assumed for them were as follows:

1) Construction of variable numbers of "vortex weirs" throughout a progressively larger proportion of the Entiat mainstem. The general impacts of these actions were to increase the amount of pool habitat, to increase LWD loading and thus habitat diversity, and to reduce channel confinement and restore a measure of riparian function. All of these effects, but especially the last three, are consistent with the diagnosis for Entiat spring and summer chinook.

   Three intensity levels of this action were evaluated:

   a. "Weirs-1", in which 20 weirs were installed in the lower Entiat (10 each in Entiat River reaches 3 and 4).

   b. "Weirs-2", in which 35 weirs were installed in Entiat River reaches 2-9 (the lower and lower middle Entiat). The number of weirs installed in each of these reaches were, respectively, 2, 5, 7, 6, 5, 5, 3 and 2.

[1] "Normative" is defined as "characteristic of the environment in its natural, undeveloped state". Therefore "normative" is roughly synonymous with "historical" insofar as historical is understood to mean "characteristic of the period before anthropogenic environmental impacts". A central tenet of contemporary conservation biology is that local populations of salmonids evolved under and are adapted to "locally normative" conditions, and therefore that they perform best when conditions are normative.

   c. "Weirs-3", in which 72 weirs were installed in Entiat River reaches 2-9. In this case, the number of structures installed per reach were 8, 11, 13, 9, 9, 11, 6 and 5, respectively.

2) Planting progressively larger portions of the riparian corridor of the mainstem Entiat River with riparian vegetation. The intended impact of these measures, in addition to stabilizing riverbanks and protecting roads and private property, were to moderate maximum & minimum water temperatures, to reduce icing damage, to increase the production of benthic invertebrates (a food resource for juvenile chinook salmon), and to enhance riparian function. All of these effects, and especially the last two, were highlighted by the diagnosis.

   Three intensity levels of this action were evaluated:

   a. "Plantings-1", which targeted Entiat River reaches 3 and 4 (the lower Entiat). Total lineal feet of plantings per reach were 2,000 and 3,900 ft, respectively.

   b. "Plantings-2", which targeted Entiat River reaches 3 and 4 (the lower Entiat), 8 and 9 (the lower middle Entiat) and 10 and 11 (the upper middle Entiat). The total lineal feet of plantings in these reaches was 2,000, 3,900, 5,175, 5175 and 1,800, respectively.

   c. "Plantings 3", which targeted Entiat River reaches 2 – 5 (lower Entiat), 6 – 9 (lower middle Entiat) and 10-11 (the upper middle Entiat). The total lineal feet of plantings in these reaches was 4700, 5900, 3900, 1450, 1450, 2000, 5700, 4650, 6600 and 3600, respectively.

3) The "Easements" action, which consisted of acquiring easements on the riparian corridor in three reaches of the upper middle Entiat mainstem -- Entiat River reaches 10, 11 and 12. The intended impact of this measure, in addition to protecting critical adult holding, spawning and early rearing areas for spring and summer chinook, was to allow riparian vegetation to recover naturally, and eventually to increase habitat diversity by increasing the recruitment of LWD. This action targets the number 1 geographic area for protection of spring chinook production, and the number two area for summer chinook.

4) The "Side Channel/Ditch" action, which consists of hydraulically reconnecting a disconnected side channel of the lower Entiat mainstem, restoring habitat quality within the side channel, and converting a portion of an irrigation ditch to juvenile rearing habitat. Because both of these actions target Entiat River reach 3, they were considered as a unit. The intended impacts of this action is to add additional high quality juvenile rearing habitat, to increase LWD loading and thus habitat diversity, and to increase the proportion of river channel consisting of pools and pool tailouts. The effects of this action are entirely consistent with the diagnosis for restoring spring and summer chinook production in the reach they target.

5) The "Log Catchers" action, which consists of installing 40 "log retention structures" in Entiat River reaches 10 and 11 (upper middle Entiat). The log retention structures

were to be evenly distributed between reaches 10 and 11. The intended impact of this measure was to increase LWD density and habitat diversity, as well as the amount of backwater pool and pool tail-out habitat. These measures affect the fry life stage more than any other, as well as some of the major limiting factors for fry in these reaches (e.g., habitat diversity, food, flow, key habitat), and therefore are consistent with the diagnoses for Entiat spring and summer chinook. They also target the number one and two intra-Entiat geographic areas for Preservation and Restoration, respectively, of Entiat spring chinook.

These were the building blocks of the restoration scenarios evaluated for Entiat spring and summer chinook. The actual scenarios evaluated were as follows:

1) Scenario 1. Weirs-1 plus Plantings-1.

2) Scenario 2. Weirs-2 plus Plantings-2.

3) Scenario 3. Weirs-3 plus Plantings-3.

4) Scenario 4. Weirs-3 plus Plantings-3 plus Easements plus Side Channel/Ditch.

5) Scenario 5. Weirs-3 plus Plantings-3 plus Easements plus Side Channel/Ditch plus Log Catchers.

4.1 Quantification of Impacts of Actions

4.1.1 Vortex Weirs.

The weirs proposed for the Entiat mainstem are channel-spanning boulder structures oriented as an inverted chevron. The weirs incorporate securely-anchored pieces of large woody debris (LWD) intended to snag and retain naturally recruited pieces of LWD drifting downstream. The banks on either end of the weirs are to be planted with riparian vegetation.

The upstream orientation of the weir chevron concentrates flow into the center of the channel and thus, over time, excavates a pool. The LWD which is assumed to accumulate on the weir will also deflect flows and scour additional pool area. The deflection of flow into the center of the channel will create slack-water areas along the stream margins which, over time, will become vegetated gravel bars and eventually new banks with somewhat more sinuosity and better riparian function.

Explicit, quantitative assumptions were as follows:

- From a pilot study conducted in the Entiat River (personal communication, Bob Rose, YN, 2002), it is known that each weir will scour a pool of approximately 1,500 ft^2 after 1-2 years.

- After ~25 years, the weirs will also have recruited enough LWD to scour additional pool area. Because most LWD recruits above reach 6, it was assumed that more LWD will eventually become associated with the weirs above reach 6. Specifically, it was assumed that 40 additional pieces of LWD will become associated with each weir in reaches 6 -9, but only 10 pieces per weir in reaches 2 – 5.

- After 25 years, an addition 500 ft^2 of pool habitat will be created by LWD associated with weirs in reaches 2 – 5, and an additional 1,500 ft^2 of pool will be created by LWD accumulated on each weir above reach 5. Thus the total pool area created per weir after 25 years will be 2,000 ft^2 for weirs below reach 6, and 3,000 ft^2 for weirs in reach 6 and above.

- It was assumed that approximately 200 ft of the stream margins downstream of each weir would be slack water areas in which sufficient gravel and sediment would accumulate to form a new streambank. These new banks, together with the plantings, were assumed to result in improved riparian function over time. The product of 200 ft and the number of weirs divided by total reach length was assumed to represent the proportion of a treated reach that would benefit from improved riparian function. Somewhat arbitrarily, it was assumed that that riparian function within each 200 ft impact zone would be one eighth restored after 25 years.

4.1.2 Riparian Plantings

- The benefits to riparian function of riparian plantings were estimated analogously to the riparian benefits of vortex weirs described above. Specifically, the ratio of the total number of feet to be planted to twice the length of the reach (for both banks) was estimated as the proportion of the reach to receive a riparian benefit.

- The magnitude of this benefit, as for weirs, was 1/8th restoration.

- Very small benefits to icing, (high and low) temperature rating and benthic productivity were assumed for several affected reaches.

4.1.3 Side Channel/Ditch

- The side disconnected channel that was to be reconnected to the Entiat River (reach 3) is 2,000 ft long, 22.5 ft wide on average. Its area is approximately 3% of the area of reach 3.

- Its stream unit type composition is 25% pools, 5% pool tail-outs, 35% large-substrate riffles and 35% small substrate riffles.

- The side channel would be "fully stocked" with LWD – viz., LWD would be given the highest EDT rating.

- The irrigation ditch essentially represents a pool 500 ft long, eight ft wide and 2.5 ft deep. This 4,000 ft^2 of additional pool habitat was added to reach 3.

4.1.4 Easements

- A 50% restoration of salmon carcass density was assumed for the affected reaches after 25 years. This benefit is partially attributable to an assumed increase in salmon production, but mainly attributable to better retention of carcasses that would become entangled in increased amounts of LWD.

- Confinement attributable to development was assumed to be 50% eliminated after 25 years of allowing the river to function naturally.

- LWD densities were assumed to be restored 30% after 25 years because of natural recruitment.

4.1.5 Log Catchers

- It was assumed that each log catcher would have collected an average of 10 additional pieces of LWD after 25 years.

- After 25 years, it was assumed an additional 800 ft^2 of backwater pool habitat would be created, as well as 200 ft^2 of additional pool tail-out habitat.

- After 25 years, it was assumed salmon carcass loading would be 30% restored, in part because more fish would be produced but largely because many more carcasses would be retained.

- It was assumed a 100-ft portion of the bank centered on each structure would experience 1/8th restoration of riparian function after 25 years (same rationale as for riparian plantings and weirs).

4.2 Integration of Actions into Scenarios

Tables 4.1 and 4.2 summarize the "non-morphological" impacts of the actions and scenarios modeled in the Entiat analysis, and Table 4.4 summarizes the "morphological" impacts.. "Non-morphological" impacts are those that do not affect the stream unit type composition of a reach – the amount of pool, riffle, glide, and other types of microhabitat within a reach. "Morphological" impacts affect precisely these attributes. Tables 4.1.and 4.2 express impacts in terms of percent restoration – the degree to which differences between current and historical attribute ratings are eliminated, and normative conditions are restored. Table 4.1 displays percent restoration by reach for each of the individual actions, and Table 4.2 shows the same thing for the different combinations of actions that were modeled as scenarios 1-5.

It was not feasible to present the impacts of actions and scenarios on stream unit type composition in the same way. This difficulty is due to the fact that there are many ways in which current and historical stream unit type compositions can differ, and not all current/historical differences are necessarily "bad". Therefore a positive percent restoration value for a given stream unit type may not necessarily represent improvement, and a negative percent restoration may not necessarily represent degradation. Moreover, certain actions can

Table 4.1. Percent restoration of historical conditions by action, reach and environmental attribute.

Action	Reach	Channel Width	Confinement (anthropogenic)	Riparian Function	Woody Debris	Temperature (minimum)	Icing	Salmon Carcasses	Benthic Productivity
Weirs-1	Entiat-3	15%	10%	11%	26%			35%	70%
	Entiat-4	20%	10%	13%	30%			35%	70%
Weirs-2	Entiat-2	2%	3%	3%	6%	5%		10%	20%
	Entiat-3	5%	5%	6%	13%	5%		20%	30%
	Entiat-4	10%	5%	7%	21%	5%		25%	60%
	Entiat-5	10%	5%	9%	27%			30%	
	Entiat-6	15%	10%	14%	67%			35%	
	Entiat-7	9%	10%	20%	46%			20%	
	Entiat-8	9%	10%		41%			20%	
	Entiat-9	6%	10%		39%			20%	
	Entiat-10							5%	
	Entiat-11							5%	
	Entiat-12							5%	
Weirs-3	Entiat-2	10%	8%	17%	25%	10%	5%	35%	70%
	Entiat-3	15%	10%	14%	29%	10%	5%	35%	70%
	Entiat-4	20%	10%	17%	35%	10%	5%	40%	70%
	Entiat-5	20%	10%	14%	36%	10%	5%	40%	
	Entiat-6	30%	25%	29%	85%	10%	5%	50%	
	Entiat-7	18%	20%	50%	70%		5%	40%	
	Entiat-8	18%	20%		60%		5%	40%	
	Entiat-9	24%	20%		63%		5%	40%	
	Entiat-10							25%	
	Entiat-11							25%	
	Entiat-12							25%	
Plantings-1	Entiat-3			1%					1%
	Entiat-4			2%					2%
Plantings-2	Entiat-3			1%		5%			1%
	Entiat-4			2%		5%			2%
	Entiat-7					5%			
	Entiat-8			5%		5%			
	Entiat-9			7%		5%			
	Entiat-10			3%					
	Entiat-11			0.4%					
Plantings-3	Entiat-2			2%		11%	5%		2%
	Entiat-3			2%		11%	5%		2%
	Entiat-4			2%		11%	5%		2%
	Entiat-5			1%		11%	5%		
	Entiat-6			1%		11%	5%		
	Entiat-7			1%		10%	5%		
	Entiat-8			6%		10%	5%		
	Entiat-9			6%		10%	5%		
	Entiat-10			4%					
	Entiat-11			1%					
Easements	Entiat-10		50%	10%	30%			50%	
	Entiat-11		50%	13%	30%			50%	
	Entiat-12		50%	20%	30%			50%	
Side Channel Ditch	Entiat-3		6%	7%	20%	13%		8%	
Log Catchers	Entiat-10			1%	27%			30%	
	Entiat-11			0.5%	21%			30%	

Table 4.2. Cumulative percent restoration of historical conditions by Scenario, reach and environmental attribute.

Action	Reach	Channel Width	Confinement (anthropogenic)	Riparian Function	Woody Debris	Temperature (minimum)	Icing	Salmon Carcasses	Benthic Productivity
S1	Entiat-3	15%	1%	12%	26%			35%	7%
	Entiat-4	2%	1%	15%	3%			35%	8%
S2	Entiat-2	2%	3%	3%	6%	5%		1%	2%
	Entiat-3	5%	5%	7%	13%	10%		2%	4%
	Entiat-4	1%	5%	9%	21%	10%		25%	7%
	Entiat-5	1%	5%	9%	27%			3%	
	Entiat-6	15%	1%	14%	67%			35%	
	Entiat-7	9%	1%	2%	46%	5%		2%	
	Entiat-8	9%	1%	5%	41%	5%		2%	
	Entiat-9	6%	1%	7%	39%	5%		2%	
	Entiat-10			3%				5%	
	Entiat-11							5%	
	Entiat-12							5%	
S3	Entiat-2	1%	8%	19%	25%	20%	10%	35%	8%
	Entiat-3	15%	1%	16%	29%	20%	10%	35%	8%
	Entiat-4	2%	1%	19%	35%	20%	10%	4%	8%
	Entiat-5	2%	1%	15%	36%	20%	10%	4%	
	Entiat-6	3%	25%	30%	85%	20%	10%	5%	
	Entiat-7	18%	2%	6%	7%	1%	10%	4%	
	Entiat-8	18%	2%	6%	6%	1%	10%	4%	
	Entiat-9	24%	2%	6%	63%	1%	10%	4%	
	Entiat-10			4%				25%	
	Entiat-11			1%				25%	
	Entiat-12			1%				25%	
S4	Entiat-2	1%	8%	19%	25%	20%	10%	35%	8%
	Entiat-3	15%	15%	22%	43%	3%	10%	4%	8%
	Entiat-4	2%	1%	19%	35%	20%	10%	4%	8%
	Entiat-5	2%	1%	15%	36%	20%	10%	4%	
	Entiat-6	3%	25%	30%	85%	20%	10%	5%	
	Entiat-7	18%	2%	6%	7%	1%	10%	4%	
	Entiat-8	18%	2%	6%	6%	1%	10%	4%	
	Entiat-9	24%	2%	6%	63%	1%	10%	4%	
	Entiat-10		5%	14%	3%			63%	
	Entiat-11		5%	14%	3%			63%	
	Entiat-12		5%	3%	3%			63%	
S5	Entiat-2	1%	8%	19%	25%	20%	10%	35%	8%
	Entiat-3	15%	15%	22%	43%	3%	10%	4%	8%
	Entiat-4	2%	1%	19%	35%	20%	10%	4%	8%
	Entiat-5	2%	1%	15%	36%	20%	10%	4%	
	Entiat-6	3%	25%	30%	85%	20%	10%	5%	
	Entiat-7	18%	2%	6%	7%	1%	10%	4%	
	Entiat-8	18%	2%	6%	6%	1%	10%	4%	
	Entiat-9	24%	2%	6%	63%	1%	10%	4%	
	Entiat-10		5%	14%	49%			74%	
	Entiat-11		5%	14%	45%			74%	
	Entiat-12		5%	3%	3%			63%	

occasionally result in the creation of more of a certain steam unit type than existed historically, which would be assessed as a percent restoration greater than 100% -- a confusing concept.

Therefore, the impact of scenarios on stream unit types was not expressed in terms of percent restoration. Instead, Table 4.3 simply displays the stream unit type composition of the reaches targeted by restoration scenarios as they exist now and as they were estimated to have existed historically. Table 4.4 then shows how various scenarios were assumed to

Table 4.3. Percent composition of wetted area of Entiat River reaches 2-12 by stream unit type currently and historically.

Reach	Scenario	Large cobble riffles	Small cobble riffles	Primary pools	Pool tailouts	Glide	Backwater pools	Beaver ponds
Entiat-2	Current	50.0%	30.0%	7.0%	2.0%	10.0%	1.0%	0.0%
	Historical	55.0%	35.0%	7.0%	1.0%	2.0%	0.0%	0.0%
Entiat-3	Current	63.0%	18.0%	7.0%	2.0%	10.0%	0.0%	0.0%
	Historical	55.0%	15.0%	20.0%	2.0%	5.0%	0.0%	3.0%
Entiat-4	Current	75.0%	10.0%	7.0%	2.0%	6.0%	0.0%	0.0%
	Historical	70.0%	8.0%	11.0%	3.0%	8.0%	0.0%	0.0%
Entiat-5	Current	66.0%	12.0%	6.0%	2.0%	14.0%	0.0%	0.0%
	Historical	51.0%	15.0%	9.0%	4.0%	18.0%	0.0%	3.0%
Entiat-6	Current	79.0%	8.0%	5.0%	1.0%	7.0%	0.0%	0.0%
	Historical	63.0%	12.0%	9.0%	3.0%	10.0%	0.0%	3.0%
Entiat-7	Current	90.0%	5.0%	2.0%	1.0%	2.0%	0.0%	0.0%
	Historical	80.0%	7.0%	4.0%	2.0%	5.0%	0.0%	2.0%
Entiat-8	Current	96.0%	2.0%	1.0%	0.0%	1.0%	0.0%	0.0%
	Historical	84.0%	5.0%	5.0%	2.0%	4.0%	0.0%	0.0%
Entiat-9	Current	94.0%	2.0%	2.0%	0.0%	2.0%	0.0%	0.0%
	Historical	87.0%	2.6%	2.6%	2.6%	2.6%	0.0%	2.6%
Entiat-10	Current	3.0%	27.0%	27.0%	8.0%	30.0%	5.0%	0.0%
	Historical	1.0%	15.0%	29.0%	9.0%	35.0%	5.0%	6.0%
Entiat-11	Current	6.0%	35.0%	20.0%	6.0%	30.0%	3.0%	0.0%
	Historical	2.0%	25.0%	25.0%	6.0%	32.0%	6.0%	4.0%
Entiat-12	Current	24.0%	35.0%	10.0%	3.0%	26.0%	2.0%	0.0%
	Historical	16.0%	30.0%	12.0%	4.0%	29.0%	4.0%	5.0%

change the stream unit type composition *from current values*. Blank cells in Table 4.4 indicate a scenario had no effect on a morphological attribute; positive entries indicate a percent increase, and negative entries indicate a percent decrease, in contribution to total wetted area for a particular stream unit type. Bold entries indicate a change from the preceding scenario, while unbolded entries indicate merely that the impact of the previous scenario was preserved.

4.3 Results of Scenario Evaluation

Tables 4.5 and 4.6 summarize the results of EDT model runs on scenarios 1-5 for Entiat Spring Chinook and Entiat Summer Chinook, respectively. Figures 4.1 and 4.2 display the same data graphically.

The incremental benefits of scenarios 1-5 are roughly the same for spring chinook and summer chinook when benefits assume current harvest and fitness impacts. Equilibrium abundance for spring chinook increases from the current value of 138 to 187 under scenario 5, an overall increase of 36%. Summer chinook abundance increases from its current value of 99 to 152 under scenario 5, an increase of 53%. The increase in carrying capacity from current conditions to scenario 5 is 29% for *both* spring chinook and summer chinook. Moreover, there are no qualitatively different improvement patterns in equilibrium

Table 4.4. Percent change in Stream Unit Type composition by reach and Scenario. Values represent the percent change (+ or -) in wetted area in a Scenario from the area occupied at present. Note that a blank cell indicates the relative area of a Stream Unit Type does not change from current values under a specific Scenario..

Reach	Scenario	Large cobble riffles	Small cobble riffles	Primary pools	Pool tailouts	Glide	Backwater pools	Beaver ponds
Entiat-2	S1							
	S2			4.3%		-3.0%		
	S3			20.0%	5.0%	-15.0%		
	S4			20.0%	5.0%	-15.0%		
	S5			20.0%	5.0%	-15.0%		
Entiat-3	S1			21.9%	5.0%	-17.0%		
	S2			11.4%		-8.0%		
	S3			24.3%	10.0%	-19.0%		
	S4			35.7%	20.0%	-29.0%		
	S5			35.7%	20.0%	-29.0%		
Entiat-4	S1			25.7%	10.0%	-35.0%		
	S2			17.1%	5.0%	-23.3%		
	S3			32.9%	15.0%	-45.0%		
	S4			32.9%	15.0%	-45.0%		
	S5			32.9%	15.0%	-45.0%		
Entiat-5	S1							
	S2			25.0%		-10.7%		
	S3			36.7%	5.0%	-16.4%		
	S4			36.7%	5.0%	-16.4%		
	S5			36.7%	5.0%	-16.4%		
Entiat-6	S1							
	S2			54.0%	90.0%	-77.1%		
	S3			100.0%	150.0%	-92.9%		
	S4			100.0%	150.0%	-92.9%		
	S5			100.0%	150.0%	-92.9%		
Entiat-7	S1							
	S2			80.0%		-80.0%		
	S3	-2.0%	-2.0%	180.0%	40.0%	-100.0%		
	S4	-2.0%	-2.0%	180.0%	40.0%	-100.0%		
	S5	-2.0%	-2.0%	1.8	0.4	-100.0%		
Entiat-8	S1							
	S2	-1.4%	-1.4%	170.0%	from 0% current to 0.7% S2	-100.0%		
	S3	-3.7%	-3.7%	360.0%	from 0% current to 1.1% S3	-100.0%		
	S4	-3.7%	-3.7%	360.0%	from 0% current to 1.1% S4	-100.0%		
	S5	-3.7%	-3.7%	360.0%	from 0% current to 1.1% S5	-100.0%		
Entiat-9	S1							
	S2	-0.4%	-0.4%	75.0%	from 0% current to 0.9% S2	-100.0%		
	S3	-3.6%	-3.6%	200.0%	from 0% current to 1.5% S3	-100.0%		
	S4	-3.6%	-3.6%	200.0%	from 0% current to 1.5% S4	-100.0%		
	S5	-3.6%	-3.6%	200.0%	from 0% current to 1.5% S5	-100.0%		
Entiat-10	S1							
	S2							
	S3							
	S4			1.5%		-1.3%		
	S5		-6.7%	1.5%	5.0%	-1.3%	29.4%	
Entiat-11	S1							
	S2							
	S3							
	S4			5.0%		-3.3%		
	S5		-2.9%	5.0%	3.3%	-3.3%	27.7%	
Entiat-12	S1							
	S2							
	S3							
	S4			4.0%		-1.5%		
	S5			4.0%		-1.5%		

Table 4.5. Results of EDT simulation on performance of Entiat Spring Chinook under restoration scenarios S1 - S5, with and without a 7% harvest rate and with and without a 15% fitness impact.

		Current	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Historical
With Harvest & Fitness Impacts	Life History Diversity	35%	37%	40%	42%	49%	50%	93%
	Productivity	1.96	1.99	2.02	2.03	2.04	2.06	12.03
	Carrying Capacity	281	294	307	334	358	363	2,789
	Equilibrium Abundance	138	146	155	169	182	187	2,557
Without Harvest & Fitness Impacts	Life History Diversity	44%	48%	50%	51%	55%	57%	93%
	Productivity	2.12	2.16	2.19	2.22	2.26	2.30	12.03
	Carrying Capacity	321	336	351	381	409	415	2,789
	Equilibrium Abundance	170	181	191	210	228	235	2,557

Table 4.6. Results of EDT simulation on performance of Entiat Summer Chinook under restoration scenarios S1 - S5, with and without a 30% harvest rate and with and without a 15% fitness impact.

		Current	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Historical
With Harvest & Fitness Impacts	Life History Diversity	13%	18%	21%	28%	31%	32%	100%
	Productivity	1.50	1.49	1.57	1.59	1.65	1.66	10.74
	Carrying Capacity	296	315	332	367	379	381	2,901
	Equilibrium Abundance	99	104	120	136	149	152	2,631
Without Harvest & Fitness Impacts	Life History Diversity	37%	45%	50%	62%	65%	66%	100%
	Productivity	2.17	2.19	2.25	2.33	2.42	2.44	10.74
	Carrying Capacity	425	451	475	526	544	547	2,901
	Equilibrium Abundance	229	245	264	301	319	323	2,631

abundance or carrying capacity between stocks in moving from scenario to scenario, and the benefits to both stocks seem to be leveling off after scenario 4. The major differences between stocks concern productivity and, especially, life history diversity. For spring chinook, productivity increases from its current value of 1.96 to 2.06 under scenario 5, an increase of only about 5%. By contrast, productivity for summer chinook increases more than twice as much – from 1.5 to 1.66, a 10.7% increase. The increase in spring chinook life history diversity of 46% is nearly quadrupled by summer chinook in going from current conditions to scenario 5. These differences in relative benefit are, however, more apparent than real, and are largely due to the extremely tenuous status of summer chinook under current conditions. Indeed, productivity, and life history diversity for summer chinook under scenario 5 are still less than the comparable measures for spring chinook without any enhancement whatever. Thus the benefits of the modeled scenarios to summer chinook production may be primarily to improve performance enough to prevent the extirpation of the population.

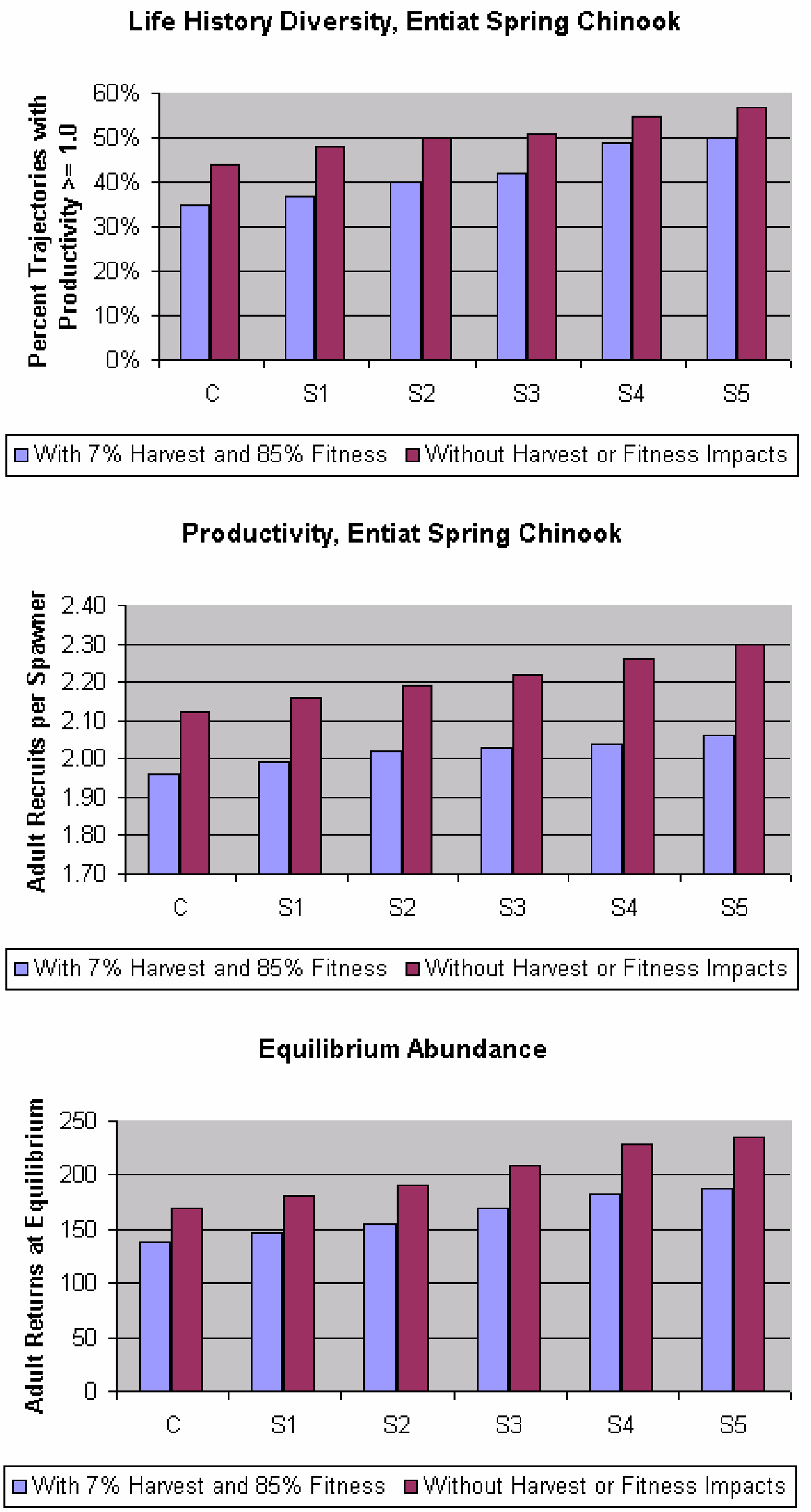

Figure 4.1 Impact on Entiat Spring Chinook performance of Scenarios 1 - 5 expressed in terms of life history diversity, productivity and equilibrium abundance. Impacts are shown both with and without a harvest rate of 7 % and with and without an assumed fitness impairment of 15%.

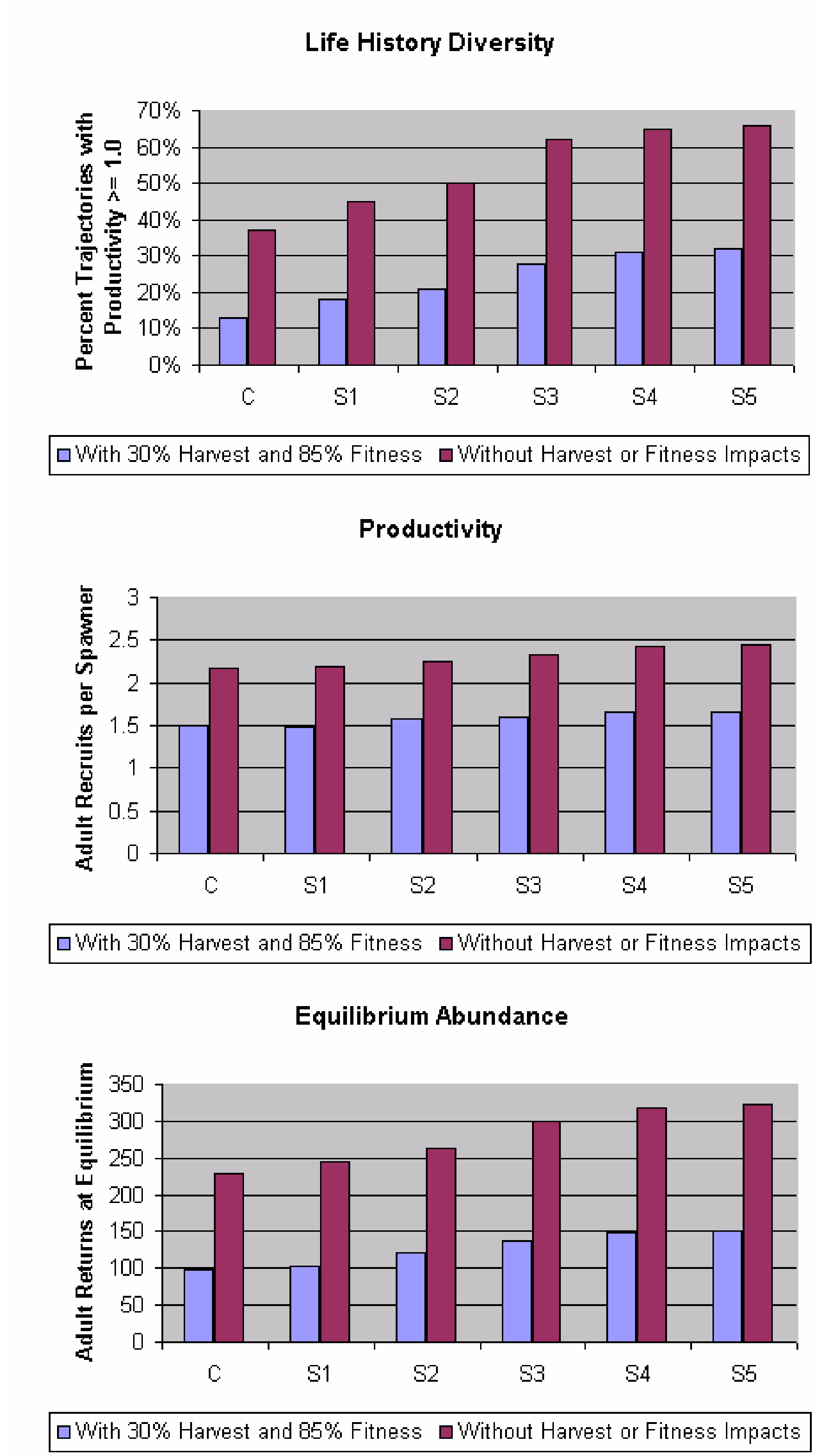

Figure 4.2 Impact on Entiat Summer Chinook performance of Scenarios 1 - 5 expressed in terms of life history diversity, productivity and equilibrium abundance. Impacts are shown both with and without a harvest rate of 7 % and with and without an assumed fitness impairment of 15%.